ABSTRACTS

Federation of Indian Geosciences Associations

2nd Triennial Congress

On

Geosciences for sustainable development goals

13-16 October 2019

Venue

CSIR-National Geophysical Research Institute, Hyderabad

Sponsored by

Ministry of Earth Sciences, New Delhi
SERB-Department of Science and Technology, New Delhi
National Centre for Polar and Ocean Research, Goa
National Centre for Earth Science Studies, *Thiruvananthapuram*
KDMIPE-Oil and Natural Gas Corporation Limited, Dehradun
Indian National Centre for Ocean Information Services, Hyderabad
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PREFACE

The Earth System Science is evolved as an interdisciplinary field with increased involvement of all other basic science disciplines creating the need to have a common platform to exchange and interlace the views and activities within the earth science communities and across the basic science disciplines. This is expected to bring in synergy across the earth sciences community and the scientific programs of national and international relevance jointly taken up by associated scientific associations. In this context, as an effective approach to bring in all the associations dealing with various facets of geosciences together and put in a concerted effort in suggesting future activities at national and international levels, Federation of Indian Geosciences Associations (FIGA) has come into being with eight Geosciences Associations as Members and eight institutions/ Ministries as Patron members. This endeavour is aimed to bring in the Geosciences Associations/Societies /Unions and Institutions on to a single platform to address a common goal fostering the developments in Geosciences and benefit the Society for suggesting future activities at national and international levels.

As a part of this endeavour, FIGA is organising Triennial congress events, the first of which was organised at ISM, Dhanbad in 2016 while the second in the series is being held at CSIR-NGRI now in October 2019. Realising the massive and effective contributions that can be made by geosciences, the focal theme of the congress is identified as 'Geosciences for Sustainable Development Goals'. The congress is participated and supported by its Member associations viz., IGU,GSI, SPG, AEG, AHI, PSI and ISES along with Patron member institutions and others viz., NCESS, AMD, IIG, CSIR-NGRI, KDMIPE, NCPOR, , MoES, WIHG, SERB-DST, INCOIS CSIR-NEERI and CSIR-CIMFR. In addition IUGG and AGU are participating in the event as a part of their Centennial celebrations. Further IAHS is also participating in the symposium on Water Resources.

The congress is organized jointly by AEG, NGRI and IGU at CSIR-NGRI, Hyderabad. The congress, apart from the focal theme covers other pertinent areas like Lithospheric Structure and Geodynamics, Advances in Hydrocarbon and alternate Energy Resources, Water Resources Management under Changing Environment and Climate, Coupling between Earth system processes and its manifestation in the humanosphere, Marine Geo-Sciences and Ocean System, Mineral Exploration: challenges for new discoveries, Understanding and combating natural hazards, Himalayan Cryosphere Climate Interactions, Consequences and Future trends preceded by a workshop on Synergic Management of Water Resources in Changing Climate.

In addition Member associations viz., IGU, AEG, AHI and PSI have a number of awards instituted in recognition of outstanding contributions in specific areas of geosciences apart from other awards bestowed on young students and scientists.

In addition a Young scientist conclave is also being organised to provide opportunities for emerging young scientists to project their talents. Out of over 450 delegates participating in the deliberations a little over 275 papers are being presented in various sessions.

Dr. VM Tiwari, Congress Director

Dr. Anand Charturvedi, Jt. Director

Dr. Kalachnad Sain, Jt. Director

PRESIDENT'S MESSAGE

India, in spite being blessed with huge natural resources that can contribute substantially to national economy, employment and sustained development, the infrastructure, management skills, knowledge transfer technologies need to be restructured and fortified to meet the contemporary needs and to realize the Sustainable Development Goals (SDGs). It is imperative to recognize that geosciences has a direct bearing on more than half of the SDGs while standing complimentary to many other disciplines in these endevours.

Various geosciences aspects like climate change, energy resources, Agro geoscience, engineering geology, geohazards, geoheritage, water resources, hydrogeology and contaminant geology, mineral and rock resources significantly contribute to the realization of all most all the agreed SDGs. Changing natural systems and the earth's environment accelerated by anthropogenic interventions, have been inducing unforeseen complexities in the process of development and sustainability. The multiple scale interactions of ecosystems with the process-response characteristics of both living and nonliving resources and systems are observed to control the productivity and sustainability. Improved engagement of geosciences community and use of geoscientific knowledge base for national and international development will play a major role in realizing such goals.

Though India has been promoting many geosciences organizations and institutions, seamless and comprehensive efforts within and across the organizations, institutions and the prevailing national policies can contribute to an accelerated growth. Utilization of scientific knowledge and suitable strategic approaches will be more effective. In this context, the efforts made to bring in all the geosciences associations and institutions together to understand and address the challenges and opportunities in the field of geosciences towards sustained national development with enhanced international visibility culminated in the evolution of Federation of Indian Geosciences Associations (FIGA). Conforming to the purpose for which FIGA has been evolved and the scope and committed involvement of the Government towards sustainable development, its major activities are built around the organization of events like triennial congress involving multiple institutions and scientific associations, the second in the series being organized now in CSIR-NGRI. The present congress supported and participated by many professional organizations viz., IGU, GSI, SPG, AEG, AHI, PSI, ISES, TPS along with major geosciences institutions like MOES, SERB-DST, NCESS, AMD, IIG, KDMIPE-ONGC, CSIR-NGRI, WIHG, INCOIS etc., would be discussing the scope and role of various facets of Geosciences in achieving the SDGs. The recommendations culminating out of the deliberations will be followed up appropriately.

It is a matter of satisfaction that more than 275 scientific papers are being presented in different symposia and workshops. It is also a matter of gratification to note that NGRI, AEG and IGU have taken the responsibility to organize the 2nd Triennial Congress of FIGA.

I wish the event purposeful, productive and successful.

SHAILESH NAYAK
President, FIGA

FEDERATION OF INDIAN GEOSCIENCES ASSOCIATIONS (FIGA)

The Genesis and Scope

Efforts to bring in all the geoscience associations in India together, to achieve synergy across the earth science community and the scientific programmes of national and international relevance have resulted in the formation of FIGA in 2014. One of the main objectives of FIGA is to bring in all the geosciences associations together to be able to put in concerted efforts, for the progress of geosciences in India. At the same time, it is always clear that FIGA would not interfere with the set goals and objectives of individual member associations. FIGA further contemplates to facilitate a collective and synergic approach to address the national needs and comply with the international requirements both from Government and geosciences fraternity points of view.

The broad objectives of FIGA are as follows:

a. promote excellence in research and development with appropriate use of technology in earth sciences;
b. initiate and facilitate coordinated research by creating technical commissions and working groups in contemporary areas of relevance in earth sciences;
c. promote interaction between individuals, bodies, institutions and industries interested in advancement in knowledge of earth sciences;
d. conduct national and international congresses, symposia, conferences and other meetings, tutorials, exhibitions, etc.;
e. promote publication of research outcome in form of a journal, bulletins, newsletters, books, and proceedings of its symposia, conferences and meetings;
f. coordinate and promote scientific activities related to earth sciences among national and regional societies and scientific community at large;
g. represent the field of earth sciences in relevant international forums;
h. cooperate with international and regional associations as well as governmental and inter-governmental bodies including UN organizations;
i. recognise and confer awards to honour meritorious achievements of individuals and groups;
j. promote and contribute education, training in the earth sciences; and
k. acquire properties such as land, office premises, for the use of the Society;
l. securing grants, funds, endowments and administering same for achieving objectives;
m. appoint personnel for smooth functioning of the Society; and
n. promote all appropriate activities to achieve its mission.

In a bid to discuss and address pertinent issues in various fields, the following Commissions have been formed with scope to initiate collective discussions bring in various associations and the interested scientific community to assess the present status, envisage the future requirements and design an action plan to address them using a scientific approach.

a. Geosciences Education
b. Climate and Global Changes
c. Mineral and Energy Resources
d. Mountain Dynamics
e. Marine Geosciences
f. Water Resources
g. Geohazards

The Commissions also would be looking at developing major scientific initiatives to address the contemporary needs of geo sciences in the country as a whole.

Presently FIGA has eight active Member associations viz., Indian Geophysical Union (IGU), Palaeontological Society of India (PSI), Association of Hydrologists of India(AHI), Geological Society of India (GSI), Association of Exploration Geophysicists (AEG), The Paleobotanical Society (TPS), Indian Society of Earthquake Sciences (ISES), Society of Petroleum Geophysicists (SPG) and seven Patron members representing Ministry and Institutions viz., Min. of Earth Sciences (MoES), ESS-National Centre for Earth Science Studies (NCESS), Atomic Minerals Directorate for Exploration and Research (AMD), Indian Institute of Geomagnetism (IIG), Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE), Oil and Natural Gas Corporation Limited (ONGC), National Geophysical Research Institute (NGRI) and Wadia Institute of Hymalayan Geology (WIHG).

One of the main activities of FIGA is to organize triennial congress events on identified focal themes along with the annual seminars of the member associations. However, FIGA will not be interfering with the set agenda of the member associations but would be very much interested to put forth challenges faced by the geoscientific community together and come up with comprehensive strategies backed by scientific approach to address them.

The first triennial FIGA congress was held at ISM Dhanbad with the focal theme on '**Geosciences for Sustainability' in November 2016,** while the second triennial congress is being held at NGRI, Hyderabad to deliberate on the role of Geosciences for sustainable development Goals.

FIGA works with the motto

"Geosciences for Development and Welfare of Society"

Indian Geophysical Union

भारतीय भूभौतिक संघ

(REGISTRATION No. 26 of 1964)

Circulating a letter signed by fifteen leading geophysicists of the country in the year 1963 formed the Indian Geophysical Union. The response to this was encouraging and about sixty geophysicists responded to this invitation. These geophysicists who enrolled themselves as Members of the Union were styled as Foundation Fellows.

The Indian Geophysical Union was formally inaugurated by Prof.Humayun Kabir, the then Minister for Cultural Affairs and Scientific Research in the year 1963, at a pleasant function organized in the Geology Department, Osmania University. Dr.D.S.Reddy, the then Vice-Chancellor, Osmania University, presided over the function, Dr.S.Bhagavantam, the then Scientific Adviser to Defence Minister welcomed the guests. Dr.K.R.Ramanathan, first President of the Union, delivered the Presidential address. Dr.M.S.Krishnan explained the aims and objectives of the Union and presented the draft constitution, which was revised in 1964.

Dr.K.R.Ramanathan, Director, Physical Research Laboratory, Ahmedabad and a past President of the International Union of Geodesy and Geophysics, was unanimously elected as President of the Union. The first Executive Council was also formed with Dr. K.R.Ramanathan, Dr. M.S.Krishnan, Dr. S.Bhagavantam, Dr. P.K.Bhattacharya, Sri L.N.Kailasam, Dr.Hari Narain, Sri M.B.Ramachandra Rao, and Dr.B.S.R. Rao and Dr.S.Balakrishna. The Union thus blessed by eminent geophysicists of India has made good impetus with the active encouragement given by the Vice-Chancellor of the Osmania University, Dr.D.S.Reddy and P.V.G.Raju the then Minister for Education, Government of Andhra Pradesh.

The Union adopted its constitution framed by a Sub-Committee consisting of Dr.M.S.Krishnan, Dr. K.R.Ramanathan and Dr.S.Balakrishna and the Union was registered on 11th March 1964.

The aims and objectives of the Union are:

- To bring together all geophysicists active in various disciplines such as seismology, magnetism, meteorology, geodesy, volcanology, oceanography, hydrology and tectonophysics and to provide them with opportunities for meeting and discussing current problems of geophysics of solid earth and the oceans.
- To encourage the study of and research in geophysical problems and to provide media for publication of the results.

- To organize and arrange for the meetings and conferences of the Union and encourage the publication and dissemination of knowledge of geophysics and of important researches in various branches of geophysics.
- To cooperate with similar learned societies in organizing and taking part in meetings, symposia, research projects, etc, and to represent geophysics both in the national and international sphere.
- To secure and administer funds, grants and endowments for the furtherance of and research in geophysics.
- To undertake and execute all other acts which shall assist and promote the usefulness, aims and purposes of the Union.

Recognition:

- Recognizes students and young researchers by providing them with the IGU-ONGC Best Poster Awards and Best Young Presenter Awards
- Encourages the first and second rank holders of M.Sc. Tech. students in Applied Geophysics from different Universities/ Institutes for participation to annual convention by providing with travel support, accommodation, fee-waiver from Prof. Jagdeo Singh & Dr. S. Balakrishna Memorial Grant
- Also encourages Young Women Researchers for their participation to annual convention by providing with travel support, accommodation and fee-waiver from the Anni Talwani Memorial Grant
- Honors both the young and senior Geo-scientists for their excellent contribution to Indian Geo-Sciences through 5 National Medals/ Awards/ Prizes and 5 Memorial/ Endowment Lectures
- To encourage authors, IGU also bestows the Best Paper Award among all the papers published in its journal in a calendar year
- Recognizes the Earth Scientists with IGU Fellowships for their excellent contributions in Geosciences

Journal`s (Journal of Indian geophysical Union) Aims and Scope

- To promote research in earth system sciences by publishing research carried out by both young and senior researchers/scientists as quickly as possible after due peer review process.
- To provide a platform to young researchers from various universities to publish their scientific findings/discoveries and basic research.
- To inculcate in contributors publication ethics and knowledge sharing.
- To enable national and international scientific community to freely access the contents of the journal.
- To promote scientific research of relevance to local and regional environs to ameliorate societal problems.

GEOLOGICAL SOCIETY OF INDIA

Background of the Society

Founded in 1958, the Geological Society of India is one of the oldest scientific societies in the country. Today, it has attained the position of a leading communicator of Earth Sciences in India – through its scholarly publishing, topical scientific conferences, educational activities and outreach to the general public and school-children. It also provides impartial scientific information and analysis to support policy-making and informed public debate about the challenges facing humanity from the geological perspective.

This is the 60th year of its existence and it is but appropriate at this juncture to reflect on the achievements of the Society in her publication related activities and the way ahead.

The Journal

The founding fathers of the Society rightly felt that one of the foremost objectives set for the Society was to bring out a scientific journal incorporating salient results of ongoing research activities in the field of Earth Sciences in India and elsewhere.

Starting in a modest way with the issue of only one annual number in 1959, the Journal has grown into a monthly issue since 1977 and reaches a large section of geoscientists in academia, governmental organizations and mining industry in India and abroad. The tradition left by our predecessors has made the Journal appear with unfailing regularity each month without missing a single issue over these many years, which in itself is a major achievement in our context. In the past one decade the Society also started co-publishing the electronic version of the Journal with Springer Nature India, which has helped in greater international visibility and ease of access by earth-scientists around the world. The online processing of papers (from submission to review and revision) has reduced the time lag in publication of papers.

Other Publications

The 2-volume comprehensive text book on the Geology of India brought out by the Society has become a standard reference work not only for students and researchers in India but also globally. The geology of the individual States of Indian Union have also been as text books. Most of the States have been covered and this text book series have become popular among the students of geology. The Society has also brought out text books on Mineralogy & Crystallography, Structural Geology, Metamorphic Petrology, Elements of Palaeontology. The Society brings out special publications including the papers presented at conferences/seminars after due processes of peer review.

The general public in the country are poorly informed about the mineral resources of the country. To fill this gap, the Society initially brought out books on the Mineral Resources of Karnataka and Andhra Pradesh. The Society has also published books devoted to specific mineral commodities of India, namely on gold, tin, platinum, diamond, coal and lignite deposits. These books give a comprehensive account of these deposits including mode of occurrence, distribution, genesis, reserves and resources.

Under Popularisation of Science series, the Society has brought out several publications on different fundamental aspects of Earth Science for school children. The first book under this series was on "Story of Oceans" in 8 languages. It is the endeavour of the Society to bring out such richly illustrated publications with Indian examples also in future, on aspects which have not been covered hitherto.

Diamond Jubilee Year

As part of the Diamond Jubilee year (2018-19) activities, the Society has undertaken to organize Seminars/Symposia in different parts of the country primarily to take stock of the present mineral resources position of the country from the perspective of future requirements and environmental concerns. In addition to mineral resources, water resources as well as shale gas and hydrocarbon resources are also to be covered under this programme. Emphasis is on strategic and critical mineral resources of importance in defence, energy and modern digital IT-based industries as well as on ocean resources.

The Future

If one is to name the single most valuable contribution of the Geological Society of India during its sixty years of existence to the wider Earth Science community in the country and the world, is the firm establishment of the Journal of the Geological Society of India as an authentic earth-science publication from India owing to its punctuality of publication, its scientific content largely devoted to the Geology of the Indian Subcontinent and its increasing international recognition. This has been made possible by the selfless services rendered by many eminent Earth Scientists of the country with the prime objective of advancing the frontiers of knowledge in the field of Earth Sciences with special reference to India and to make India stand tall in the comity of nations. Many tasks set before them as aims and objectives of the Society are yet to be realized though a good foundation has been laid.

The Society intends to include more review articles, lead articles, invited articles from subject experts. It is also contemplated to publish theme-based regular issues, which include articles on similar theme or include it as special section in a regular issue.

Another important line of activity that the Journal intends to provide is to encourage mining industries to send brief articles/notes on modern mining technologies, techniques, regulations and acts (e.g. MMRD Act) so as to have a greater interaction which will enable the country to develop minerals and metals so vital to its economy keeping in mind the environmental issues that threaten to overtake us. The Society strongly encourages all the Geo-institutions and University Geology Departments catering to Earth Sciences to send brief report (not exceeding 4 pages) so that everyone is aware of the research activities that are being carried out in the country.

SOCIETY OF PETROLEUM GEOPHYSICISTS

The Society has been conducting from time to time seminars, workshops, confrences and training courses at the national and international level. Mention may be made of the 10th International Kimberlite Conference at Bangalore during 2012 and the 7th International Earth Science Olympiad in Mysore in 2013. The MoES has entrusted the Society with the responsibility of the participation of Indian higher secondary school students in the International Earth Science Olympiads each year since 2009.

In India, Geophysics has been in curriculum in few selected universities at postgraduate level. However its application in industry was limited to very few companies/ institutions. Consequently, there had been a realization growing strongly amongst the geophysical community that the exchange & sharing of technical ideas and practical experience, though important, was lacking. With these thoughts in the background, a group of geophysicists resolved to form a Geophysical Society with its headquarters at Dehradun. As a result, the **Society of Petroleum Geophysicists, India** was born on August 15, 1992, wherein about 30 dedicated Geophysicists were present and the modalities for the formation of association, for improved interaction and technical exchange of knowledge between industry and academia, were deliberated and formalized.

The Society was registered with the Registrar of Societies as a non-profit organization on January 4, 1993.

From such a humble beginning, at present the society has ten regional chapters, including one overseas; in North America, 18 student chapters, all in India and a total membership of around 2800 which includes Life, Annual & Student memberships.

The SPG-India, publishes half yearly technical journal GEOHORIZONS, which contains technical papers, case studies and activities of the various regional and student chapters regularly. In addition, invited talks & workshops are held at different centres to disseminate the geophysical knowledge.

SPG is presently affiliated to international societies "Society of Exploration Geophysicists (SEG)" USA, European Association of Geoscientists & Engineers (EAGE) - Netherlands & Australian Society of Exploration Geophysicists (ASEG), Australia.

SPG, India has been organizing its international conference and exposition on petroleum geophysics biennially. Till date, SPG has organized 12 international conferences at different centres of India. 13th international conference **"Kochi 2020"** is going to be held during Feb 23-25, 2020 at Lulu Bolgatty International Convention Centre(LBICC), Kochi with the theme ***"Energy Sustainablity: Challenging New Frontiers".*** The theme aims to address the challenges of new frontiers and yet to find hydrocarbon potential for energy security and sustainability of the country. The conference will focus on all aspects related to petroleum E&P, conventional, unconventional as well as renewable energy sources and will provide an appropriate platform to geoscience professionals to discuss and get acquainted with recent advancements in concepts and technologies. Pre conference courses on advanced topics along with geological field trip also has been planned with the ensuing conference.

AN OVERVIEW OF THE ACTIVITIES OF THE ASSOCIATION OF EXPLORATION GEOPHYSICISTS (AEG)

Association of Exploration Geophysicists (AEG) established and registered in the year 1974 is one of the oldest scientific organizations in India with a goal of strengthening Geo-scientific awareness in the country by effective co-ordination of research and investigation in exploration geophysics and allied disciplines. The Association nurtured and supported by many dedicated and selfless Geoscientists, occupies a prominent position today among the Geo-scientific societies in India. Many Leading scientists of country served AEG as its president, Vice Presidents and Executive committee members. Prof V L Bhimashankaram and Prof Y. Sreedhar Murthy, Secretaries of AEG made immense contributions in shaping and growth of this association. Starting with a modest beginning of thirty-one members, the Association has now increased its membership to around 1450. The Association serves actively to build the bridge between the academic experts, Earth Science practitioners and R&D needs of the industry by conducting seminars, workshops and lectures.

So far, the Association has successfully conducted 40 annual meetings and seminars with special themes of relevance and national importance. AEG seminars, annual conventions and exhibition are organized in different parts of the country to enthuse and involve Geo-scientists from various Geo-scientific organizations, academic experts from Universities and IIT's, geosciences service providers, industry experts and bring them all to a common platform. The Scientific community represents scientists drawn from the field of Hydrocarbon, Mineral, Groundwater, Environmental, Engineering, Research and Educational institutions.

AEG takes pride in continuous publication of its Journal, the Journal of Geophysics, a quarterly magazine for the past three decades or even more. The Association also confers AEG Award for the best Ph.D. Thesis in Geophysics, Sriram Srinivasan Award for Significant Contributions in field of Exploration and AEG Best paper Award to research paper published in its Journal. Best Exhibitor award ispresented to the best exhibitor during the seminar. To motivate more members to be part of the Association, AEG encourages young scientists and supports students to attend AEG conferences. AEG extends open invitation to Geoscientists, in the country to write text books, monographs, for publication for benefit of scientists.

Main Objectives of AEG:

- To promote the cause of advanced study and research besides effective co-ordination of Research and Development in all disciplines of Exploration Geophysics and allied fields.
- To promote and exchange ideas amongst the Geoscientific community and also to promote discussions on subjects of interest in the field of Exploration Geophysics and related disciplines. This is achieved by organizing conventions, meetings, seminars, symposia and annual lecture programs etc

- To strengthen the level of geophysical education by providing published teaching and training aids related to the field of Exploration Geophysics
- To encourage research activities and disseminate information of Exploration Geophysics by publishing research bulletins, journals, memoirs, monographs etc
- To institute prizes, medals, etc and honor scientists for their outstanding contribution in any branch of Exploration Geophysics or related discipline and encourage young and talented scientists in their pursuits in such disciplines
- AEG membership is open to all geo-scientists engaged in Exploration Geophysical activities.

Dr. A. K. CHATURVEDI
Secretary, Association of Exploration Geophysicists

Association of Hydrologists of India (AHI)

The Association of Hydrologists of India was instituted in 1981 with the objective of providing a common platform to scientists working on various aspects of hydrology like civil engineering, meteorology, geophysics, geology and remote sensing, environmental engineering and sciences etc., for exchange of ideas and concepts. To realize its objectives a number National / International seminars are organized annually in different locations in the country. During the last 38 years of its existence AHI has organized 37 seminars including three international seminars in different parts of India and abroad. The AHI is an accredited member of the United Nations Committee on Environment and Development (UNCED).

The AHI has the good fortune of having Padmasri Prof. Dr. Harinarayan, a long term director of National Geophysical Research Institute and also a former Vice-Chancellor of Banaras Hindu University as well as a former Surveyor General of India as its first President. It was also fortunate that Padmabhushan Prof. Dr. P. Koteswaram, the former Director General of India Meteorological Department and well know ineternational expert in Water resources was the first Vice-President of AHI and a long time President of the AHI.

Further, the organization of an international seminar on Hydrology at Kathmandu, Nepal in 1993 and during April 19-21st 1993 on "Environmental problems and water resources of Himalayan region" in collaboration with the Nepal Geological Society at the Tribhuvan University and the organization of 8th IAHS Scientific Assembly and 37th IAH Congress in collaboration with NGRI at Hyderabad have made an indelible mark in the national and International Hydrological community. The critical appraisal and recommendations made based on the surveys carried out on the status of Irrigation and drinking water tanks in the country and the comprehensive hydrological and medical surveys carried out in CKD affected areas of AP reflects the role and services of science to society.

Realizing the need to bring out a quality journal in Hydrology 'Journal of Applied Hydrology' has been published quarterly since 1988. Since then the journal, with the patronage of the readers and the authors, has been brought out uninterruptedly. The AHI has been establishing a strong relationship with IAHS and been regularly associated with the activities of IAHS for more than a decade. The AHI has been playing a key role in bringing together National Hydrological Associations and became a member of 'National Hydrological Associations' forum created under the aegis of International Association of Hydrological Sciences (IAHS). AHI has represented the NHA meetings held in Iguassu, Melbourne, Gothenburg and Prague and Montreal. The AHI has been the founder member of FIGA and has been actively participating in its endeavors to propagate geosciences at national and international levels.

The AHI is involved not only in the promotion of Hydrological Education and mentoring of the upcoming hydrologists but also recognized the need to recognize and duly reward the Hydrologists contributed to the promotion of Hydrology. As a part of this endeavor AHI along with CSIR-NGRI confers three awards annually viz., i) NGRI-AHI Life Time Achievement Award in Hydrology, ii) NGRI-AHI Indian National Hydrology Lecture Award & iii) NGRI-AHI Young Hydrologist Award.

The AHI would be taking a leading part in the growth and development of hydrological sciences in India as also its dissemination not only among the scientists but also the larger public. Hydrology is the science of water – needed for all living human beings, animals, creatures, birds and plants.

Adbhyassambhutah Prthvyairasacca

The Palaeontological Society of India

(Registered under Society's Registration Act XXI of 1860 at Lucknow on 12/08/1950)

Centre of Advanced Study in Geology, University of Lucknow, Lucknow 226007.

Website: www.palaeontologicalsociety.in

The society was established in the year 1950 by **Late Prof. M.R. Sahni,** a renowned palaeontologist and former President of the International Palaeontological Association (IPA) to promote palaeontology and allied disciplines in India, with headquarters at Lucknow.

The Society is instrumental in organisation of scientific meetings, conferences and field workshops on topics of contemporary issues in geology and palaeontology. Its main activities are publication of the Journal of the Palaeontological Society of India, Field Guide Books, Catalogues, Monographs, Atlas, Special Publications, etc. It organises several memorial lectures and also the International Fossil Day. The Society also confers various Awards and Medals for encouraging and promoting the discipline of palaeontology among the academicians, young researchers and students in India.

The society publishes a SCI journal of international repute biannually, the **Journal of the Palaeontological society of India** which is of international repute. 64 volumes have been published till date. This journal has citation index of 0.667. In addition, Special publication (6), Monographs (3), Field Guide books on different geoscientific areas (5), Atlas (1) and Proceedings of seminar and symposia have also been published. The Society encourages free dissemination of palaeontological knowledge. It makes available all its publications as an open access on its website

The Society has organised / sponsored / co-sponsored several National and International Field Workshops, Seminars and Brain Storming Sessions on palaeontological and stratigraphical aspects, viz. Precambrians, Vindhyans, Lametas, Sedimentation in Indus Basin (Ladakh), Geoscience Education, etc.

The Society regularly organizes **lectures** in memory of Prof. M. R. Sahni, founder of the Society (since 1983), and also Prof. S.N. Singh (since 1995), and Prof. R.C. Misra (since 2013) former heads of this department. Renowned geoscientists from India and abroad are invited to deliver Lectures and interact with the students of this department.

Being a Corporate Member of the International Palaeontological Association (IPA), the society is organizing since 2016, the **International Fossil Day** on 16th October in Lucknow and other parts of India to promote the palaeontology.

The Society also confers various **Awards and Medals** (instituted by benevolent grants / funds received through the families and friends of the Fellows of the Society) for encouraging and promoting the discipline of palaeontology among the academicians, young researchers and students in India.

INDIAN SOCIETY OF EARTHQUAKE SCIENCE (ISES) was registered on 29.07.2009

Indian Society of Earthquake Science (ISES) was registered on 29.07.2009. Currently over 250 are its Life Members.

OBJECTIVES: (i) To further and popularize the science of earthquakes (ii) To create synergy between different disciplines like Geology, Geophysics and Geotechnical Engineering which lead to understand earthquakes, and also to create synergy between Geoscientists and Engineers.

ACTIVITIES TO ACHIEVE THE OBJECTIVES: Provide logistic support to Researchers, Organize International and National Seminars, Organize Workshops and Training courses for Geosciences and Geotechnical Engineering for Geoscientists, Engineers and students, Organize Lecture Programs, Execute research projects with the national and international collaborations, Publish Newsletter, Journal and Special Volumes, Organize Quiz Competitions, Confer Awards, etc. Publication of Journal was suggested by Seismologists in order to have an Indian journal which can publish fast the earthquake investigation reports even prior to obtaining final results.

ORGANIZATIONAL SET UP OF INDIAN SOCIETY OF EARTHQUAKE SCIENCE

Patrons: Dr. M. Rajeevan, Secretary, MoES, GOI, New Delhi; and Shri Dhananjay Dwivedi, Secretary, DST, Govt. of Gujarat

Executive Committee Members:

President: Dr. B. K. Rastogi,

Vice Presidents: Prof. V.P. Dimiri, NGRI and Prof. T.G. Sitharam, IIT, Guwahati

Secretary: Dr. Sandeep Gupta, NGRI,
Jt. Secretary: Prof. Vikram M. Patel, Adani Instt., Ahmedabad,

Treasurer: Dr. K. M. Rao, ISR

Council Members: (1) Dr. D. Srinagesh, NGRI, (2) Dr. Abhhey Ram Bansal, NGRI,
(3) Dr. M. Ravi Kumar, ISR, (4) Dr. Paresh Patel, Nirma Univ., Ahmedabad, and
(5) Mr. Vipul Kumar Nagar, NHPC

Meetings of Executive Committee, General Body and Annual General Body are regularly held.

Ministry of Earth Sciences (MoES)

सत्यमेव जयते
Ministry of Earth Sciences

The Ministry of Earth Sciences (MoES) was established in the year 2006 to holistically address all the aspects relating the Earth System Processes for providing weather, climate, Ocean, coastal state, seismological, tsunami, air quality warning and water quality services. The services provided by MOES are being effectively used by different Indian agencies and other countries for saving human lives and minimizing damages due to natural disasters. These services also include the Agro-meteorological advisories to about 40 million farmers and Potential Fishing Zone advisories to about 7 lakh fishermen which have led to huge socio-economic benefits. The seismic micro-zonation program envisages preparation of seismic hazard maps at micro level for assessment of ground motion level expected at different locations due to major earthquakes.

MoES has developed an Advanced Data Assimilation and Ensemble Seamless Weather Prediction Systems to generate probabilistic forecasts at a very high horizontal resolution of 12 km. In addition a State-of-the-Art Earth System Model has also been developed to generate future regional climate change scenarios at 25 km resolution and conduct climate impact assessment studies. The Ministry has a High Performance Computing facility of about 8.0 Peta Flops to undertake all its operational and research and development activities.

MoES has a major program for exploration and sustainable harnessing of ocean resources (water, minerals and energy) and development of suitable technology like manned submersibles, deep sea mining system, etc. MoES has developed indigenized technologies for producing clean drinking water from the ocean, especially for the Lakshadweep Island. The economic development of island community is also supported through the development of applications such as artificial reefs and fish aggregating devices. The Ministry also undertakes assessment of shoreline changes and development of innovative coastal protection measures. A new program "Deep Ocean Mission" is being launched for underwater exploration and deep sea mining to support the Blue Economy Initiatives of the Govt of India.

Indian Scientific expeditions to Antarctica, Arctic, Southern Oceans and Himalaya are undertaken on a yearly basis in a phased manner with a focus on geological, glaciological, cryospheric, biological, environmental and atmospheric studies with multi-institutional participation. India has two operational research bases in the Antarctic viz Maitri and Bharati, one in Arctic (Himadri) and one in the Himalayas (Himansh).

ESSO

National Centre for Earth Science Studies

Ministry of Earth Sciences, Government of India

NCESS

The National Centre for Earth Science Studies (NCESS) is an autonomous research institute under the Earth System Science Organization (ESSO) of the Ministry of Earth Sciences (MoES), Government of India. The vision of NCESS is to excel in understanding the deep internal and surface processes of solid earth, its interactive mechanism with the hydrosphere and atmosphere, and to address various scientific issues of concern to the society. The institute hosts a state-of-the-art laboratory infrastructure which enables multidisciplinary research in emerging areas with an integrated approach.

Scientific Infrastructure

NCESS is equipped with modern laboratory facilities which include

- Rock section making and petrology laboratory, X-ray Fluorescence and eX-ray Diffraction laboratory, SEM with EDS, Fluid inclusion laboratory with Raman Micro laser Spectroscopy, Palaeomagnetism laboratory and Resistivity imaging system required for study of internal/surface processes. Additional laboratory infrastructure like LAM-ICP-MS, LA-MC-ICPMS, Magnetotellurics (MT) have been procured.
- Geomatics Laboratory with Remote Sensing and GIS facility for producing thematic maps including cadastral scale maps for demarcating coastal regulation zone.
- Seismological Observatories with seven broadband seismographs for earthquake and crust-mantle studies.
- Low (380m above MSL) and high (1830m above MSL) altitude Observatories with Disdrometer, Micro rain Radar, Ceilometer, Rain drop charge sensor and Automatic weather stations to measure drop size distribution and cloud base height as part of cloud physics and lightning studies
- Marine field equipment like Acoustic Doppler Current Profiler (ADCP), Wave Rider Buoy, Current meter, Echo sounder, Tide gauge for near shore hydrodynamic study.

Core Science Programs

The Centre has made significant contributions in the fields of geodynamics and deep interior of Earth, palaeo-climate, surface processes, interplay between surface and subsurface processes, coastal hydrodynamics, landslides and land subsidence, coastal erosion, submarine ground water discharge, coastal zone management and cloud physics. NCESS functions under four core programs namely (i) Geodynamics of Indian subcontinent and landscape evolution with special emphasis on the Western Ghats (ii) Coastal morphology and hydrodynamics (iii) Water and Environment (River Basins and rivers having their catchment in Western Ghats) and (iv) Natural Hazards (Landslides/land subsidence, cloud processes and lightning, coastal flooding).

ESSO
ESSO - NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
ई एस एस ओ - राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र
Ministry of Earth Sciences, Government of India
पृथ्वी विज्ञान मंत्रालय, भारत सरकार

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वेबसाइट/WEBSITE www.ncess.gov.in
NCESS

Committed to Our Earth Our Future| हमारे भविष्य हमारी पृथ्वी के लिए प्रतिबद्ध

ACTIVITIES OF ATOMIC MINERALS DIRECTORATE FOR EXPLORATION AND RESEARCH (AMD)

Atomic Minerals Directorate for Exploration and Research (AMD) is one of the oldest units of Department of Atomic Energy (DAE) and plays an important role in the front and back ends of the nuclear fuel cycle. AMD was established as Rare Minerals Survey Unit in 1949, subsequently renamed as Raw Materials Division (RMD) and brought under the Atomic Energy Commission on October 3, 1950. RMD was later renamed as Atomic Minerals Division in 1958 and rechristened as Atomic Minerals Directorate for Exploration and Research (AMD) in 1998. AMD has a mandate to: a) Identify and evaluate mineral resources of uranium, thorium, niobium, tantalum, beryllium, lithium, zirconium, titanium and rare earths containing uranium and thorium, b) Approve the mining plans in respect of Atomic Minerals {Part B, First Schedule of The Mines and Minerals [Development and Regulation] (MMDR) Act, 1957], c) Buy from private mine owners, prescribed minerals produced incidental to mining of other economic minerals at prices fixed by Government from time to time and d) Carry out R&D on designing and fabrication of radiometric instruments, development of new analytical techniques for multi-elemental determination at trace and ultra-trace levels and petro-mineralogical characterisation and mineral beneficiation of radioactive ores. Sustained exploration by AMD, over the last seven decades, has established adequate resources of atomic minerals required for India's Nuclear Power Programme.

The programmes of AMD is closely linked to different phases of nuclear fuel cycle viz. survey for identification of atomic mineral deposits (front), site selection for nuclear power reactors (middle) and selection of suitable sites for waste disposal (back). The front phase activities are of major importance and are carried out in the field with adequate laboratory support. The exploration programmes of AMD spread all over the country, with Headquarters at Hyderabad, are implemented from seven Regional Centres located at New Delhi, Bengaluru, Jamshedpur, Shillong, Jaipur, Nagpur and Hyderabad and two sectional offices at Visakhapatnam and Thiruvananthapuram. AMD at present is pursuing a multi-disciplinary exploration strategy, in potential geological domains of the country, involving geological, radiometric and geochemical surveys, heliborne and ground geophysical surveys and drilling for augmentation of additional reserves of uranium and other atomic minerals. The exploration activities is ably supported by Geochronology, Stable Isotope, Petro–mineralogy, XRD, XRF, Electron Microprobe, Mineral Technology, Radiometric and Chemical laboratories equipped with state-of-the art equipments.

Uranium Exploration:

Uranium exploration in India dates back from 1949 and the first mineralized area was located in the early 1950's in Singhbhum Shear Zone (SSZ), Jharkhand. India possesses a wide variety of geological terrains ranging in age from Achaean to Recent, suitable for hosting several types of uranium deposits. Sustained exploration during the last six decades using multi-disciplinary methods has identified several geological domains which have immense uranium potential and a number of uranium deposits have been established in these domains. The potential uranium provinces include Singhbum Shear Zone, southern and northern parts of Cuddapah basin, North Delhi Fold Belt, Mahadek basin and Bhima basin. Exploration in these geological domains is in advanced stages and substantial uranium resources have been already established in these sectors. Further, a number of promising geological provinces have also been identified, where sustained exploration will augment uranium resources in near future. These provinces are Siwalik Basin, Chhotanagpur Granite Gneiss Complex (CGGC), Aravalli Fold Belt, Kaladgi basin, Gwalior, Vindhyan, Chhattisgarh and Indravati basins, Shillong and Gondwana basins, Dharmapuri Shear Zone and Kotri-Dongargarh belt.

Rare Metal and Rare Earth elements Exploration:

AMD also carries out exploration, prospecting and exploitation of rare metals (Nb, Ta, Be and Li) and rare earth minerals (La to Lu & Y) in different parts of the country. The insitu and eluvial soils, derived from the mechanical weathering of host rocks, mainly mineralised complex pegmatites, normally contain rare metal minerals namely columbite-tantalite (niobium-tantalum), beryl (beryllium) and spodumene & lepidolite (lithium). The soil containing these minerals is excavated, treated and recovered in the plants normally established near the source. Currently, such recovery plants are in operation in Odisha and Karnataka. Some of the streams in Chhattisgarh and Jharkhand also contain higher concentrations of yttrium bearing placer mineral (xenotime), which is currently recovered through recovery plant established in Chhattisgarh. AMD has intensified exploration in the caorbonaite complexes, acidic-basic effusives in India. In this direction, substantial extents of REE mineralisation has been established Ambadongar, Chhota Udepur district, Gujarat (LREE rich) and Siwana Ring Complex, Rajasthan (HREE rich).

Beach Sand Minerals Exploration:

The beach sands of Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra and parts of Gujarat contain rich concentration of heavy mineral resources of titanium (ilmenite, leucoxene and rutile), zirconium (zircon), REEs (monazite) besides magnetite. All these minerals occur as placers in the sand. AMD identifies such heavy mineral rich placer sand regions along the coast, and estimates the resources of individual minerals. The sand containing heavy mineral resources are mined and treated in the plants operated by M/s Indian Rare Earths Ltd (IREL). Further, the inland placer sands of Odisha and Andhra Pradesh and Teri (red coloured) sand occurring in the southern part of Tamil Nadu also contain heavy minerals.

INDIAN INSTITUTE OF GEOMAGNETISM

IIG has an enviable antiquity of over 175 years, which was instrumental in spawning geomagnetism in the Indian sub-continental region. It has evolved from being a data gathering organization to using long series geomagnetic data, to tackle applied aspects that benefit society, in an obvious and abstruse ways. **Indian Institute of Geomagnetism (IIG)** was given a full-scale mandate to pursue geomagnetic and allied field research in 1971. It has been an autonomous institution since its inception and is now functioning directly under the Department of Science and Technology, Government of India. The evolution of geomagnetism in the country has been interminably linked with the growth of this institution. IIG currently operates 12 geomagnetic observatories and three regional centres at Tirunelveli, Allahabad and Shillong. The Institute regularly participates in the Indian Expeditions to the Arctic and Antarctic.

Geomagnetism has many societal applications and this science impacts all of humanity in one form or other. The very survival of all the life forms on earth is related to the existence of this geomagnetic field. It's in the fitness of things that we all understand the very significant role this component plays in cosmic natural processes. A significant contribution to research in the field of geomagnetism started in India as back as in 19th century. Geomagnetic observations commenced in India and rest of the world almost concurrently. **The first magnetic observations in India were started at Madras in 1822, followed by the recordings at Simla (1841), Trivandrum (1841) and Colaba (1841).** Among these, only Colaba observatory continued uninterrupted since 1841. The combined observations at Colaba and Alibag observatories provide the longest series (nearly 175 years) of magnetic field data.

IIG is actively engaged in basic and applied research in Geomagnetism and allied areas of Geophysics, Atmospheric & Space Physics and Plasma Physics. Geomagnetism is an area of study that is truly multidisciplinary encompassing such disciplines like physics, mathematics, geology, geophysics, atmospheric physics, plasma physics, fluid dynamics, geochemistry, geomorphology and non-linear dynamics, to name a few. The study of Geomagnetism encompasses the entire Heliosphere starting from the centre of the Earth extending to all the planets and the Sun itself. IIG has a number of active scientific groups involved in theoretical, experimental, and observational research work.

The vision of IIG is to enable India become a global knowledge centre in Geomagnetism and allied fields. The Institute's mandate is also to maintain and modernize the magnetic observatories under its magnetometer network, establish new observatories and publish high quality data as Indian Magnetic Data volumes. The magnetic records from these observatories serve as useful tools for the study of electrical current systems flowing in the near space environment, the understanding of which has a bearing on monitoring and assessing the health of satellite navigation systems. The World Data Center (WDC)-Geomagnetism, Mumbai, is now a member of the International Council for Science-World Data System. IIG is also involved in the calibration of magnetic compasses of Indian Navy, Indian Coast Guard, Naval Air Stations, and providing services to ISRO, DRDO, DoS, NHPC etc besides providing high resolution digital magnetic data to several research and other government organizations. The Institute has a modern laboratory for design and fabrication of instruments used in Geomagnetism and allied fields.

On the research front, IIG has been doing cutting edge contemporary science in deciphering the cause and effects related to Earth-Atmosphere coupled observations on various time scales using a variety of geophysical tools. In the areas of space geomagnetism and plasma physics, radio and optical remote sensing along with geomagnetic field variations are employed as diagnostic tools to probe the Earth's near space environment. Several theoretical studies are being carried out on charged particles, electric fields and currents in the space environment comprising the solar wind, magnetosphere and ionosphere. Recently, three new interdisciplinary research programs viz., (a) Space Weather Prediction, (b) Climate Variability and Change and (c) Coupling & Dynamics of Lithosphere-Atmosphere-Magnetosphere (LAIM) have been initiated at IIG, which has immense societal value and relevance.

Capacity building for scientific research is another major mission of the Institute. To attract, motivate and train young talent to undertake research in geomagnetism and allied areas, new initiatives have been taken by IIG, such as 'Inspiring Minds of Post-graduates for Research in Earth and Space Sciences' (IMPRESS) and Dr. Nanabhoy Moos Post-Doctoral Fellowship to research scientists.

CSIR-National Geophysical Research Institute (CSIR-NGRI)

Hyderabad

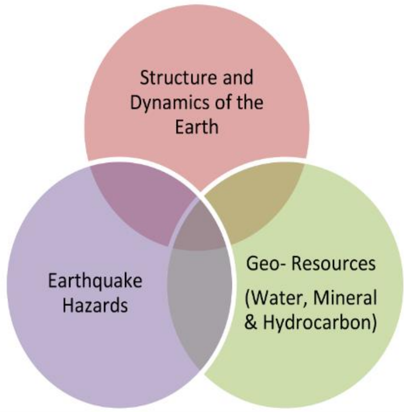
India`s Premier Earth Sciences Research Institute

Vision : Pursuit of earth science research, which strives for global impact and its application for optimizing sustainable societal, environmental, economic benefits for the Nation

CSIR-National Geophysical Research Institute (CSIR-NGRI) was established in the year 1961 at Hyderabad for carrying out the national mandate to coordinate geophysical activities and research in the country to bring emphasis on the exploration for water, hydrocarbons and minerals as well as assessment and mitigation of natural hazards such as earthquakes. During last 56 years, the institute has established an enviable reputation both in India and abroad for its research excellence and multidisciplinary R&D programmes in Earth System Sciences. CSIR-NGRI is pioneer in carrying out air and Heli-borne geophysical surveys for mapping of natural resources throughout the country. The institute has built-up self sufficiency in ground and heli-borne geophysical surveys centered around a dedicated team of scientists with expertise in data acquisition, quality check, processing, modelling and integrated interpretation and has completed Aquifer Mapping in 5 states of India and is executing uranium exploration program for Atomic Minerals Directorate (AMD) of Department of Atomic Energy (DAE). Apart from this, CSIR-NGRI also contributes to many earth science mission mode projects of the country supported by the Department of Science & Technology (DST), Ministry of Earth Sciences (MoES), Department of Atomic Energy (DAE), Department of Space (DOS), Ministry of Environment & Forests (MoEF), Ministry of Steel & Mines (MoSM) and such other wings of Government of India and many governmental agencies of different States.

Unique R&D Facilities to map near Surface Resources and Deep Earth Structure

- Deep Earth Probing
- Shallow Sub-surface Exploration
- Active Crustal Deformation
- Geotechnical Investigations
- Groundwater Exploration
- Geochemistry and Geochronology
- Gas hydrates, Hydrocarbon
- Mineral Exploration
- Environmental Monitoring
- Geophysical Observatories



Providing S&T Solutions for the Society and Strategic Sectors

KESHAVA DEVA MALAVIYA INSTITUTE OF PETROLEUM EXPLORATION (KDMIPE), ONGC, DEHRADUN

Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE) is premier R&D Institute of Oil and Natural Gas Corporation Limited (ONGC). Situated in picturesque Doon Valley (Dehradun, Uttrakhand), KDMIPE was established as Research and Training Institute in 1962 to provide geoscientific insights to ONGC in its quest for hydrocarbon resources. It was rechristened as Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE) on 19th December, 1981 in the memory of the father of Indian Petroleum industry and first chairman of ONGC, Shri Keshava Deva Malaviya.

KDMIPE is a centre of excellence for research in petroleum geoscience and allied discipline. It is unmatched among petroleum exploration research institutions around the world. The institute is at the forefront of petroleum geoscience research for conventional and unconventional hydrocarbon resources in diverse geological settings, including deep offshore and tectonically challenged terrains. The institute undertakes world-class research in petroleum geoscience and reservoir engineering with capabilities in regional tectonics and basin analysis, seismic interpretation, sequence stratigraphy, tectonic and structural control on basins development, petroleum system modelling, sedimentary petrology, clastic and carbonate deposition system, reservoir characterization, biostratigraphy, palaeontology, palynology, petrophysics, non-seismic prospecting including remote sensing & geomatics, gravity-magnetic & magnetotelluric, surface geochemical-geomicrobial surveying, stochastic modelling, numerical simulation, reservoir engineering, resource assessment, techno-economic evaluation and exploration of unconventional hydrocarbon resources. The institute provides expert geoscientific support to field operations in domains of formation evaluation, reservoir management and geomechanics to alleviate challenges in conventional, unconventional, HP-HT and mature field rejuvenation applications.

KDMIPE has a demonstrated record of conscientiously and proficiently finding oil and natural gas in Indian and global sedimentary basins over the decades for nation's economic development and energy security. Whether it is exploration efforts in deep abyss of Mumbai Offshore, tectonically challenged regime of Assam, or exploring unconventional, KDMIPE has been at forefront. It is the nodal agency for multidisciplinary synergistic basin scale and domain-specific research in exploration.

KDMIPE is credited to have prepared the first ever Tectonic Map of India in 1968, which was later revised in 2003. The institute has prepared the sedimentary basin map of India with exploration categorization and steered preparation of first detailed document on

Lithostratigraphy of Indian proliferous basins. It spearheaded R&D on unconventional resources, such as CBM, Gas Hydrates, Shale Gas, and Basin Centered Gas and played key role in planning, monitoring and execution of expeditions for India's National Gas Hydrate Program. It carries Resources and Reserves Estimation for all known sedimentary basins of India on a continual basis.

KDMIPE is home to technical specialities and has a wide-ranging expertise in niche areas of petroleum exploration. From outcrop studies to exploratory test and beyond, KDMIPE covers all aspects of research with excellent human resources, world class technologies, state of the art laboratories and knowledge hubs. KDMIPE facilitates multi-disciplinary research amongst geoscientists and engineers who invoke leading-edge technologies to E&P process. Innovation is the mainstay of geoscience research and at the nucleus of innovation at KDMIPE is high calibre, accomplished and creative geoscience professionals working in integrated, multi-disciplinary research teams to expand scientific research and knowledge. Undoubtedly, technical capabilities and human resource strength sets KDMIPE apart.

KDMIPE carries out collaborative research with national and international academic institutions, domain specialists, and industry partners and provides E&P consultancy to help companies and business organizations in the upstream segment. Prof. N.A. Ermenko Library and Oil Library constitute knowledge hubs of the institute. The institute has one of the largest repository of subsurface core samples in India. KDMIPE encourages knowledge sharing and dissemination through publication of frontline journal 'ONGC Bulletin' on a biannual basis.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY (WIHG) DEHRADUN

The Wadia Institute of Himalayan Geology (WIHG) at Dehradun is an autonomous institution of Department of Science & Technology (DST), GoI, which came into being in 1968. It has been pursuing basic researches to unravel the orogeny of majestic Himalaya, and to provide improved understanding on seismogenesis, geodynamic processes, climate-tectonic interactions, evolution and extinction of life, ore formation, glaciology, river system, natural hazards (landslides, floods, and earthquakes), anthropogenic impact etc. towards the well-being of population and safe-guarding the properties and structures in the Himalaya and adjoining areas. The research activities to understand mountain building processes and shed light on above topics are based on observations using rudiments of structural geology, petrology, paleontology, stratigraphy, sedimentology, geomorphology, geophysics, remote sensing etc. In the back drop of wide ranging claims on the likely impact of climate change on Himalayan glaciers and their far-reaching consequences on Indian economy, the DST has established the *'Centre for Glaciology'* at WIHG. The Institute has been nurturing a monitoring system in an integrated manner by hosting *'Multi-Parametric Geophysical Observatory (MPGO)'* at Ghuttu (Tehri), Uttarakhand. This is a unique set up to perceive changes in subsurface properties that may lead to earthquake precursory study in the Himalayan region. The Institute has established as many as 54 Broad Band Seismographs and 16 Acceleragraphs spread over H.P., Uttarakhand, J&K, Punjab, Haryana and Arunachal Pradesh. Similarly, around 17 GPS instruments are installed in H.P., Uttarakhand, J&K and Ladakh. The WIHG is well equipped with sophisticated analytical instrument facilities run by competent scientists and technicians. The facilities are being utilized by the research scientists of Wadia as well as researchers from state & central universities and other organizations. Some important instruments available in the Institute are LA-MC-ICP-MS, Stable Isotope Mass Spectrometer, EPMA, ICP-MS, XRF, SEM, XRD, Raman Spectrometer, TL/OSL, Magnetic Susceptibility meter etc. The institute also provides consultancy services for engineering projects, drinking & ground water surveys, natural hazards, road & rail alignments in the Himalaya and adjoining region. During the glorious journey, a few scientists were honored with the Padma Awards and 15 Researchers with the National Geosciences Awards. The Institute has published more than 2000 research articles in the National & International Journals, and produced more than 120 Ph.Ds. The vision of WIHG is "**Questing for Himalayan Seismogenesis, Geodynamics, Natural Hazards, Climate Variability and Natural Resources through Geoscientific study to fulfil the Societal Needs and pursue Basic Sciences**".

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LITHOSPHERE STRUCTURE AND GEODYNAMICS (LSG)

Hadean to Mesoarchean geodynamic processes in the Singhbhum Craton, eastern India: constraints from zircon age-Hf isotopes

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The Paleo- to Meso-archean Singhbhum craton, eastern India is among the oldest of the Archean cratonic nuclei of the Indian shield. The Archean basement of this low-medium grade (greenschist-amphibolite facies) metamorphic terrane comprises ~3.53–3.29 Ga tonalite-trondhjemite-granodiorite (TTG) gneisses referred to as the Older Metamorphic Tonalite Gneiss (OMTG) and over a dozen granitoid plutons collectively known as Singhbhum Granite (SG) with supracrustal rock enclaves, the Older Metamorphic Group (OMG). The central granite-gneiss domain is surrounded by belts of 3.5–3.4 Ga supracrustal rock successions (greenstones), the Iron Ore Group (IOG).

There has been a proliferation of zircon age-Hf isotope data from the Singhbhum craton, eastern India in the last couple of years. Of particular significance are the reports of Hadean and Eoarchean zircons from the craton, both xenocrystic and detrital, the oldest yet reported from India. Xencrystic zircons of 4.24 Ga and detrital zircons from modern river sand as well as 2.91 Ga Mahagiri quartzite with ages between 4.1 and 2.91 Ga. The zircons with Hadean ages (4.24 to 4.1 Ga) are mainly xenocrystic occurring in OMTG rocks and one zircon recovered from modern river sand. The Eoarchean ages of detrital zircons from the Mahagiri quartzite vary from 3.95 to 3.6 Ga covering the entire period. The dacite belonging to the IOG yield a U-Pb age of 3505±5 Ma. The TTG gneisses seems to have emplaced at 3.45 Ga and the granitoids known as SG at 3.32 Ga. Interpreted in the light of global data sets on ancient zircon age-Hf±O isotope record, the Singhbhum data provide valuable insights into the compositions and geodynamic evolution of Earth's early crust. MThe U-Pb ages and Hf isotopic from the Singhbhum craton show a prominent shift in Hf isotope compositions at ~3.6–3.5 Ga towards super-chondritic values, which signify an increased role for depleted mantle and the relevance of plate tectonics. The Paleo-, Mesoarchean zircon Hf isotopic record in the craton indicate crust generation involving the role of both depleted and enriched mantle sources. We infer a short-lived suprasubduction setting around ~3.6–3.5 Ga followed by mantle plume activity during the Paleo-, Mesoarchean crust formation in the Singhbhum craton.

Ambient Noise Rayleigh wave Tomography across the Madagascar I

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The unusual complex lithospheric structure of Madagascar is a product of a number of important geological events, including: the Pan-African Orogeny, episodes of Late Cenozoic intraplate volcanism and several phases of deformation and metamorphism. Despite this rich history, its crustal structure remains largely underexplored. Prior to 2013 and the recent seismological experiments like the MAdagascar, COmores and Mozambique (MACOMO) and the Seismological signatures Signatures in the Lithosphere/Astheno-sphere system of Southern Madagascar (SELASOMA) seismic experiments, there has been no island-wide seismological study of the region, and its crustal structure was mainly constrained from magnetic and gravity measurements. The few studies conducted so far are either of limited geographical extent or of relatively low resolution and as a result, its present day lithospheric structure is not well known. In this study, we take advantage of the recently obtained dataset of the RHUM-RUM (Réunion Hotspot and Upper Mantle–Réunions Unterer Mantel) seismological experiment which consists of over 50 Ocean Bottom Seismometers (OBSs), in addition to previously available datasets to generate the first Rayleigh wave group velocity maps across the entire island at periods between 5 and 30 s using the ambient noise tomography technique. Data from OBSs are contaminated by local noise (tilt and compliance noise) which are detrimental to the retrieval of surface wave empirical Green's functions. These data are specially treated to suppress the influence of these local signals before all data (including those from island- and land-based seismic stations) are subjected to the well established ambient seismic noise data processing routine. Group velocities were then measured to perform surface wave tomography. The addition of data from OBSs increased the raypath coverage which ultimately improved the resolution and fidelity of the Rayleigh wave group velocity maps obtained. These high-resolution maps have excellently imaged the three sedimentary basins in the western third of the island: Morondava, Mahajanga and Antsirinana Basins, never before observed in such detail. In agreement with previous studies, at shallow to mid-crustal depths (~ 5 and 10 s maps), our results show fast isotropic group velocities all over the Precambrian shield occupying two-thirds of the island to the east in contrast to the adjacent sedimentary basin in the western coast that is delineated by slow velocities. Low velocity anomlies appear to persist up to the 20 s Rayleigh wave group velocity map implying a probably more thicker sedimentary basin compared with findings of previous studies. At deeper depths (~ 30 s maps) corresponding to the lower crust and roughly the uppermost part of the upper mantle, relatively fast velocities preponderates the western third of the island indicating a thinned crust and uplifted mantle. Although the 30 s map reveals the island is thickest at the center and thins away towards the margins, it however, also reveals a high velocity anomaly that appears to demarcate southern and central Madagascar. We interpret it as a relatively thinned crust related to the Ranotsara shear zone (re)activation. Our results provide first-order constraints on the crustal structure beneath and around the Madagascar island.

Lineament mapping of the Northwestern Dharwar craton using aeromagnetic anomalies and their temporal evolution

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The region under study comprises of the northern part of Western Dharwar Craton (WDC) which extends from 14ºN-16ºN latitudes and 73º-76ºE longitudes and is bounded by Deccan

Traps in the North and Southern Granulite Terrain in the South. Analysis of aeromagnetic data of the onshore and continental shelf region along with available gravity data of the region reveal different tectonic elements as well as economic resources.

The aeromagnetic anomalies are broader on the east of the Western Ghats indicative of deeper and/or lesser magnetized sources. A huge three-dimensional magnetic anomaly is observed north of Netrani Island in the Shelf region. The numerous high low anomaly pairs along the entire coast in the study region are attributed to the exposed and sub-surface iron ore bodies which are economically feasible. From the aeromagnetic data, three major tectonic trends were delineated in the region, the evolution of which can be attributed to the temporal phases of the global evolution of the WDC. The continental shelf is characterized by NNW-SSE trends which can be correlated with the breakup of India-Seychelles-Madagascar during the post-Cretaceous period. Within the land, major lineaments trend in NW-SE and NE-SW directions. While the NW-SE is in accordance with the regional trend of the Dharwar craton, the NE-SW trends show parallelism with the major rivers that drain the region and lithologic contacts. One such NE-SW trending lineament, Dharma-Tungabhadra Ln. (DTLn), coincides with the southwestward extension of the Tungabhadra River. This lineament is associated with earthquake epicenters. Another NE-SW lineament, almost parallel to the DTLn, towards the northern part of the region coincides with the Chapporo lineament marking the lithologic contact between Deccan Trap and the Peninsular Gneiss. Most of the NE-SW lineaments are found to extend into the continental shelf region and dislocated at places by the NNW-SSE trends. These tectonic lineaments suggest that there were different episodes of deformation leading to the evolution of the present-day WDC. Results of the analysis carried out using aeromagnetic, gravity and other supplementary geophysical data will be presented.

Insight into extension of Delhi fold belt towards north using gravity modelling

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The litho-tectonic units of the Delhi fold belt are considered to be buried under the Quaternary sedimentary cover of Gangetic alluvium towards north. The Bouguer gravity anomaly above the Delhi fold belt shows a prominent NNE-SSW trend towards south of the Indo-Gangetic plain. In this study, we constrain the crustal structure of the Delhi fold belt using the results from different methods: 2D radially averaged power spectrum, edge enhancement techniques, filtering and derivative analysis, the Depth from Extreme Points (DEXP) method, and 3D structural inversion of the Moho. Our model suggests presence of upwarping in Moho and underplated mafic material, which represents a residual plume head and produces the prominent gravity high. The trends of filtered gravity anomalies and depth variations of the

Moho from 3D structural inversion indicate absence of northward extension of the Delhi fold belt underneath the Indo-Gangetic alluvium and deflection of this Moho structure towards NW direction along the Delhi Sargoda Ridge axis. The results will be presented in light of the tectonics of the study region.

Geophysical scanning of Madawara Igneous Complex (MIC): results from integrated gravity-magnetic survey

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Mafic-ultramafic rocks around Madawara village in the southern part of Bundelkhand Craton is commonly known as Madawara ultramafic complex or Madawara Igneous Complex (MIC). Existing geochemical and petrographical studies indicated possibilities of Cr-Ni-PGE mineralization in chromite and sulphide bearing ultramafic rocks. However, no geophysical studies are reported over this region till now. Thus, for the first time, an integrated gravity-magnetic study has been carried out over MIC to delineate the extension and position to delineate the extension and position of mafic-ultramafic rocks and related structural features. Upward continued regional gravity anomaly map has effectively deciphered the SW-NE decreasing trend of the Bouguer anomaly map of the study area. Such a decreasing trend of gravity anomaly indicates the presence of significantly different crustal configuration towards SW and NE part of the study area. Correlation among high residual gravity, high reduced to pole (RTP) magnetic anomaly and exposed mafic-ultramafic rocks at the central part of the study area has deciphered the continuity of mafic-ultramafic intrusive body from Madawara to Pindar villages in EW direction. Distinct gravity anomaly gradients towards north and south of this central high anomaly zone reveal the presence of Madawara-Karitoran and Sonrai-Girar shear zones, respectively. 2D radially averaged power spectrum and 3D Euler deconvolution have revealed average basement depth for gravity sources as ~0.3 km, 1.2km and 3km, and for magnetic sources as ~0.3km and 1.2km. Based on local geology and magnetic signature, it can be inferred that the shallowest layer associates with sedimentary sources and intermediate basement mostly consists of high magnetic mafic-ultramafic intrusive rocks. Below this intrusive unit, there exists a high density basement layer with average depth to the top of the layer is ~3km. These results are consistant with the findings of 3D Euler deconvolution and later suggest the sources as dike and spherical in shape which also agrees with existing geological knowledge of the region. Correlation between high gravity-magnetic anomalies with previously identified high concentration of Cr-Ni-PGE in the mafic-ultramafic samples from Madawara, Ikauna and Pindar villages has also established probable geophysical signature for PGE mineralization in MIC. This has led to delineation of new prospective PGE mineralization zones in MIC belt. Thus, the study has effectively revealed the gravity-magnetic signature of existing geological features, their continuity, as

well as prospective locations for mineralization thereby providing initial input in understanding the subsurface configuration of the region.

Recent investigations using the hybrid seismological network at Koyna, India

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CSIR-NGRI is operating a unique combination of borehole and surface seismic network as a part of the scientific deep drilling investigations, a major program initiated by Ministry of Earth sciences (MoES) Govt. of India during 2011 at Koyna, a famous site for the continued reservoir triggered seismicity. With the advantage of borehole seismic network, the absolute locations of earthquakes have been improved significantly, achieving a major leap in one of the prime objectives. During January 2016 to May 2019, a total of 5423 earthquakes of M_L -0.8 to 4.0 have been located including 2726 micro-earthquakes (M_L -0.8 to 0.4) are from borehole seismic network alone. The spatial distribution of earthquakes indicated few new zones of seismicity clusters in the vicinity of the borehole locations. The recent largest earthquake being M_w 4.0 that occurred on 20th June 2019 which followed by several aftershocks. The P- wave analysis of this earthquake indicate a complex onset and multiple event. A significant improvement in the estimation of absolute locations, relocations and fault plane solutions of earthquakes at Koyna are presented. Also, a 3D velocity inversion is carried out in the source zone of 1967 main Koyna earthquake and Warna fault regime to investigate subsurface structure and seismogenic layers. Initial results on tomograms of Vp and Vp/Vs using the surface broad-band and borehole data are discussed. For the first time, an automated detection algorithm 'MStudio' has been implemented for the Koyna earthquake data sets, where a significant improvement is achieved in identifying the huge number of micro-earthquakes.

Geophysical study of Tonk and Dausa districts, Rajasthan: a new perspective and its implication for regional geology

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Regional geophysical survey employing gravity and magnetic methods have been carried out in 4320 sq. km of Tonk and Dausa districts, Rajasthan with aims in identifying the regional geological units and to bring out the associated structures that may have bearing on possible mineralization. The objective of the survey is to delineate subsurface structural features.The

study has brought out some gravity and magnetic features of the area. A total variation of Bouguer gravity is 39 mGal ranging from –33 mGal in north–west part and –72 mGal in south–east part. A gravity high zone has been delineated in the north-west part around Jaipur. This zone is associated with two high closures of –30 mGal trending NE–SW and –28 mGal trending NW–SE direction respectively. The abrupt change in disposition indicates a N–S fault. The continuous decrease in gravity from north-west to south–east indicates deepening of the basement. The magnetic (TF) map shows variation of 310 nT from -250 nT to 60 nT. Highly localized shallow features are observed throughout the study area. High magnetic anomaly closures are observed in the north–east and south central part of the study area. These two high magnetic anomalies are separated by low magnetic zone trending E–W direction which is indicative of contact of lithological units. Radially averaged power spectrum of gravity data indicate average depths of 5.5 km and 2.5 km corresponding to the Archaean basement and top of the rock formation. Magnetic data shows deeper sources lying from 1.5 km to 2.5 km and shallow sources ranging from 0.5 km to 1.5 km. Euler deconvolution provided possible depth solution map, which shows the majority of clusters generated, range from 1500 m to 2500 m and are well corroborated with the results obtained from power spectrum of magnetic anomalies. The maximum number of depth solution is generated along the contact of lithological units.

Delineation of structural features using gravity data: a case study in northeastern part of India

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The area of study is situated between latitude 23°–28°N and longitude 88°–96°E and situated in the northeastern part of India is one of the most seismically active tectonic provinces in the world with seismic zone-V. The complicated geotectonic setups develops various smaller and larger magnitude earthquakes and senses seismic activities along the Shillong Plateau, Naga Hills, Mikir Hills, Mishmi Hills of Himalayan foothills and Arakan-Yoma Folded Belt, This area had demonstrated several thrust-faults activities in the recent past and still continuing. It is also suggested that Brahmaputra Thrust, Dauki Fault, Naga Thrust, Disang Thrusts and Kopili Faults have key responsibilities for high seismicity and tectonic movement causing upliftment and depression that encouraged some anti-clockwise rotation in the area. It is important to acquire wide-ranging learning tectonic configuration, thrusts-faults/lineament delineation for improved geoscientific study. There are various known prominent thrust-faults have been marked by studying GIS map, field geological study and other geo-scientific studies, however, many active and hidden thrust-faults are still un-identified. As seismic data can provide better information about the thrust-faults locations, but due to small number of seismic data, the information is not adequate.

In this paper, attempt has been made to study and re-interpret the available ground gravity data of northeastern part of India for understanding thrust-fault / lineament locations using various applications of gravity derivatives like, like analytical signal analysis(ASA), horizontal gravity gradient (HGG), tilt derivative (TDR), horizontal tilt angle derivative (TDX), Cos(θ) analysis and source edge detection technique (SED). It is understandable that the low gravity is observed at Assam valleys which contributed sediment accumulations and higher gravity anomaly observed at Shillong Plateau and Bengal Basin containing denser formations. Bouguer gravity data is used after isostatic correction assuming Airy's isostasy root depth model and first order trend removal using least square technique. The derived thrust-fault locations from the present study are superimposed with the existing thrust–fault locations for correlation. Some additional thrust-faults are narrated which are not previously mapped and can help for better geo-scientific study for details analysis

Applicability of Rock Failure Criteria for Estimation of Minimum Mud Weight in Upper Assam, India

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The entire province of Upper Assam is one of the oldest producing basin of India, rich in hydrocarbon reserves with complex tectonics. The study area lies in the Upper Assam of North East India surrounded by Mikir Hills, Main Boundary Thrust, Mishmi Thrust and the Naga-Disang Thrust. Two wells, M1 in the extensional region of Assam Gap and J1 in the Naga Thrust of Belt of Schuppen has been chosen to study wellbore stability using borehole collapse modelling. Wellbore stability necessitates a proper balance between the factors which can be controlled while drilling (mud weight, well trajectory) and those factors which cannot be controlled (horizontal and vertical stresses, pore pressure, rock strength). Poroelastic modeling of the two wells has been carried out to estimate horizontal stress magnitudes. Ratio of minimum horizontal stress (S_h) to vertical stress (S_V) is observed to be 0.72 in normal faulted well and 1.02 in thrust faulted well. Density of drilling fluid, that is the equivalent mud weight plays a major role to maintain wellbore stability and should be predicted with confidence. Proper mitigation of the issue is addressed in the current study by analysis of rock failure criteria through borehole collapse model. Mogi-Coulomb rock failure criteria is found to be better suited to derive minimum mud weight for well M1 in normal faulted region. Mud weight of 1.27 g/cc is observed at 3897m for M1 to ensure stability which matches with the actual mud weight used in the depth interval. In thrust faulted regime, it is observed that Mohr-Coulomb predicted mud weight yields better results. High density mud weight is observed for stability in J1 (≥1.2g/cc at 600-1100m). Borehole collapse model defines safe well

trajectory with lower mud weight. From disc plots we may conclude that M1 in normal faulted region would have maximum stability if drilled vertical perpendicular to maximum horizontal stress. J1 in thrust faulted region would attain stability if drilled horizontally along the direction of maximum horizontal stress.

Seismic Hazard Assessment of Gangtok Region–A Direct Amplitude-Based Approach

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The Seismic hazard estimate gives the probability of exceedance of a certain level of ground motion intensity, at a particular region, for a given return period. Though conventional Cornell's approach to hazard assessment is a useful tool, it has certain limitations as the method uses empirically derived ground motion prediction equations (GMPEs) that predict the intensity of ground shaking disregarding the rupture details of the source and site characteristics. The direct amplitude-based (DAB) method, which is derived analytically from Cornell's approach, overcomes these limitations by incorporating the exact details of each potential earthquake source mechanism and site characteristics. The main objective of this study is to demonstrate the application of the DAB method to estimate the hazard of the Gangtok region in light of the 2011 September 18th Mw6.9 earthquake. All the earthquake events in the vicinity of 400 km from the political boundary of the Sikkim state are considered for the analysis. The earthquake catalog is processed for completeness. The evaluated PGA for 72, 475 and 2475 years return period, using DAB will be reported for Gangtok.

Love Wave Group Velocity Tomograms for NE India and Adjoining Region: Geodynamic Implications

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NE India and surrounding area is a geologically and tectonically complex area. Many geological and geophysical studies have been carried out to understand its subsurface structure and relate it with the seismicity to understand the geodynamic processes that shaped this complex area. In this study we have used Love waves recorded at 23 stations, 20 in NE India and 3 in nearby regions, to estimate 3-D variation in group velocity for NE India and adjacent regions like Bengal Basin to its south, Eastern Himalayas to its north, Indo-Burma Ranges to its east and western margin of Bengal Basin. Such tomograms could be estimated at a number of periods ranging between 6 second to 65 second. As surface wave group velocity at a given period is affected by S wave velocity of medium at depths of about 0.4 times of corresponding wavelength, the estimated tomograms can throw light on how the medium property changes with depth too. It is observed that at lower periods (less than or equal to 24 second, Bengal Basin has lower Love wave group velocity compared to regions towards its north and west. This may be a manifestation of presence of thick layers of low velocity sedimentary rocks in the Basin. At the same low group velocity range Shillong Massif and Mikir Hills, as well as the western margin of Bengal Basin show higher velocity. This is supported by the fact that these areas have higher velocity crystalline rocks at shallower depths. On the other hand, at periods greater than or equal to 48 second, Bengal Basin and its western margin as well as Shillong Plateau and Mikir Hills have higher group velocity compared to those observed for the Eastern Himalayas, southern part of the Tibetan plateau and Indo-Burma Ranges. This may be a manifestation of presence of low velocity material below the latter group at deeper regions compared to the former one caused by underthrusting below the Himalayas and southern Tibet and subduction below Indo-Burma Ranges.

Spatial variations of radioelemental concentrations and heat production of the granitoids from the Singhbhum craton, eastern India and their geodynamic implications

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Long-lived radioisotopes of Th, U, and K are responsible for radiogenic heat production (A) of rocks. Radiogenic heat production plays an important role in thermal modeling of the lithosphere and to understand the processes related to the evolution of the Earth.

First time, radioelements have been measured on 206 granitoid samples, by high-sensitivity spectrum-stabilized laboratory gamma-ray spectrometric set-up, from the oldest craton (3.53 to 3.25 Ga) of the Indian shield, known as Singhbhum craton. Study region is spatially divided into four zones, i.e., north-eastern part (Hata-Saraikela-Raiangapur) as NE Zone or Zone-1, the central part (Haat Gamhariya-Champua) as Central Zone or Zone-2, southern part (Keonjhargarh and surrounding) as South Zone or Zone-3 and south-western part (Pala Lahara) as SW Zone or Zone-4. Samples consist of Paleoarchaean gneisses (OMTG; 3.45-3.30 Ga), three phases of Paleoarchaean granites (SBG I, II, III; 3.38 to 3.25 Ga) and early Neoarchaean granites (YG; 2.8 Ga).

Radioelements and heat production fall in a narrow range for the Paleoarchaean granitoids, while slightly higher for the early Neoarchaean granitoid. Further, for the coeval granitoids within the craton, radioelemental abundances vary from north to south as, *Zone-1≤ Zone-3<Zone-2*. The study corroborates that spatially separated coeval granitoids are formed from different magma sources, indicating the existence of heterogeneous magma beneath the craton. The observed low radioelemental abundances along with its spatial variations, for the granitoids in the core of the craton, will have great implications in thermal modeling of the craton.

Understanding geodynamic and earthquake processes through geodetic meaurements

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Ongoing crustal defromation and occurrence of earthquakes are the manifestations of plate tectonic processes occurring in various regions on different time scales and with different magnitudes. They are more intense in the plate boundary regions in comparison to that in the plate intrior regions. Even the diffused plate boundary regions get illuminated by the occasional but strong earthquakes where the deformation is generally low. The geodetic measurements in the plate boundary regions, namely, the Himalaya and Indo-Burmese and Andaman-Sumatra arc have provided constraints on the short term convregnce rate and how they are related with the long term rates, role of various structural units participating in the process of convergence and geological evolution, mode of convergence and the status of strain accumulation on these structural units, spatial and temporal variation of strain field and slip deficit, and finally the seismic hazard of the region. Understanding of earthquake processes and their associated crustal deformation in the plate interior regions is more challenging due to their low magnitude and longer recurrence intervals. We demonstrate the difference between the deformation processes in the plate boundary and plate interior regions by elaborating upon two cases, the Garhwal Kumaun Himalaya region and Koyna Warna region.

Unusual crustal and lithospheric thermal structure of Southern Granulite Terrain, South Indian shield

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Numerous studies now confirm that the Indian shield is unique among global stable terrains, having undergone multiple geodynamic upheavals in the past. It contains five major Eoarchean to Paleoproterozoic cratons, bounded by rift valleys, Gondwana basins, sutures

and mega lineaments, which have been getting repeatedly rejuvenated since at least 1500 Ma. Dharwar craton is by far one of the oldest and largest among them, covering almost entire region of the south Indian shield. Southern granulite terrain forms its southernmost part, which too has undergone extensive regional metamorphism during late Archean and Pan African times and exposes one of the largest Precambrian lower crustal sections in the world, corresponding to P-T regime of 5-12 kb and 700-900°C.

This terrain has been extensively investigated by heat flow studies. Altogether, 20 heat flow measurements are available over this terrain, which range from 28 mW/m² to 58 mW/m². In its northern part, which contains most of the deep rooted shear zones, heat flow range from 28 to 42 mW/m² with a mean of about 36 mW/m². In this part, Moho temperature, mantle heat flow and lithospheric thickness varies respectively from 510-610°C, 24-31 mW/m² and 100-135 km. In comparison, heat flow is relatively higher in the southern part, varying from 40 to 54.8 mW/m² with a mean of about 45 mW/m². In this segment, Moho temperatures (590-660°C) and mantle heat flow (31-36 mW/m²) is relatively higher and consequently, lithosphere is thinner at around 85 to 100 km. It would further suggest this crust and lithosphere beneath this terrain is much warmer than the western part of the Dharwar craton, as well as global shield terrains, where lithosphere is about 250 -350 km thick.

Recent Earthquake Swarm activity in the Northwestern Deccan Volcanic Province of India

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The Northwestern Deccan Volcanic Province of India (NWDVP) comprises three physiographical units namely, Kachchh, Saurashtra and Mainland Gujarat (south and north), with a diverse tectonic setup. The NWDVP has been experiencing episodic swarm activity with reports of sounds, whose association remains unclear. The Chobari village in the Kachchh district has experienced 200 earthquakes (M 0.8 - 2.5) during Jan. 2016. During Dec. 2015-Feb. 2016, a total of 70 (M_L 0.8 - 1.8) events are recorded in Khopla village, Saurasthra. A total of 1048 (M_L 0.7 - 2.9) earthquakes were located around Keliaya dam in the Navsari district of south Gujarat and 229 (M_L 0.9 - 3.2) events in the Dadra and Nagar Haveli (DNH) region, from September 2016 to June 2018. Further, since, Nov. 2018, a swarm activity got initiated in the Palghar district of Maharashtra state. A total of 135 earthquakes (M_L1.6 - 3.7) were located in the region till Feb., 2019. Many of the swarm events were accompanied by audible sounds, like blasting, that caused severe panic among local occupants. Spectrogram analysis of the events with associated sound reveals significant energy at frequencies ≥20 Hz, in the audible frequency range, in contrast to the lower frequencies for those that did not generate the sounds. The relocated earthquake distribution shows that seismicity at Chobari follows a ~NS trend, confined to an area of 20 km × 8 km with a depth extent of 3 km, where as in Kopala region, it follows ~NE–SW trend, confined to an area of 6 km × 2 km with a depth extent of 2 km. The seismicity in the Navsari district and DNH region follows a ~NW–SE trend, confined to an area of 13 km × 2 km with a depth extent of 3 km and to an area of 15 km × 2 km, down to a depth of 6 km, respectively. A broad N-S trend is observed in the Palghar region, confined to an area of 10 km × 2 km, down to a depth of 8 km. These swarm patterns seem to corroborate with the local tectonic trends that include lineaments/dykes/basement faults in the respective regions, possibly activated by rheological heterogeneities.

Magnetotelluric study in the Palghar region of the western Deccan Volcanic Province, Maharashtra, India

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The Deccan Volcanic Province in the western part of the peninsular India is constituted of a thick pile of flood basalts that overlie mainly on the Archaean and Proterozoic rocks forming the basement. This region has moderate seismic activity, the most recent one being a swarm-type activity in the Palghar region, about 120 km north of Mumbai, that started in November 2018 and has produced a few thousand micro-earthquakes and a 4.3 magnitude earthquake since then. We have carried out a magnetotelluric (MT) study along a 35-km-long profile across the seismic zone to delineate the subsurface structure to understand the possible cause for the seismic activity. Broadband MT data were acquired at 18 sites with average station spacing of 2 km. Impedance tensors were analyzed for distortion and dimensionality, decomposed into TE- and TM-mode, and inverted by a 2-D inversion algorithm. The geoelectric structure suggests a highly variable thickness of basalt layer which steepens near the vicinity of the Panvel flexure zone down to 2.5 km. Further, the model infers an assemblage of highly resistive and moderately conductive blocks in the uppermost crust resting on a major listric-type fault, that possibly reaches the surface at the West Coast Fault from a depth of about 15 km beneath the Panvel flexure zone. We infer that the upper crustal heterogeneities coupled with the basement fault and low rheological strength of the fractured upper-to-middle crust might be leading to triggering of the seismicity in the region.

Finite element modelling of tectonic Stress of the Arabian Plate

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The Arabian plate is bounded by the transform fault (Dead Sea), rifting (Red Sea), divergence (Gulf of Aden), convergence (East Anatolian fault, Bitlis suture, and Zagros collision zone), and Owen fracture zone. The variable convergence and divergence rates of these plate

boundaries made complex in terms of tectonic stress orientation and its magnitude. In this plate, in-situ stress orientations available from the borehole breakouts, hydro-fracture and focal mechanisms are very limited and sparse distribution. Therefore, we conducted two dimensional (2D) plain stress finite element model of Arabian plate with incorporating the material heterogeneity in term of Young's Modulus and lithospheric thickness. The results of these models show in four different scenarios (1) Homogeneous plate with constant plate thickness (2) Heterogeneous plate with constant plate thickness (3) Homogeneous plate with vary plate thickness (4) Heterogeneous plate with vary plate thickness. The results of stress orientation of case Heterogeneous plate with vary plate thickness is showing the good correlation with observed stress orientations. The variable strength of plate, plate boundary forces, and thickness of the plate is the cause of the variation of magnitude and stress orientation of the Arabian plate.

Three-dimensional Qp, Qs attenuation structure of the Koyna-Warna region, India

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Attenuation of the seismic waves plays a crucial role to understand the wave propagation and the nature of a seismic zone. It is also an essential parameter for accessing earthquake hazard in any region. Here, we present a frequency-independent three dimensional Qp and Qs attenuation models for the Koyna-Warna region to understand the structural heterogeneity and fluid saturation of rocks in the region. For this study, we have used three-component digital waveforms of local earthquakes (1.5 $\geq M_L \leq 3.0$) recorded from 6th January 2010 to 28th May 2010, by a close temporary seismic network of 97 stations. The estimates of attenuation operator (t*) are obtained from the non-linear least squares fitting of Fourier amplitude velocity spectrum of P- and S-waves by assuming a ω^{-2} Burne's source model for the frequency band of 4.0 to 25Hz. We adopted an inversion scheme to estimate Qp and Qs through the 3-D velocity model derived from the non-linear velocity inversion. Our preliminary results show that Qp increases with depth, but in the vicinity of the seismic source zone, it reduces (i.e. high attenuation) with depth. The highest attenuation anomalies coincide with the seismogenic zone, which is interpreted as a fluid-filled fracture zone near the South-west of Warna Reservoir extending up to the Koyna reservoir.

Geodynamic evolution in the Dharwar craton during the Archean Eon: a synthesis focusing on zircon age-Hf isotope data

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The formation of Earth's continental crust, its growth history and changes in the geodynamic regime with time, especially during the Hadean (4.56 to 4.0 Ga) and Archean (4.0 to 2.5 Ga) Eons remain equivocal and the subject of an active debate. The specific question; when did plate tectonics begin on Earth? remains unresolved with suggestions ranging from Hadean to as late as the Neoproterozoic. There appears an increasing consensus for the view that Earth's geodynamic regime witnessed a fundamental transition towards plate tectonics around 3.0 Ga although such a change was not abrupt and may have extended over hundreds of millions of years. The transition implies a distinct change in the thermal structure, composition, thickness and growth rate of the continental lithosphere and crust around 3.0 Ga ago. However, such a transition may have been diachronous calling for detailed studies of different cratons. Here, we review geological, geophysical and geochronological data (mainly zircon U-Pb age–Hf isotope compositions) from the Dharwar craton representing over a billion year-long geologic history between ~3.5 and 2.5 Ga. The Archean crust comprises an oblique section of ~12 km from middle to deep crust across low- to medium-grade granite-greenstone terranes, the western and eastern Dharwar cratons (WDC and EDC), and the high-grade Southern Granulite Terrain (SGT). A segment of the WDC preserving Paleo- to Mesoarchean gneisses and greenstones is characterised by 'dome and keel' structural pattern related to vertical (sagduction) tectonics. The geology of the regions with dominantly Neoarchean ages bears evidence for convergent (plate) tectonics. The zircon U-Pb age–Hf isotope data constrain two major episodes of juvenile crust accretion involving depleted mantle sources at 3.45 to 3.17 Ga and 2.7 to 2.5 Ga with crustal recycling dominating the intervening period. The Dharwar craton records clear evidence for the operation of modern style plate tectonics since ~ 2.7 Ga

Paleomagnetism, Rock magnetism and Anisotropy of magnetic susceptibility Studies on Nagercoil Charnockites from Southern Granulite Terrain, India.

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New Paleomagnetism, Rock magnetism and Anisotropy of magnetic susceptibility (AMS) results are presented on ~2.0 to 1.9Ga Nagercoil charnockites in the southern granulite terrane, south India. 67 oriented samples from 14 sites have been studied in detail using JR-6, Alternating field demagnetizer (AFD), Thermal demagnetizer (ThD), Advanced Variable Field Translation Balance (AVFTB) and MFK1-FA multi-function Kappabridge instruments. Characteristic remanent magnetization (ChRM) directions of six sites showing two components viz., component (A) gives N = 3 sites, Declination = 19^0, Inclination = 1^0, k = 16, α_{95} = 11, with a virtual geomagnetic pole (VGP) at 69^0N and 188^0E (dp= 5 and dm=11); component (B) yielded N=3 sites, D = 284^0, I = 47^0, k =47, α_{95} = 9, with VGP at 16^0N and 15^0E (dp = 7 and dm = 12). The Remanence ratio (Mrs/Ms) and the Coercivity ratio (Bcr/Bc) ranging from 0.04 to 0.53 and from 1.18 to 5.19, respectively. The saturation of magnetization was at 300mT and the coercive force ranges from 24 to 41mT for all the samples. The results of k-T study indicate that the Curie Temperature was between 570-590^0C indicating the presence of Magnetite. The Susceptibility values range between 9.94×10^{-2} to 1.08×10^{-4} SI. The principal AMS axes for samples from all sites are tightly clustered on equal area plots and two main fabrics are observed. The first is showing the minimum susceptibility axes horizontal to sub-horizontal and maximum susceptibility axes plot near the horizontal. The second fabric is minimum susceptibility shows intermediate to vertical and maximum susceptibility axes plot near the horizontal to sub-horizontal.

Paleomagnetism results reveal that the pole moment was migrated from high latitude to low latitude. The rock magnetic results indicate that magnetite (Fe_3O_4) is the dominant magnetic carrier and the magnetic grains are dominantly show Multi-Domain (MD) nature. The AMS results reveal that magma flow was sub-horizontal to horizontal upward and the magma source of the charnockites to be far from the sampling sites. The present study suggests that charnockite propagation in the southern granulite terrane is a multiple magma flow induced fabric during the Paleoproterozoic period.

Robust machine learning and inversion for basement depth estimation from gravity data

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The present article examines the potentiality of four machine learning (ML)-based regression techniques. Support Vector Machine Regression (SVMreg) Gaussian Process Regression (GPreg), Automatic Relevance Determination-Bayesian Neural Networks Regression (ARD-BNNreg) and Adaptive Neuro-Fuzzy Inference System Regression (ANFISreg) are developed and employed for prediction of basement depth. Geo-spatial co-ordinates (e.g., latitude and longitude) are used as inputs and basement depth by 2D radially averaged power spectrum of gravity anomaly data as target for the SVMreg, GPreg. ARD-BNNreg and ANFISreg models. Comparative analysis suggests that the performance of the ARD-BNNreg is better than that of GPreg, SVMreg and ANFISreg models when data is assumed to be noise free according to Pearson's correlation coefficient (R), and mean square error (MSE) whereas,

SVMreg model is found to be more robust tool when the data is assorted with various level of correlated red noise. Further, spatial variability analysis based on ML-regression in conjunction with semi-variogram modeling with ML-Ordinary Kriging (MLOK) produces spatial variability of basement depth with fair accuracy. Comparison to conventional gravity inversion based on Parker- Oldenburg algorithm for basement depth, the present results suggest that ML can be an interesting and robust alternative means for finely mapping basement depth. The potential application of the proposed scheme can further be explored in other complex geological areas.

Crustal structure across Deccan Volcanic Province and Eastern Dharwar craton inferred from receiver function modelling

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The Deccan Volcanic Province (DVP) and Eastern Dharwar Craton (EDC) are two important geological region of the Indian sub-continent. The DVP is one of the largest flood basalts region which covers an area of half a million sq. km in central and western India. On the other hand, the EDC is cratonic part of age Neo-Archean (~2.5 Ga). Over the last four decades, the DVP has been geophysically well studies region. These studies mostly focus on southwestern part of the DVP due to location of seismically active Koyna-warna region. Seismic tomography and ambient noise correlation studies reveals a high velocity anomaly at ~10 km depth in the DVP region. This region has been prone to earthquakes since historic time that include Killari earthquake (M_w 6.3) occurred in 1993. Hence, characterization of the crust and its relation with the cratonic domains around the DVP is importance of investigation.

To investigate the crustal structure, we have used the well-known and effective methods i.e Receiver Function analysis. The method utilized the P to S converted phase from Moho and provides the S-wave velocity structure which can be interpreted in term of composition and structure over a range of depths extending from shallow levels to upper mantle. In this view, we analysis the teleseismic receiver functions obtained from 18 digital broadband seismic stations along the ~850 km profile across the Deccan Volcanic Provinces and the Eastern Dharwar Craton operated from 5/2015 to 10/2016. The calculated Receiver functions show significant variation of P to S conversions from the DVP to EDC suggesting the variations of crustal parameters. We present the crustal structure through different techniques like H – Vp/Vs stacking and generalize Neighbourhood Algorithm inversion of receiver functions. We find large variation in the crustal thickness 33-40 km as well as V_p/V_s ratio 1.73-1.86 beneath the DVP while the EDC reflect slightly less variation in crustal thickness 32-33 km and V_p/V_sratio 1.70-1.78. The result of inversion shows variation in distribution of shear wave velocity (V_s) in between the EDC and DVP. The High V_s (~3.5-3.8 km/s) corresponding to the mid-crust is dominated in large portion of the crust in the DVP compare to EDC and V_s (>4.0

km/s) corresponding to magmatic underplating layer is also observed at lower crust beneath the DVP. These details clearly suggest that the crustal structure beneath the Deccan flood affected DVP (~65 Ma) is differ in compare to the EDC (~2.5 Ga).

Ambient seismic noise characteristics in Koyna-Warna region, India

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Seismic ambient noise-based investigations to decipher the crustal velocity and its variations associated with hydrological loading and stress are gaining attention of earth science community. In view of the importance and significance of seismic ambient noise, we analyse its spatial and temporal variations surrounding the Koyna and Warna reservoirs. We estimate the changes in source directionality and spectral powers of primary and secondary micro-seism signals using data from 23 broadband stations involving the estimates of probability density functions (PDF) of power spectral density (PSD) and frequency domain beam former. We noticed significant temporal and spatial variations in power and probability of micro-seism energies between periods 2 to 15s.

The comparison of monthly seismic ambient noise levels within the frequency band 0.01Hz to 3Hz for each station with the global model suggests high spectral energies and probabilities at frequencies associated with anthropogenic processes and secondary micro-seism, particularly for the sites close to Koyna reservoir. Over all, high frequency and micro-seism noise energies are above the global mean and low noise models respectively. Our results demonstrate a clear evidence for the temporal variation in primary and secondary micro-seism energies synchronous to seasonal climate cycle. The annual average secondary source energies are dominant along the direction of Koyna reservoir. In addition, we have also noticed a systematic cyclic variation in secondary micro-seism source directionality from January to December. Although it is not possible to provide a complete physical mechanism that is responsible for the observed cyclic change in secondary micro-seism directionality, it may be inferred as an action of local water bodies/ reservoirs on the secondary micro-seism sources.

Evaluating the Capricorn Plate motion relative to its surrounding plates using the GPS- Geodesy

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We calculated the kinematics of the Capricorn plate relative to its adjacent tectonic plates using the GPS sites M.S.University (MSUN), Cocos (COCO), Bakosurtanal (BAKO), Yaragadee (YAR2), Zambia (ZAMB), Suther Land (SUTH), and Singapore (NTUS) in order to understand the plate motion around the Capricorn plate. The lengths of baseline are estimated from the DGAR GPS site to different GPS sites located in the surrounding tectonic plates. The estimates of baseline length suggest a relative divergent tectonics between Capricorn and India. On the other hand, we found a clear convergence between the Capricorn and Sunda plates. Convergence rate, if persists, would shrink the wide diffusive boundary that exists today between the Capricorn and Sunda blocks. The change in baseline length between Capricorn and Australia indicates a shortening, which is in good agreement with the findings of earlier studies with a clear diffusive convergent boundary between them. A complex rate of change in baseline length is noticed between Capricorn and two different sites inside the African Plate. The DGAR-ZAMB station pair shows divergence between the two plates, while the DGAR-SUTH (site in the southern margin of Africa) pair shows a convergence. Our results suggest the dominance of northward motion of Africa over the baseline increase generated by the active spreading occurring along the Central Indian Ridge (CIR) that forms the boundary between the Africa and Capricorn plates. The estimated strain rates for the different pairs from DGAR vary from 1.46874×10^{-9} to -6.65889×10^{-9}. The strain rate between DGAR and NTUS is -5.34064×10^{9}. This higher strain accumulated in the Sumatra subduction zone resulting in significant seismic hazards in the region.

YOUNG GEOSCIENTISTS CONCLAVE (YGC)

Application of Full Waveform Inversion (FWI) for Shallow Cavity Detection: A Numerical Study

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Nowadays due to the availability of the high-performance computing facility, it is possible to apply Full Waveform Inversion (FWI) technique frequently to produce a high-resolution image (velocity model) of subsurface properties. By using FWI, we iteratively update the subsurface model by minimizing a misfit function to measure the difference between observed and model data. In general, FWI uses low central frequency for model updating but in our study, we demonstrated the content of FWI technique that how it able to give an image of the subsurface for shallow cavities by using it with a high central frequency of 100Hz.

Old abandoned coal workings create major hazards in the form of subsidence of the coalfields. To avoid such hazards, shallow mine cavity detection is a very important aspect of deeper seam mining. In order to execute the detectability of above stated, FWI applied over two different cavity models (water-filled as well as air-filled) associated with old coal working. The considered initial velocity model is contaminated with 30% Gaussian noise during smoothing. From the final result, it is observed that the application of FWI with high frequency successfully updates the earth model. All the geological boundaries along with cavities are updated at their true depth location as correlate to the true model. The observed convergence curve further demonstrates its robustness and effectiveness.

Recovery of Methane from the Gas Hydrates: Insight into the Molecular Replacement Mechanism

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Availability of energy resources plays a pivotal role in the development and economic growth of the nation. By and large, our country spends a considerable amount on fuel imports. The naturally occurring gas hydrates (NGH), a solid form of the smaller hydrocarbon and water molecules, are stable under some suitable thermodynamic conditions. These are often stable in certain permafrost and oceanic strata across the globe. The energy embedded in such source is vast and a pragmatic global estimate (mainly from the marine strata), by considering the inputs from drill data, host sediment properties and nature of gas hydrates from various scientific drilling projects, of the methane gas in hydrate deposits is around ~1500 Gt. Unlocking this energy resource by destabilizing its structure, by some suitable means, without hazards, is a technical challenge and many countries are making serious attempts. Most vividly employed methodologies are the thermal stimulation, depressurization, and combination of both. The chemical injection, however, is expensive and parsimoniously used in gas fields, although this concept found a prominent place in the pipeline network. Molecular replacement of the caged methane with carbon dioxide in the NGH system is attracting the attention of the scientific community and is being pursued rigorously in recent times. In the present study we demonstrate that the replacement/ occupancy of partly empty cages of sI methane hydrate system by the carbon dioxide and/ or nitrogen (air) molecules are plausible, even under lesser gas pressure (than actual reservoir) conditions. However, as inferred from the thermodynamic and the micro-Raman spectroscopic studies, a prominent replacement/ rearrangement of the guest molecules occur closer to the reservoir temperatures. The nitrogen molecules facilitate efficient guest replacement/ rearrangement in NGH systems. Injection of an optimized content of nitrogen to carbon dioxide mixture is a viable means for the extraction of methane gas from NGH deposits. The study provides a lucid understanding of the molecular replacement behaviour of the presence of feed gases (N2 & CO2).

A review of Middle Holocene high sea stand deposits from the west coast of India

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Studies have shown that sea level curves are no longer global and are mostly influenced by local tectonics, leading to wider acceptability of regional relative sea level curves. In the present paper, we re-examine various coastal deposits of the west coast of India and evaluate the suitability of various datasets in being a realistic relative Sea Level Index points. The west coast of India has been scantily studied for sea level research, with lack of reliable chronology being the major hurdle. The available data suggest a much lowered sea level during the Early Holocene which was rising at a faster pace post the LGM. The sea level reached at present day level around 6 ka and kept on rising upto 4 ka, leading to wide spread aggradation in coastal rivers of western India. The Middle Holocene period from 6 to 3 ka experienced a sea stand higher than present, which was variable on various parts of the coastline ranging between 2m ± 1m. The constraint is loaded with errors as there are fewer on-land sites which are studied. The high stand reached to present day stand around 2 ka, however the major puzzle is the causal driver for this high stand and the subsequent fall. The available archaeological datasets reveals the occurrences of port towns in inland locations from the present day level which are supportive to this analogy. The study highlights; vital need to generate reliable relative sea level index points from the west coast of India, for better understanding of the human responses to this sea level change, shifting of the shoreline changes etc.

Prediction of Pore Pressure using Machine Learning Models: An example from the site U1343E of IODP Expedition 323 in the Bering Sea

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Pore pressure (PP) study provides information about evolution history and/or geological process taking place over a region. Pore pressure (PP) prediction from well logs is a difficult and non-trivial problem. Conventional approaches for PP prediction using well logs are mostly of deterministic, and these approaches do not consider the underlying nonlinearity, variability and uncertainty. Here we implement machine learning (ML) -based scheme to estimate PP from well log data and/or hydrostatic pressure. We compare four ML techniques (viz. Adaptive neuro-fuzzy inference system (ANFIS), Automatic Relevance determination based Bayesian neural network (ARD-BNN), Gaussian process regression networks (GPRN), and Support Vector Machine (SVM)) for the prediction of PP at well 1343 E of site IODP 323. These four approaches have been used as regression techniques. Here we have considered two situations; first, well log (i.e., density, porosity, seismic p-wave velocity/travel time) as input and PP as a target. Secondly, well log + hydrostatic pressure (HP) as inputs and PP as target. To build up and generalize ML-based models, in total 357 samples are used for PP prediction when models are first trained on training interval and cross-validated in validation and test intervals using PP data estimated using Eton's and porosity method of the site 1343E IODP 323. We conducted partial auto correlation function (PACF) analysis to select the input lag for the development of the iterative predictive model and consequently, the heuristic technique is employed for fixing optimal hidden node and hyper-parameters. The performances of the ANFIS, ARD-BNN, GPRN and SVM models are evaluated on the basis of Pearson's correlation coefficient (R), mean square error (MSE) and coefficient of determination (R^2). The present comparative results according to R^2 value show that the GPRN model is superior to the other three employed models. An uncertainty analysis was carried out for GPRN-based modeling for PP prediction. In addition, an ML-driven equation is developed from the GPRN model which can predict and identify the high pore pressure zone assumed to be created by the process of diagenesis of clay minerals at the site.

Mineralogical mapping of Ohm crater on the Far Side of the Moon: Investigation of regional geological evolution.

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This paper aims to study mineralogical characters of Ohm crater (18.4 ° N, 113.5 ° W) of the Moon. Data of Moon Mineralogy Mapper (M^3), a NASA-supported guest instrument on ISRO's remote sensing mission to Moon, Chandrayaan-1 is used to characterize mineralogy

of Ohm. The Minimum Noise Fraction (MNF) suggests a distinct compositional variation in the Ohm crater. The compositional analysis suggests that Ohm is a heterogeneous crater with varying crustal composition within. The M^3 data observed the presence of minerals like high-Ca pyroxene, Spinel and mixtures of pyroxene with hydroxyl and plagioclase. The HCP exposures suggest penetration up to the greater depth, exposing pyroxene composition of the lower lunar crust. The hydroxyl traces detected with HCP and feldspar mixture might be of exogenic or endogenic origin. Whereas Spinel mineral exposures might be the part of extruded lower crustal material excavated during the formation of Ohm crater or brought up by mafic intrusions.

Mio-Pliocene drainage reorganisation affecting syntaxial tectonic and uplift-incision regime in the eastern Himalaya

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The presence of elevated low relief landscape at the orographic edge of Tibet in the tectonically active syntaxial zone in eastern Himalayan is modeled to understand evolution of regional landscape, drainage reorganization and associated tectonics. The elevated low relief landscape in Dibang basin represents abandoned paleo-course of the Yarlung-Dibang river, which was captured by the headwards eroding Siang river. The river capture caused ~4-17 times loss of drainage area and causing the Dibang river to evolve as a parched transient landscape since ~4-6 Ma, which also represent the time of river capture. The area gained by the Siang river resulted in the enhanced channel discharge that caused enormous incision at the capture location, i.e. the Namcha-Barwa gorge. This led to the thermal thinning of the upper crust triggering focused rapid exhumation by incision and uplift coupling along the Namcha-Barwa gorge. The above assertion is also supported by provenance studies in the Brahmaputra foreland sediments and Indo-Burma ranges suggesting a possible sediment supply through Yarlung-Dibang river course prior to late-Miocene.

X-discontinuity in the Indian shield and its implications

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The X-Discontinuity is a second order upper mantle seismic discontinuity that lies at ~250-350 km depth range and is characterized by the downward positive jump in seismic velocity. The global seismic studies suggest that it is identified sporadically and could probably be associated with the mineralogical phase changes. The present study is an attempt to probe the presence (if any) of X-discontinuity using receiver function analysis. Seismological data from

69 stations show clear presence of X discontinuity, however rest of stations do not show its presence either due to the interference of other phases or the amplitude of X-phase is too week to be detected in the background of noise. The depth of occurrence of this phase beneath Indian shield varies from 260 to 330 km and it is little deeper in the Himalayan region. The results revealed that, the intermittent presence of the X-discontinuity beneath the Indian shield do not have any clear tectonic relation.

The genesis of such discontinuity is a subject of debate and because of its large depth variability its difficult to explain its origin with a single phase transformation. However, some of the possible explanations for the origin of the X-discontinuity are phase transformation from coesite to stishovite containing excess silica and the orthoenstatite(OEn) to high-pressure clinoenstatite(HPCen) transformation at pressures ~8-10 GPa and temperature ~1100°C. Variations in minor water content in the upper mantle may also explain the observed depth variability in the X-discontinuity. Here, we will present its possible geodynamic implications and its role for the evolution of the upper mantle beneath.

COUPLING BETWEEN EARTH SYSTEM PROCESSES AND ITS MANIFESTATION IN THE HUMANOSPHERE (CEM)

Crustal flow rheology of Eastern Himalaya region and implications

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The deformation in the eastern Himalaya and adjoining regions is characterized by clockwise crustal flow, governed by the rheological parameters viz. temperature, viscosity, crustal strength. Heat produced due to thick crust, magmatism and radioactivity reduces the viscosity of the crust beneath and becomes susceptible to flow when subjected to tectonic and gravitational forces. Though many geophysical studies facilitate studying the crustal flow, GPS and gravity observations in tandem provide an excellent tool. While the direction and magnitude of the GPS derived strain rates are sensitive to crustal dynamics, the space borne gravimetric data are found to be extremely useful in delineating the large scale structures pertinent to crust and lithosphere. In this paper, using extensive GPS and space borne gravity data, supleented by other geophysical data, we provided plenteous evidence in substantiating crustal flow. The rigid Sichuan Basin, Chuan Dian Fragment (CDF) and Eastern Himalaya Syntaxis (EHS) seem to play vital role and accounting for most of the flow pattern. We have conclusively demonstrated these aspects and also provided some implications pertaining to earthquakes in the eastern Himalaya region.

Validation of LAI (Lithosphere Atmosphere Ionosphere) Coupling Theory of Seismo-Electromagnetic Phenomenon of Earthquake Precursors

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The geophysical shell scheme (lithosphere, air, ionosphere) is regarded an over - the-counter complicated dissipating nonlinear system in which earthquake planning might be viewed as an autonomous method which leads to a critical state of the structure. This article brings together latest scientific progress in knowing the issue of seismo-ionospheric connections. The primary fields of modern studies are LI (Lithosphere Ionosphere) Coupling, major ionosphere variants and the statistical characteristics that enable the use within practice. This study relies on three key fields: the verification of the LAI (Lithosphere Atmosphere Ionosphere) couplement. The layout model in this study, The geophysical shell-system is regarded an affordable, non-linear complex system with dissipation in which earthquakes can be regarded as an autonomous technique which contributes to the critical status of the system. The system is based on an earthquake-planning system. This article presents the most recent science in the knowledge of the seismo-ionosphere bonding problem. Present study relies on three primary fields: the Validation of LAI (Lithosphere Atmosphere Ionosphere) Coupling, the primary phenomenological characteristics of earthquake-related ionospheric differences, and their statistical characteristics that enable them to be used in practice. The concept template for this model is a walkways the traditional earthquake and ionospheric precursors. Throughout this respect, the scaling law and the relationship between the geochemical precursors, the anomalous electrical field engaged in ionospheric variations initiated and the ionospheric irregularities themselves are major factors in the earthquake readiness zone. Confirmed Seismo-Electromagnetic Phenomenon Theory of Earthquake Precursors ionospheric forerunner sesimo and the statistical parameters are used to create a method for information processing and other statistical processing methods which can be used in earthquake prediction in the temporary manner. Lastly, for national and international surveillance and feasible short-term forecast of damaging earthquakes, a feasible scheme of ground-based readings and satellite monitoring is suggested.

Contributions of tectonic and non-tectonic forcing mechanisms on the evolution of Co-seismic Ionospheric Perturbations

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The ground displacements associated with earthquakes introduce mechanical waves in the atmosphere which further propagate to the ionosphere and introduce electron density perturbations termed as Co-seismic Ionospheric Perturbations (CIP). When the seismically/tectonically induced waves propagate in the ionosphere, geomagnetic field, ambient ionospheric density and satellite observation geometry play significant roles in the evolution of resultant CIP in terms of amplitude, polarity, propagation extent, directivity etc. All these parameters which restructure the tectonically induced perturbations are termed as non-tectonic forcing mechanisms. The quantification of these non-tectonic contributions are important to extract the earthquake source parameters from its ionospheric manifestations. The present study investigates the tectonic and non-tectonic contributions in the evolution of near field CIP associated with two large dip-slip earthquakes occurred in the Nepal region. The selected events are the Mw 7.8 Nepal Gorkha earthquake occurred on 25 April 2015 and the Mw 7.3 Nepal earthquake occurred on 12 May 2015. The Total Electron Content (TEC) derived from dual frequency GPS data are used to study the ionospheric perturbations and the co-seismic ground deformations are estimated from GPS and InSAR. The study revealed that the ground deformation pattern reflect in the near field CIP distribution only when the non-tectonic forcing mechanisms are supportive as observed in the case of Mw 7.8 Gorkha earthquake. When the non- tectonic forcing mechanisms are not supportive, the tectonic energy distribution may get restructured in the associated CIP distribution.

Distinguishing seismic signatures in ionospheric TEC

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Geohazards, such as earthquake, volcano and tsunami, often occur and result in civilian casualties and huge damages, particularly in largely populated cities / countries. Monitoring and quick responses to geohazards are still a major concern for many countries. The co-seismic signatures in ionospheric total electron content (TEC) are well known but are not enough classified to delineate which type of event has occurred on ground from the signature of ionospheric response alone. These ionospheric perturbations may carry traceable information about the earthquake itself that generated them. Different seismic events were studied from ionospheric signatures and multiple parameters to understand the propagation mechanism of Rayleigh waves to ionosphere. In this presentation we will discuss how different are the seismic signatures in ionosphere from other events/forces of different origin affecting the ionosphere both by statistically and qualitatively.

Forced terrestrial resonant oscillations during the 11 April 2012 doublet Wharton Basin earthquake

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The Earth exhibits normal modes surface oscillations at ~3.7mHz and ~4.4mHz frequencies. These frequencies resonantly couple with the atmospheric acoustic modes and it results in the maximum energy exchange close to these frequency windows. In the present study we demonstrate the forced resonance coupling between the earth's surface and the atmosphere during the 11th April 2012 doublet Wharton Basin earthquake and offer possible explanation for this phenomena. Following both these earthquakes we observed continuous ionospheric oscillations in the GPS (global positioning system) derived total electron content (TEC) over a restricted region towards North-North-East (NNE) of the epicentres within the Wharton Basin. These oscillations are explained in terms of the trapped long period Rayleigh surface waves at the sedimentary basin region along the Andaman Sumatra arcs owing to the conducive tectonic structure towards NNE of epicentres; which subsequently triggered atmospheric resonance.

Effect of Galactic Cosmic Rays on Earth's Atmospheric Processes and Human Health With Special Reference to Solar Cycle 24

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GCR modulation is anticorrelated with interplanetary magnetic field and solar activity alterations with 11-year and 22-year solar cycleswith peak-like or plateau-like temporal contours in solar minimum during negative or positive solar magnetic polarity, during 22-year solar cycle. GCRs display short-term and long term variations, prominent among which are the 27−day solar rotation variations caused by the passage of corotating interaction regions and Forbushdecreases.The 27−day variation amplitudes of GCR during $A > 0$ solar minima (outward directed magnetic field) are larger than that during $A < 0$ solar minima (inward directed magnetic field) . FD is caused by the chaotic field generated behind the CME associated interplanetary shock and closed field line geometry of CME discharge.Among the long term variations,during the 11-year solar cycle, barrier modulation is dominant at solar maximum, and drift effects control modulation during solar minimum.Effects of GCR modulation on lightning discharges ,electrical environment of earth's atmosphere, spaceweather, earth's climate and hazards to human health with special reference to solar cycle 24 has been analysed.It has been proved in this paper thar CR's control long term and short term variations in climate ,which inturn ,control hazards occurring to human health.

Changing frequencies of Heat waves over India during the present and future climate

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In the 21st century, climate change is considered to impose the greatest environmental threats to the world. Associated changes in climate extremes are hypothesized to have greater negative impacts on human society and the natural environment than the changes in mean climate. In this study, an assessment of temperature extremes is made for the Indian subcontinent to identify the changes since 1951 to 2015, and for the future climate periods till 2100.

The frequencies of the days having thresholds of 40C, 42C and 45C for the maximum temperature over India during the pre-monsoon is evaluated using the grid-point maximum temperature data of the India Meteorological Department [IMD] for the period 1951–2015. Corresponding temperature predictions from CMIP (Coupled Model Intercomparison

Project) model outputs and statistical downscaling model (SDSM) methodology was compared with the IMD gridded maximum temperature data for validation. Statistical metrics of BIAS, RMSE, and MAE have indicated low BIAS, high correlation and high IOA (Index of Agreement) validating CMIP climate simulations.

Similarly, the model projected maximum temperatures from the future climate projections using the same model for the two thirty periods of 2021-2050 and 2070-2099 are calculated. The data for the period from 1 March to 31 May, for each of the two climate periods, are used to characterise the heat waves in future climates. Specifically the characteristics of heat waves in terms of intensity, duration and area extent are calculated and compared to heat waves of the current climate. An increase in the heat waves duration, mean maximum temperatures and frequencies of heat wave days in future climate periods have been identified.

Preliminary Analysis of Various Parameters of NavIC Signals for Marine Applications.

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Global Navigation Satellite System (GNSS) is a satellite based navigation system which provides autonomous geo-spatial positioning with global coverage. These global systems provide services to all the users, anywhere on or above the earth surface. The regional navigation satellite systems like Indian Regional Navigation Satellite System (IRNSS) of India and QZNSS (Quasi-Zenith Satellite System) of Japan provides regional services mostly for their country. The Indian Regional Navigation System (IRNSS) has seven satellites (3 GEO, 4 GSO) in Orbit and it is operational. The IRNSS provides Standard Positioning Service and Restricted Service, both the services operates on L5 (1176.45MHz) and S1 (2492.028MHz). It covers the mainland of India and a region extending 1,500 km around it. Recently, field trails to analyze the performance of IRNSS are performed at various research organizations and academic institutions in India. However, not much significant research is carried out in sea environment.India has a vast coastline of 6100 Km along the mainland and 7516.60Km coastline including the island groups. It is the 20th largest maritime country in the world. About 95% of the country's trade by volume and 70% by value is moved through maritime transport. So IRNSS need precise & secure navigation performance is necessary, as the performance accuracy is depends on ionospheric delays and multipath. To carry out this work, IRNSS data is collected from Data patterns Receiver at Goa (Lat:15.39^{0}N Long:73.87^{0}E), India. Multipath is one of the prominent error sources in GNSS. The multipath error from the acquired data in sea environments is estimated using Code Minus Carrier (CMC) technique. The analysis also done for altitude variations, Geometric Dilution of Precision (GDOP) with respect to Number of Satellites (NSAT), variations in Carrier to Noise (C/N0) ratio and ionospheric delay time variations.

Tsunami induced traveling ionospheric disturbances and offshore forecasting

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Tsunami induced ionospheric perturbations during the Sumatra 2004 tsunami which travelled much faster and arrived at the Indian east coast ~90 minutes before the actual water tsunami have been studied. Based on this, an alternative tool to forecast the arrival of impeding tsunami towards the coastal regions from the ionosphere is proposed which can be potentially important for the tsunami early warning. We attempt to investigate further utility of ahead of tsunami travelling ionospheric perturbations to improvise the tsunami offshore forecasting from the ionosphere.

Comparative Evaluation of IRNSS Performance with Reference to Positional Accuracy

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The Indian Regional Navigation Satellite System (IRNSS) is a seven-satellite constellation developed by Indian Space Research Organization (ISRO), India. IRNSS provides two services, with the standard positioning service open for civilian use, and for authorized users (including the military) with an assured absolute positional accuracy. IRNSS is designed to cover all the parts of India and also extending beyond the Indian borders. The coverage area of IRNSS with directions of satellites resources and includes area covering entire Pakistan, Afghanistan, most of China and Middle East along with Indian Ocean. IRNSS downlink signals have two bands: S1 band and L5 Band. Presently Indian users are dependent on the civil GPS signals with a positional accuracy of 5 m. IRNSS system is planned to provide an absolute position accuracy of (i) better than 10 m throughout Indian landmass (ii) better than 20 m over the Indian Ocean and (iii) approximately in a region of 1500 km around India. There are 15 ground stations across the country responsible for operating and/or monitoring the IRNSS seven satellite constellation. A comparative analysis of IRNSS and GPS navigational satellites shows that the IRNSS consists of sufficient number of satellites for regional navigation system and it can also exhibit better performance. The main parameters selected in this study are orbital characteristics, position accuracy and positional error including Circular Error Probable (CEP), Altitude variation, Geometric Dilution of Precision (GDOP) with respect to Number of Satellites (NSAT), variations in Carrier to Noise (C/N0) ratio. Our analysis showed that IRNSS systems shall be used as stand-alone systems.

WATER RESOURCES MANAGEMENT UNDER CHANGING ENVIRONMENT AND CLIMATE (WRMC)

Detection of water leakage from Lake using self-potential and geoelectrical resistivity methods in Jodhpur city, Rajasthan India

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In the present paper utilization of electrical methods for characterizes and understands the origin of the water leakage problem in the Kailana Lake in Jodhpur city Rajasthan India. Self-potential method was used to delineate leakage paths, whereas electrical resistivity method was used to delineate fracture zones favorable for water leakage and hydrogeological condition in the study area. Special consideration was focused on the lake, which is supporting water infiltration/leakage through cracks, joints, faults, and fractures. The analysis of the integrated results revealed a water leakage which could take place in certain locations through unconsolidated or fractured zones and pass through the Kailana Lake. Additionally, the presence of an alternating lithological heterogeneity between permeable and impermeable layers may lead to water leakage through the geological formations of the city. These processes are most likely causing to hydrostatic pressure developed due to the continuous increase of water level of the Kailana Lake. Consequently, hydraulic connections lead to water leakage throughout the lake.

Delineation of shallow groundwater aquifers in the coastal villages of Thoothukudi District, Tamil Nadu, India using electrical resistivity tomography

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An attempt was made to delineate shallow fresh water aquifers near the coast villages of Thoothukudi District, Tamil Nadu. The area is covered by salt pan, teri land and barren land. Geologically the area comprises unconsolidated sand and silt, teri sand and calcarious sand stone. Coastal plain is the major geomorphologic unit and soil type is sandy. To locate shallow fresh water aquifers, 2D electrical resistivity tomography has been carried out in four villages such as Venkatachalapuram, Therkukalmedu, Kailasapuram and Vallinayagipuram. Wenner-Schlumberger configuration was adopted using SYSCOL JUNIOR Switch-48 model and 48 electrodes have planted at an interspacing of 3m. The maximum depth interpreted was 26m. The 2-D resistivity data of subsurface was calculated through inverse modelling using Res2D software. The resistivity images of all the locations show similar pattern of continuous structure of layering or layers with some lenses with resistivity ranging from <1 to 173 Ωm. The resistivity variation in Venkatachalapuram, Therkukalmedu, Kailasapuram and Vallinayagipuram location were <1 to 31.8 Ωm,<1 to

61.8 Ωm, <1 to 14.4 Ωm and 6 to 173 Ωm respectively. The interpretation reveals that freshwater zones have identified in Venkatachalapuram and Therkukalmedu locations whereas in Kailasapuram and Vallinayagipuram locations freshwater pockets have identified. Besides, saline water zones also observed in locations of Kailasapuram and Vallinayagipuram below 8m bgl.

Correlation study of Surface Geo-electrical Methods with Subsurface Lithology for groundwater investigation in Bishnupur village of Rajarhat Taluka, W.B, India.

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Hydrogeological assessment is necessary to find suitable location for extraction of ground water and also to determine the quantity/quality along with the economic feasibility. Bishnupur village is neighborhood of Kolkata city located in Rajarhat taluka of North 24 Parganas district lying just on the periphery of Newtown. Huge spurt in real estate development has raised the depletion of groundwater and scarcity of drinking water, which has awaken the researchers for hydrogeological investigations in the study area. An attempt has been made to investigate the different subsurface layers by using surface geo-electrical methods (both resistivity and self-potential) at different locations in the central part of the village. Resistivity surveyes were done by Vertical Electric Sounding (Schlulmberger arrangement) using Signal Stacking Resistivity Meter (Model-SSR-MP-AT). SP survey were conducted by PQWT-TC-500 instrument using non-polarizing electrodes. The VES data were plotted by Inverse Slope method and VES curves were made. By Interpretation of Inverse slope graph and VES curves, recommendation and suggestion for probable strata selection were obtained. From analysis of natural electric field response curves and frequency response curves of SP method, soil strata prior to drilling were ascertained and suitable site for drilling were allocated. During the drilling process litho-logs were recorded and by observing the grain size and color of the formation recommendation for aquifer zone and strainer position were given. The findings of all the methods has shown a high correlation and based on the correlation study a deep borewell of depth 150m were constructed. Water sample from the borewell were given for quality test and the results obtained are pH-7.7, TDS-747ppm, EC-0.01115 S/m, Hardness-330mg/l, Fe-0.936mg/l, Cl-142mg/l, Ca-92mg/l and Mg- 24mg/l.

Comprehensive assessment from electrical resistivity tomography, borehole lithology and conceptual geological studies to decipher groundwater in Chhotanagpur gneissic complex

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Groundwater is the only source of fresh water that is used by human being throughout the country as well as globally. The amount and availability of groundwater varies from type of geological formation as well as associated geological structure.High resolution electrical resistivity tomography data were acquired up to a depth of 220 m for delineating the source of groundwater as well as mapping the geological structure in a plateau region of Chhotanagpur gneissic complex. The geophysical inversion of the 2D resistivity data revealed prospect groundwater zones at six sites based on the hydrogeological interpretation. The geophysical resistivity anomalies was confirmed and validated by borehole drilling at four sites up to a maximum depth of 215 m. The yields of the exploratory boreholes varies from 5,632 to about 64,000 litres/hr of groundwater exploitation and is rated as the good aquifer in the plateau region of Chhotanagpur gneissic complex. The integrated interpretation from the results of resistivity and borehole lithology data provides the characteristics resistivity for fracture zone, which varies from 140-1300 Ohm.m while for saturated weathered/fractured it ranges from 10-1000 Ohm.m as well as the average resistivity of the aquifer zone lies in the range 50 to 500 Ohm.m. The conceptual geological models were prepared with the help of geology, resistivity results as well as borehole lithology of the area, which suggests the area is composed of granite-gneiss rocks, which is tectonically deformed. The present study in the plateau region with complex geological settings had helped to achieve significant results for groundwater exploration, prospecting, development and sustainability of the resource in the area of study. The present integrated study can be upscale in a similar geological settings for groundwater exploration and prospecting.

3D Electrical Finite Element Modelling and Simulation of Variant Groundwater systems

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Ever-increasing water crisis and resultant declining groundwater level invoke the government agencies to take initiatives for sustainable management and rejuvenation of the aquifer system, river, etc. This has necessitated the increasing application of noninvasive geophysical methods for near-surface characterization during the last few decades. Direct Current (DC) electrical resistivity imaging techniques such as vertical electrical sounding

(VES), continuous resistivity profiling (CRP), and electrical resistivity tomography (ERT), etc. and others, electromagnetic methods both in time and frequency domains, applied over the varieties of near-surface problems including groundwater exploration. However, there is still a requirement of more advancement on data processing and inversion algorithms for improved mapping of near-surface 3D heterogeneities. Presently, ERT utilizes the regular-shaped rectangular meshing for forward modeling using the finite difference method (FDM) with Gauss-Newton and, or Quasi-Newton optimization methods. It provides regularized smooth models with less accurate solutions for complex geometries. Here we present new development where DC electrical imaging uses the unstructured tetrahedral meshing for forward calculation using finite element method (FEM) with Gauss-Newton optimization. This provides an extremely flexible solution with the possibility to work on irregular target geometries with time-lase considerations. We applied the finite element modeling for accurate and precise 3D mapping of the main features of the variant groundwater systems such as arsenic contaminants, saline water intrusions, and groundwater pathways, etc. We also compared it with the available borehole data as well as classical ERT resistivity models for the calibration of main features. Moreover, forward computations using FEM with fine mesh discretization requires significant memory and time consumption but gives more precise and accurate results for shallow irregular geometries, unlike FDM. With the available computational resources, we may provide more accurate and precise high-resolution 3D electrical images of the studied groundwater systems for further hydro-geological interpretation.

Estimation of Aquifer parameters using Geoelectric Method and Pumping Test

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Groundwater is being distinguished component of the hydrologic cycle which occupies the void of the saturated zone of earth's crust. The uncertainity about the occurrence , distribution and quality aspect of groundwater and energy requirement for its withdrawal impose restriction on exploration of groundwater. Inspite of its uncertainity, groundwater is much protected from pollution. Protecting it from contamination and managing its use will ensure its future as an important of ecosystems and human activity. Groundwater resources has become scarce and polluted, it is essential to understand the sub-surface formation to efficiently exploit the groundwater resources.

In this study geophysical investigation and pumping test was conducted to extract a clear picture about the existence of subsurface formation in the Sriperumbudur Region, Kanchipuram District. The study area falls under the Watershed and total of 37 points were selected to carry our Vertical Electrical Sounding and the results are analysed in 1X1D Resistivity software. The results from the software showed that there were two to three layers exist in the study area namely top soil, sand and sandy clay and sandstone formation. The unconfined aquifer in the study are yields very little quantum of groundwater which fails during summer season. The third layer, shale and sandstone formation which is the potential zone in that region.

From the resistivity data, resistivity and thickness of each layer were found. In addition longitudinal conductance and transverse resistance were estimated that helps in zoning the groundwater potential zones. The transverse resistance is proportional to the transmissivity of the aquifer, hence higher the transverse resistance, greater the groundwater potential. Thus the water bearing formations were identified and mapped. Pumping test was carried out in a open wells in the water table aquifer to estimate aquifer parameters.

Semi-Distributed and Data driven Rainfall-Runoff Modelling of Sarada River Basin

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A hydrological model is a commonly used tool to estimate the hydrological response of a watershed to precipitation. Hydrologic Modeling System (HEC-HMS) is physically based semi-distributed hydrologic modelling software developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers. The input data required for the model are precipitation, meteorological parameters, river discharge, soil characteristics, land use characteristics and topographical characteristics of the study area. Data driven rainfall-runoff models like Wavelet Neural Network (WNN), Artificial Neural Network (ANN) and Autoregressive Moving Average (ARMA) are most suitable in case of data scarcity. In the present study, Hydrologic Modeling System (HEC-HMS) is calibrated and validated for the Sarada river basin in Vishakhapatnam district of Andhra Pradesh, India and an attempt also been made to develop data driven models: Linear (ARMA) and non-linear models (ANN and WNN). The catchment area of the Sarada river basin is 2663 Sq km. The observed daily rainfall obtained from IMD and daily runoff data obtained from CWC for a period of twenty four years (1989-2013). Data used in HEC-HMS model for calibratation from 1996 to 1997 and for validatation from 2012-2013,Where as data driven models data used from 1989 to 2013 for the analysis. The 60% of observed data has been used for calibration and 40% of the data for validation in the data driven model. The comparison of model performance was conducted based upon different statistical indices. From this analysis, it was found that efficiency index is more than 75 % for WNN models whereas it is 59% for HEC-HMS, 56 % for ANN and 42% for ARMA models respectively The result indicates WNN model performed better than HEC-HMS, ANN and ARMA for rainfall-runoff modelling of Sarada River basin.

Development of Rainfall Intensity Duration Frequency Curves for Vadodara City, Gujarat, India

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The change in rainfall pattern and intensity is a matter of concern for many water resources engineers. In many parts of the world extreme rainfall events are observed. In July 2005, Vadodara experienced highest rainfall event of 315 mm in 24 hours amongst 56 years i.e. between 1961 to 2016. An intensity-duration-frequency curve (IDF curve) is a mathematical function that relates the rainfall intensity with its duration and frequency of occurrence. These curves are commonly used in hydrology for flood forecasting, for the appropriate design of hydraulic structures and for the planning and design of urban drainage system in an area. Very less information in available about rainfall intensities, particularly for short duration. The aim of the present study is to derive the IDF curves for the rainfall in the Vadodara city, Gujarat, India. Observed rainfall data from 1961 to 2016 is used in the present study to derive the IDF curves. Initially, the proposed IDF curves are modelled using the Gumbel probability distribution method for annual maximum rainfall and then to derive the IDF curves by incorporating the varying return period concept and by using the empirical equations given by Tablot, Bernard, Kimijima and Sherman. The durations considered for developing IDF curves are 1h (h – hour), 2h, 6h, 12h and 24h. and for the return periods of 2, 5, 10, 15, 20, 25, 30, 50, 75 and 100 years.

Rapid inundation mapping using Sentinel-1 data for southwest rainstorm season 2018 in Kerala

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The aim of this research is to move towards near real-time determination of inundation extents caused by heavy precipitation and flooding using multi-temporal satellite SAR data sets, with methods that are both quick and easy to apply over large areas as new data becomes available. Kerala encountered an abnormally high precipitation from 1 June 2018 to 19 August 2018. Kerala State has an average annual precipitation of about 3000 mm. As per the report published by India Meteorological Department, precipitation over Kerala amid southwest rainstorm season 2018 (1 June to 19 August, 2018) has been incredibly high. This rainfall was about 42% above the normal. Inundated areas in districts (Alappuzha and Kottayam) and partially (Kollam, Pattanamtitta, Idukki and Ernakulam) as on 21 August 2018 have been mapped by processing of Sentinel-1 ground range detected (GRD) data acquired in interferometric wide swath (IW) mode with VV polarisation, which are routinely being acquired over several land masses. Two subsets of a scene of Sentinel-1 GRD VV and Sentinel-2 (B3 and B8 bands) derived Normalized Difference Water Index map have been used to carry out the research, and the derived inundation extent has been validated against cloud free optical data.

Effective and quick response is required during the disasters like flooding. Rapid mapping of such event will be beneficial to urban and infrastructure planners, risk managers and disaster response during extreme and intense rainfall events. The study shows simple and efficient method for mapping inundation extent over part of Kerala, occurred during amid southwest rainstorm season 2018 (1 June to 19 August, 2018). Surface roughness makes it difficult to have contrast between the tones of the land-water covers. Backscattering coefficient value become high as the water roughness cause the high signal return which decreases the contrast which makes the separation of the land-water covers difficult. Caution must be taken in interpreting the data as an accurate representation of the inundation, due to the difference in acquisition dates in Sentinel 1 and Sentinel 2 data, and the surface roughness in SAR data. The results of this study show the potential for monitoring the damages, providing basic information that can help local communities manage water related risk, planning land and water management as well as other activities such as flood control programs.

Development of a Rainfall-Runoff model using soft computing techniques

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Determining the relationship between rainfall and runoff for a basin is one of the challenging tasks faced by hydrologists and engineers. Conceptual rainfall-runoff models are most suitable in case of data scarcity. If good quality of Hydrological time series data is available in a basin, data driven models are more useful to develop suitable rainfall-runoff model. These models are very useful for management of water resources in the basin and also for forecasting runoff. In this paper, an attempt has been made to develop data driven model for the Vamsadhara river basin in sub-zone 4 (A), India. The catchment area of the Vamsadhara river basin is 10,452 Sq km and covered Andhra Pradesh and Odisha states. The major land use types are forest (52%), agricultural land (35%), barren land (11%) urban (0.2%) and water body (1.33%) and elevation range is between +10 m above mean sea level in the South (Kalingapatnam) to + 1545 m on the Northwest Hills (near Bissam Cuttack). The soils in the basin are classified as mixed red, black soils and red sandy soils. The total annual evaporation in the basin is about 170 cm. The average annual rainfall is 1300 mm and it increases from coast to hilly terrain. The river has two observed gauge discharge (GD) stations at Gunupur and Kashinagar. The observed daily rainfall obtained from IMD and daily runoff data obtained from CWC for a period of twenty four years (1971-2013) have been used to develop

Rainfall-Runoff model in the basin. Autoregressive Moving Average (ARMA) model, Artificial Neural Network (ANN) model and Wavelet Neural Network (WNN) models have been developed for the Vamsadhara River basin. The 60% of observed data has been used for calibration and 40% of the data for validation. The best model was identified based upon different statistical indices of Root Mean Squared Error (RMSE), Correlation Coefficient (r), Coefficient of Efficciency (COE). Among ARMA, ANN and WNN models it is found that the WNN is the best model at Gunupur and Kashinagar G/D stations. The statistical indices of WNN model during the calibration period at Gunupur and Kashinagar are: RMSE= 40.67, r = 0.98, COE = 97.86 and RMSE= 43.04, r = 0.975, COE = 95.03 respectively. Similarly the validation period the statistical indices at Gunupur and Kashinagar are: 48.07, r = 0.93, COE = 84.85 and RMSE= 59.46, r = 0.96, COE = 91.35 respectively. Therefore the recommended model can be used for water resources management in the basin.

Hydrological response of cryospheric changes in the Ganga headwaters

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River flow variations in the Ganga headwater region gives the best insights on hydrological response of cryospheric changes in the monsoon regime of the Himalaya. A study being carried out under the National Mission on Sustaining Himalayan Ecosystem (NMSHE) at Maneri dam site, where contribution from all 231 glaciers in the Bhagirathi basin congregate. Total basin area of the basin is 4205.46 km^2 and 14.19% of the basin is covered by the glaciers (596.19 km2). Discharge data of nearly 27 years showed reducing trend in discharge. Inter-annual discharge variations, represented in terms of coefficient of variations, shows a low value of 0.12 suggesting a stable annual runoff regime. Runoff stability of this basin with 14.19% glacier cover is better than the European Alps catchments (~0.2) with 40 to 50% glacier cover. Most stable discharge regime is observed during the winter months representing the low flow regime. Second most stable period observed during the high flow period of July and August that coincides with peak monsoon and glacier melt. Most unstable flow regimes are observed in the month of May, June and September months with a coefficient of variation ranging from 0.27 to 0.32 for twenty-seven year time span from 1989 to 2015. Decadal scale analysis shows a significant increase in the inter-annual variations during the pre-monsoon months of May and June as well as in the post- monsoon month of September during 2000-2015 period as compared to 1989 to 1999 period. May values show increase from 0.28 to 0.36 and June values from 0.23 to 0.33 followed by September values from 0.15 to 0.35. Snow cover is the prominent cryospheric component covering an area of 82.96% of the basin. During the observation period, no specific trend observed for annual maximum snow cover, while yearly minimum snow cover in the basin show an increasing trend since 2010. Seasonally, December and June month witnessed significant changes in the snow cover. December experience declining trend in snow cover between 3000-6000 m a.s.l elevation band covering 88% of the

basin area. Whereas, June shows an increasing trend between 4500 to 6000 m (a.s.l.) covering 61% of the basin area, including core 86% of glacier area within the basin. September and October experienced highest inter-annual snow cover variability. Maximum snow cover month of February and minimum snow cover month of August, experienced the least variability. The present study suggests the cryospheric changes occurring in the basin is elevation-dependent and increase in snow cover in the month of August is one of the factors contributing to the stability of July, August flow along with enhanced glacier contribution.

Reclamation of water logged saline soils for re agriculture from Ganegaon - Tandali villages of Pune District – A success story

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Ganegaon dhumala and Tandali group of villages are situated in the floodplain formed at the confluence of Bhīma and Ghod Rivers in Shirur taluk of Pune District in state of Maharashtra. Both Bhīma and Ghod rivers originate in uplands of Sahyadris in the west, in the region of high rainfall and flow in general in NW-SE direction more or less in parallel. During the confluence both the rivers change in reverse flow direction-NE-SW. Flooding is common and hence vast fertile clayey loam soils plains are formed around the banks of Bhīma river, in the past; and are now supported by economic agriculture. Sugarcane and Onions are the only crops practiced, without any break in cropping, throughout the year, by all farmers, since last 30 to 35 years. These practices are now alarming for soil quality deterioration, lesser yield of crops and salination to the extent of salt incrustation on the surface and at shallow depth, especially along the 4th order stream, running through the village to meet Bhīma River before the confluence.

Impact of land use and climate change on hydrological services of forested and agricultural headwater catchments in the Central Himalaya

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Forests are considered making vital contributions both to people and the planet, conserving biodiversity, soil and water, and responding to climate change. Land use and climate change have severe effects on water availability in Central Himalaya (Uttarakhand) particularly in the Kosi catchment with overall change in precipitation pattern including high intensity rains occurring over a short period regulating in a higher incidence and intensity of floods and reduction in groundwater recharge, reducing water storage. In order to explore the influence of land use and climate change on hydrological services, a long-term hydro-meteorological monitoring programme was launched in pine forested and agricultural catchments. The pair instrumented catchments are the headwaters of the Kosi river - the life-line of Kumaun region. We have monitored various hydrometeorological parameters in the instrumented forested catchment (1987- 2019) and agricultural catchment (1993-2010) and conducted detailed studies on individual storm events in both the headwaters. The long-term data suggest that on an average, there is a decrease of about 290 mm in the annual rainfall with a decreasing trend and a significant increase in the rainfall intensity. The lean flow capacity of Kosi river during summer has witnessed a massive about 700% drop. Rainfall-runoff and sediment discharge from the pair catchments suggest that high intensity monsoon rainfall on a 1.83 km^2 forest catchment produced a peak discharge of 91.945 l sec^{-1} including 983 mgl^{-1} suspended, 310 mgl^{-1} dissolved and 716051 cm^3 bed load sediments. This increase several fold runoff 661.733 $lsec^{-1}$ km^2 and sediment discharge including 2190 mgl^{-1} suspended, 295 mgl^{-1} dissolved and 865606 cm^3 bed loads in the 0.21 km^2 agricultural catchment. Analysis of long-term data reveals that land use and climate change induced hydrometeorological phenomena in the instrumented experimental catchments are active. This paper highlights the role of protective forests in the hydrological services and also highlight on the changes of these services due to land use and climate change in the mountain headwater catchments.

Mapping of Aquaculture in Western Godavari Delta using Remote Sensing technique

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Aquaculture involves cultivating aquatic produce under controlled conditions.Among the coastal states, Andhra Pradesh is largest producer of shrimp and Vannamei in India. In terms of area of cultivation and production, majority of fresh water and brackish water aquaculture is mainly concentrated in the Godavari Delta region in the coastal Andhra Pradesh.There is a significant increase in aquaculture in Godavari Delta region and is being a serious threat to the shallow groundwater over the years. The objective of the present study is to identify the changes in the area ofaqua ponds and other water bodiesusing Remote Sensing technique in Western Godavari deltaduring the years 2012 and 2019. The LISS III data is analyzed for the year 2012 and Sentinel-2A data is analyzed for the year 2019for mappingof aquaculture regions. During the year 2012 and the year 2019, the Normalized Difference Water Index (NDWI)image has interpreted that total area of waterbodies such as aqua ponds found to be 211 km^2 and 386 km^2 respectively. Hence during the last 7 years (2012-2019) it can be observed that, the water bodieshaveincreased to 175 km^2. From the satellite images during the past seven years, it is observed in Western Godavari Delta that, the decreasing trend of paddy cultivation and increasing trend of aquaculture practices may be causes for increased salinity inshallow groundwater. It is also confirmed by spatial distribution of shallow groundwater

Electrical Conductivity(EC) variations from the years 2012-2019 in the Western Godavari delta.

Geospatial Technology in Water Resources Management

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Geospatial technology is going through technological evolution at a great pace over some decades. High precision and accurate mapping of natural resources are possible with latest development in the field of technology. Ground and surface water management, raw materials identification, draught monitoring, air quality monitoring etc. can be done with the help of dedicated high precision tools. This paper deals with combination of various geospatial tools for creating accurate predictions and monitoring of natural resources, which can further aid in the extraction of those resources. Digital elevation models have been developed for 44 river basins of Kerala State and assessed the Morphometric/Hypsometric parameters in the GIS Environment. Further, drought risk mapping of Northern Kerala State has been carried out for the proper management water resources. Drought can be detected by monitoring the vegetation health status of a region and comparing it with the status of the same region for the same season in previous years. Normalized Difference Vegetation Index (NDVI) is the major parameter used to measure vegetation health obtained from MODIS, Terra satellite products MOD13Q1, MOD02QKM. The daily anomalies of NDVI from its long term mean NDVI over the same period was determined based on which drought risk classification was done. The daily anomalies of NDVI from its long term mean NDVI over the same period was found. High negative NDVI anomaly areas are susceptible to drought and the severity of drought risk on each crop can be identified using Landuse/Landcover data. Daily NDVI Anomaly based drought risk of Northern Kerala is viewed by this web application, with an intention that common people can understand the severity of drought on each crop.

Groundwater modeling of Suddegedda river sub-basin of East Godavari district for better water management strategies

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Over the years, the groundwater levels are gradually plummeting in the non-command upland region of East Godavari (E.G.) district of Andhra Pradesh, India and there is an

urgency to augment groundwater resource in this area. Hence, in this region, to estimate the impact of excessive use of groundwater and also to suggest appropriate better water management strategies, a groundwater flow model has been constructed for a micro-watershed namely 'Konda Kalava watershed' of 'Suddegedda river basin'. The Konda Kalava watershed (nearly 50 km^2) is mainly composed of cystalline rocks in the northern part and sandstones in the southern part. A steady state groundwater flow model is simulated to seven observation wells of the watershed. The litho-units used in this model are collected from the previous studies conducted by the Deltaic Regional Centre, Kakinada. It is observed from groundwater levels in the basin that, annually, even though deeper groundwater levels (up to 27 m) are exist in pre monsoon season in sandstone aquifer than crystalline aquifer, the sandstone aquifer is being recharged more during monsoon season comparatively crystalline aquifer. Hence in the model, more groundwater recharge is considered for the sandstone aquifer than crystalline aquifer. From the model, the input and output stresses are assessed with water budget analysis and also identified the over-stressed areas within the basin. The prognostics for the 20 years (2019-2039) with the present constant rate of pumping by 1% increase has revealed that the villages namely Chinna Jaggampet and Tatiparthi which are in southern part of the basin are experiencing huge aquifer stress due to over-dependence on nearly hundred deep (150 m) tube wells. In this scenario, the villages namely Chinna Jaggampeta and Tatiparthi are going to be dried in the years 2030 and 2036 respectively and the drawdown up to 31 m and 37 m respectively is encountered for the next 10 years. It is recommended from the model that, artificial recharge techniques are to be applied for the crystalline aquifer to improve the recharge conditions in northern part of the watershed. The better water management strategies such as reducing pumping rates by using low horsepower submergible pumps in deep tube wells, promoting irrigated dry crops etc. are to be applied for sandstone aquifer in southern part of the watershed.

Optimal Reservoir Operation to Meet Irrigation Demands Under Drought Situations in Ghataprabha Command Area

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This study proposes application of Linear Programming Optimization technique for the optimization of reservoir release followed by optimal allocation of land and water resource for the maximization of net annual farm income from the study area. The study is conducted in Ghataprabha Command area, a significant portion of Krishna river basin situated in Northern part of Karnataka, India where two distinct scenarios have been considered involving four different hydrological years which is very essential for scheduling of irrigation

water supply and better management of existing water resources. Scenario-I representing average weather condition whereas Scenario-II consists of different hydrological years such as dry, wet and normal corresponding to probability of exceedence P_{80}, P_{20}, P_{50} respectively. Further in view of the persistent demand from the people of Belagavi district of Karnataka State who are facing drought situations very often and suffering a lot, this proposed reservoir project found a valid place for study and determining suitable operation policy so as to mitigate drought situations and to provide the people some positive reliefs. The paper discusses the principle of reservoir operation to determine the monthly reservoir releases which is supposed to meet the irrigation requirement in the best possible manner under drought situations. The net benefit incurred from command area for Scenario-I was about 5740 Million Rupees. The results of Scenario-II demonstrated that the net income for dry, wet and normal years was 4201, 5912 and 5386 Million Rupees respectively.

Signal separation of time-variable gravity: case study for hydrology

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Terrestrial Water Storage (TWS), is vertically integrated water storage comprising soil-moisture surface and ground water, which transits in response to dynamics in hydro-climatic variables such as precipitation, evapo-transpiration, runoff etc. Time variable gravity anomaly is caused by all time-dependent mass exchange process including hydrology. In the recent times, since 2002 GRACE satellite has been providing extensive time variable gravity data. Signal separation is a method applied to GRACE data to separate hydrology from other existing mass change processes. The same signal separation methods can be applied to separate components of TWS i.e. surface and ground water and soil moisture. The signal separation methods are applied to an alluvial river basin i.e. Ganga and a hard rock basin i.e. Krishna basin. Empirical orthogonal function(EOF) analysis via singular value decomposition (svd) is used as the method for signal separation in this work. The aim of this work is to demonstrate the working of non apriory signal serration akin to un-supervised classification. River basins of completely different geo-hydrological and climatology are chosen. In the case of alluvial basin where major input source in ISMR a liner relationship between TWS components and precipitation can be expected. In this basin vertically integrated TWD components can be separated by depth. Dependency on rainfall anomaly. In the arid Krishna basin which is dependent in ISMR and winter rainfall, such components of TWS couldn’t not be deconvolved. Dependence of storage on rainfall anomaly is high. The cause for the difference in result for the same method in two different areas are analysed and presented.

Interaction entropy-based model for estimating natural groundwater reserve in a granitic terrain, Southern India

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It is vital to assessing dynamic groundwater resources in volumetric terms for sustainable management of groundwater resources. It is also a fact that this resource assessment is uptight with uncertainty of its several components. Worldwide assessment of groundwater resources poses additional challenges especially in terms of data availability and maintaining uniformity and comparability of the results. Therefore, a trade-off between best scientific techniques and their applicability to use more than one methods for reliable estimates on a regional scale is important. It is well-known that rainfall is one component of hydrogeological cycle and only source of groundwater input being a dynamic system, the methodology for assessment requires continuous updating keeping abreast with the evolution in technologies, improvement in data availability and demands of planning requirements.

Thus an interaction entropy-based model has been adopted for estimating natural groundwater reserve at limited open well sites in a granitic terrain from Southern India. The area is a prone to hard rock with frequent droughts and last 10 years, is reeling under severe drought to meager rainfall. Thus the information contains in the precipitation data calculated with the help of marginal entropy coupled with the interaction-based information embedded to the corresponding water table measurement of unconfined aquifer has been statistically estimated the natural groundwater reserve due to the rainfall. This reserve yields a good agreement with the results of site specific recharge zones obtained using Remote Sensing (RS) and Geographical Information System (GIS) techniques. It is also comparable with the estimate reverse adjacent areas by tritium injection method. The reserve varies from 3.37 to 11.10% during NE monsoon with an average of 6.44%. It has also observed that the groundwater reserve of the area varies from 1.391 to 3.446 MCM during the SW-monsoon for the period of 2012-2018, whereas 2.958 to 6.554 MCM during the NE-monsoon. On average, the maximum natural groundwater reserve is about 8.571 MCM in both the monsoons of year 2015, but it is almost half in the years of 2013 and 2016, which are 4.428 and 4.458 MCM, respectively. The calculated seasonal groundwater reserve could be utilized for sustain groundwater management.

Impact of Landscape Dynamics on Hydrological Parameters and Springshed Development

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Mountain springs emanating naturally from unconfined aquifers are the primary source of water for the rural households dominantly in parts of Western ghats and also in patches of the hard rock aquifers distributed in Peninsular India. With impacts of climate change, manifested in the form of rising temperatures, rise in rainfall intensity, reduction in its temporal spread with a marked rise or fall in rainfall pattern and increased human intervention, the problem of dying springs is being increasingly felt across this region. Therefore, it is time to look for various sources of water bodies with a specified focus on rejuvenation of springs and adjoining watershed for the sustainable water supply and also for other human needs which includes both agriculture and recreational purposes. In this context, a detailed analysis of a springshed located on the hills of Belagavi city (Kanbargi hills). The major challenges faced in springshed development were identifying recharge areas accurately, developing local capacity, incentivizing rainwater harvesting in farmer's fields and sourcing public financing. The mean discharge of the springs was found to peak at 45 litres per minute during the post monsoon (sep-nov) and then diminish to 6 litres per minute during spring (Mar-May). The lean period (mar-may) discharge is perceived to have declined by nearly 50% in drought prone areas and 35% in other areas over the last decade. The springshed development approach to revive this springs using rainwater harvesting and geohydrology techniques showed encouraging results, with the lean period discharge increasing substantially. Accordingly to initiate an action plan as a part of the smart city program, detailed hydrogeological investigations have been carried out using remote sensing data products and discharge variations based on stress conditions. Simulation studies of the springshed was carried out to understand the impact of LULC changes on groundwater recharge using SWAT model. Based on the model results rainwater harvesting and conservation measures have been adopted to enhance the recharge using simple recharge structures and also to revive the existing spring to sustain the unforeseen drought condition and at times of excess rainfall/recharge the water may be used for the revival of lake water bodies present in the downstream part of the springshed. The said study is under implementation as a part of the Belagavi Smart City program for both revival of lakes (3 numbers in the downstream) which will be used for recreation purpose of public in the region.

Assessment of occurrence, fate and transport of contaminants in the aquifers beneath the city in the age of Urbanisatoin, Hussain Sagar catchment, South India

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Contamination of aquifers in the urban areas is a major threat to drinking water security in many parts of the world. However, there are not many scientific studies carried out to understand the complete hydrogeochemical processes in the aquifers beneath the Hyderabad city to reduce contamination. The present research is focused on identifying sources of the pollution and related hydrogeochemical processes in the highly urbanized Hussain Sagar lake catchment located in South India.Different hydrogeochemical, multivariate statistical and numerical groundwater flow and contaminant transport models were applied aided by using hydrogeological, seasonal groundwater levels and quality (pH, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{2-}, Cl^{-}, SO_4^{2-}, NO_3^{-}-N; TH as $CaCO_3$) data for four years from the year 2009 to 2012. The results revealed that groundwater quality is of a mixed type of hydrochemical facies in both pre and post-monsoon seasons. Groundwater is contaminated by nitrates above maximum drinking water permissible limits at upto 71% locations in the dry years whereas it is upto 46% of locations in wet years. The statistical anlysis show that industrial pollution loads upto 45.7% and domestic pollution loads upto 43.4% are contributing to the total pollution load with dominant mixing, dissolution and ion exchange geochemical processes. The contaminant transport model shows predominant mixing of pollution with groundwater along its flow pathsthat are transporting contaminants to the lake. The study also addresses the possible restoration plans and its impacts under different scenarios, to improve the ecosystem of the lake catchment.

Groundwater Quality investigations in Subledu Basin of Khammam District, India

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The present study deals with the groundwater quality of Subledu Basin, located at Khammam district, Telangana state, India with latitude 17°13' N to 17°24' N and longitude 79°51' E to 79°59' E and covers an area of 130.29 km^2. All together 22 groundwater samples were collected during the premonsoon season of 2019 from the bore wells for analyzing the major anions and cations in the groundwater. The fluoride concentration has exceeded at three places in the study area. Excess use of fertilizers for agriculture is causing the nitrate pollution of groundwater in more than 50% of the samples. In the present study area all the groundwater

samples are reported to have total hardness ranging between 200 to 820 mg/L which is very high as per the standards. On the basis of Sodium Absorption Ration, Residual Sodium Carbonate, Kelley's Ratio, Permeability Index and Sodium Percentage, five samples are not suitable for irrigation. Similarly, 13 samples are not suitable for drinking water purpose based on the excess presence of fluorides, nitrates. Maps depicting areas suitable for irrigation and drinking water are also prepared.

Hydro-geochemistry and Groundwater Quality in Sedimentary part of Gadilam River Basin, Cuddalore District, Tamil Nadu, India.

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Groundwater quality is a major issue of the human society for domestic, drinking and agricultural purposes. A hydrogeochemical investigation was carried out in the part of cuddalore district, to identify the influence of saltwater intrusion and suitability of groundwater for domestic, agricultural and other water related activities. Geographically, the aerial extent of the study area is 663.65 Sq.Km. For this purpose, 50 groundwater samples were collected based on the equal grid method from various bore wells in different blocks of entire study area on January 2018 and analyzed for physicochemical properties. Major ion abundance are pH, EC, TDS, Ca > Mg > Na > K, and HCO 3 > NO 3 > Cl > SO 4 > H 4 SIO 4 > PO 4 . Spatial maps prepared and integration analysis from GIS platform, using ArcGIS software 9.3.1 version. The spatial map preparation based on WHO standards of water for drinking purposes. Most groundwater samples of the study area are within the desirable limit of WHO standard. The Gadilam river basin show that the groundwater is nearly acidic to alkaline by from west to central part of the research area. Interpretation of hydrogeochemical data of describes that secondary leaching, salt water intrusion and anthropogenic impact through industry in this regime.

Seasonal influences on Submarine groundwater discharge aided by diverse techniques in Sankarabarani river estuary, Pondicherry, India

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Sankaraparani River, a semi diurnal tide influencing estuarine region has been selected for the estimation of chemical fluxes to the coast aided by Submarine Groundwater Discharge (SGD). Recently river discharge, industrial, sewage, recreational activities, and onshore advection of deep ocean water has triggered episodic hypoxia in shallow coastal and estuarine system due to associated major population centres delivering large nutrient fluxes to coastal and marine waters. Geology of the area is dominated by alluvium formations. Groundwater is mainly utilized for drinking, domestic, agricultural and industrial activities. Attempt has been made to discriminate the sources for SGD aided chemical fluxes using multiple techniques. Darcy law and water budget methods signify SGD fluxes at ranges of about 6.5×10^6 m^3 y^{-1}. Numerical flow modelling suggested groundwater velocity about 7.6 m day^{-1} to 13 m day^{-1} irrespective of diverse layers from land to sea. Electrical resistivity imaging demarcated influence of tides aided by seasonal fluctuations. Seepage meter demarcated fluxes of about 817.15 to 1067.04 m^3 day^{-1} and found to be guided by tides. Major ion chemistry infers water samples representing fresh ($Ca\text{-}HCO_3$) to slight intrusion type (Na, Mg-Cl) type. Radon calculated SGD fluxes for diverse samples ranges between 0 to 7.2 m day^{-1} that clearly demarcated terrestrial, subterranean and recirculated groundwater flow to the oceans. The calculated nutrient fluxes found to be influenced by seasons with average fluxes of DIP, DIN and DSi as 1.92×10^2 mol day^{-1}, $4.15 X 10^2$ mol day^{-1} and $5.3 X 10^3$ mol day^{-1} respectively. Rare earth elements fluxes calculated were 255 m^3 $year^{-1}$ which has a good correlation with radon attributed fluxes. In general, SGD fluxes in the study area seem to be influenced by distance from the coast, meteorological conditions and seasonal time windows.

Assessment of Human Exposure Risk due to Heavy Metal Contaminated Groundwater in the Noyyal River Basin

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Noyyal river basin is actively engaged in industrial and agricultural activities.Groundwater is one of the major resources utilised by the basin for drinking, domestic and irrigational purposes. The water resources of the basin are mainly polluted due to the textile processing units, sewage disposal, solid waste dumping, intensive agriculture, etc. Such anthropogenic effects lead to addition of heavy metals in the water resources. The excessive intake of heavy metal could bioaccumulate and leads to different problems on human health. The common pathway of heavy metal exposure for humans through ingestion (drinking and eating) and inhalation (respiration). Human health risk due to intake of heavy metal depends on the nature of metal, the level of concentration(dose), duration of exposure and gastrointestinal absorption of metals. A primary survey is conducted and about 48 groundwater samples were collected to study the heavy metals contamination in the study area. The heavy metal concentration of chromium (Cr), manganese (Mn), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), lead (Pb) and cadmium (Cd) in the groundwater is estimated with the help of Inductively Coupled Plasma Mass Spectrometer (ICP-MS).The human health risk is calculated based on the exposure of heavy metalsto humansthrough drinking is assessed withthe Average Daily Dose (ADD), Hazard Quotient (HQ) and Hazard Index (HI)for infants, children and adults were calculated by following theUnited States Environmental Protection Agency (USEPA) guidelines. The resultsof HQ for the heavy metals of Pb and Cd exceeds the value 1 for infants.The Cr, Pb, Ni and Cd were found to be in the range of high hazard quotient for the children and adults. Based on the results obtained, children are identifiedas more prone to health risk due to consumption of contaminated groundwaterand a special attention is needed to overcome the health issues.

Hydrogeochemical characteristics and groundwater quality of Perambalur District, Tamil Nadu, India

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Assessment of groundwater chemistry of a region is important as it is used to meet various requirement. The objective of this study is to understand the groundwater chemistry and the groundwater quality in the weathered and gneissic terrain of a part of southern India. This work was carried out in the hard rock terrain of Perambalur District, Tamil Nadu, where groundwater is used without treatment for drinking and agricultural purposes. Groundwater samples were collected once in three months from forty four representative open wells. The groundwater samples of electrical conductivity and pH were analysed in the field by a portable meter. Calcium and magnesium were measured by volumetric titration method, sodium and potassium were measured by a flame photometer. A spectrophotometer was analyzed sulphate and chloride was analyzed by using Meterohm titrando 905. Ca-HCO_3, Na-Cl, mixed Ca-Mg-Cl, and mixed Ca-Na-HCO_3 types in the groundwater are the predominant hydrochemical facies of the study area. Based on major ion concentration, the suitability for drinking purpose was estimated, the study area of the groundwater are with suitable for drinking purpose. The suitability of groundwater for irrigation purpose was estimated by sodium percentage, Sodium Adsorption Ratio, Residual Sodium Carbonate, Kellys Ratio, Magnesium Hazard, and Permeability index and at a few locations, groundwater is with unsuitable for irrigation purpose. Correlation matrix indicates that correlation between major ions was strongly good between ions in the groundwater.

Evaluation of Groundwater Quality and its Suitability for Drinking and Agriculture use in the Central Delta of Godavari, East Godavari District, Andhra Pradesh

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Groundwater is a major source of water for agricultural and domestic requirements in the central delta of godavari, east godavari district, Andhra Pradesh. Due to increasing domestic

and agricultural requirements the abstraction of groundwater has increased manifold in the last two-to-three decades. The quaternary alluvium hosts the aquifer in the present study area. Although the area hosts potential aquifers, these have been adversely affected by poor management. For effective ground-water management of the basin it is essential that a careful study should be carried out. Keeping this in mind hundred ground water samples were collected and analysed to understand the ground water quality based on different indices such as TDS, Sodium Adsorption Ratio, Kelly's ratio and Soluble Sodium Percent (SSP) for drinking and irrigation suitability assessment. The analytical results shows higher concentration of total dissolved solids of groundwater are highly variable rising along flowpath from the west to the east, implying significant deterioration and salinization. Higher concentration of total dissolved solids (20%), electrical conductivity (50%), chloride (10%), total hardness (30%) and magnesium (40%) for pre monsoon and total dissolved solids (30%), electrical conductivity (40%), chloride (30%), total hardness (30%) and magnesium (40%) for post monsoon which indicates degradation of water quality as per BIS Standards. On the other hand,50% groundwater sample is unsuitable for irrigation purposes based on irrigation quality parameters.

Hydrogeochemical Characteristics of Upper Manimala River Basin, Idukki, Kottayam and Pathanamthitta Districts, Kerala

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The study aims to undertake the hydrologeochemical analysiss from the point of view of the ground water occurrence, distribution and quality in upper Manimala river basin, which spreads in three districts of the state Kerala; Idukki, Kottayam and Pathanamthitta. This includes an assessment of variation of ground water quality with respect to different chemical and physical parameters, its distribution patterns with respect to geological aspects. In order to determine the water quality, samples were collected from open wells and bore wells representing the shallow water and deep water aquifers from the study area. The samples collected were analyzed for various hydogeochemical parameters and various thematic maps were prepared using GIS for interpretation. The hydrogeological parameters of the water samples collected from the study area exhibits excellent quality for drinking and good quality for irrigation purposes, whereas in the areas of high population observe a very high quality changes in physio-chemical parameters, which indicating a declining trend in the quality of water due to urbanization.

Assessment of hydrogeochemical characteristics and groundwater quality for its suitability for various purposes using integrated geochemical methods in upper Krishna river basin, India

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Groundwater plays an increasingly important role in water supply, particularly to rural communities of semi-arid regions. The objective of this study is to evaluate the hydrogeochemical processes that may affect the quality of the groundwater using 58 samples collected from Wanaparthy watershed falls in upper Krishna river basin. The groundwater samples were analyzed for various physicochemical parameters, major cations and anions . Two predominant hydrochemical facies Na-Cl and Na-HCO_3-Cl have identified based on the hydrochemical analysis from Piper trilinear diagram. Gibbs diagrams suggested rock weathering as a major driving force for controlling the groundwater chemistry whereas no influence of evaporation or precipitation is observed in the study area. Statistical parameters such as the mean, median, standard deviation were used to analyze the hydrogeochemical characteristics of the groundwater. The observed values of groundwater data were compared with BIS and WHO standards. Results showed that most of the groundwater samples exceeded the acceptable limit for fluoride (18%) and nitrate (39%) for drinking water standards. Based on Wilcox diagram, the study area is categorized under permissible to doubtful (58%) and doubtful to unsuitable (19%) category for irrigation purposes. Further, it indicates that the groundwater quality in the study region is generally poor and unfit for drinking. This study will be useful to understand the groundwater quality status for effective management and utilization of the groundwater resource.

Conservation and management of urban water supply reservoirs of Hyderabad city under the growing environmental threats

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Urban freshwater reservoirs are under great threat around the world due to rapid changing of land use and climatic variability posing serious threat to drinking water security. Hyderabad city is one of the biggest cosmopolitan city in the world and is rapidly expanding. In the early 19th century Osman Sagar (OS) and HimayatSagar (HS) reservoirs were constructed with a total storage capacity of 194 MCM covering 2074 km^2 catchment area to supply drinking water to the city. The builtup land increased by 75%, the industrial area is doubled, forest land and water bodies decreasedby 11% and 3.7 % from 2004 to 2016. The total inflows into the reservoirs have declined from 384 MCM to 121 MCM from the year 1962 to 2009 with reducing storage capacity due to changing land use patterns, encroachments and dwindling rainfall. The observed water quality shows deterioration trend. In order to protect these reservoirs, we proposed a methodology for the delineation of source water protection zone (SWPZ) as part of the conservation plan.The time of travel, mean rainfall, land use, soil type, the source of pollution and drainage density were integrated using the Weighted Index Overlay Method for deriving vulnerability indices for SWPZ. Protection zones were proposed based on vulnerability indices, and classified into five categories ranging from low to very high. The new protection zones will be of immense help in implementing the conservation plan not only for OS and HS reservoirs but also for other drinking water reservoirs in India.

UNDERSTANDING AND COMBATING NATURAL HAZARDS (UNH)

Cyclone Web-based Dynamic Composite Risk Atlas and Decision Support System for Risk Mitigation and Response Planning

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The recent cyclonic disasters, Fani, Hudhud, Phailin, Thane and Titli caused extensive socio-economic losses over coastal districts of India. Thus, provision of precise prediction and warning of cyclones is of great interest over the region. Keeping this in mind, RMSI India is developing a Cyclone Web-based Dynamic Composite Risk Atlas and Decision Support System (Web-DCRA & DSS) for all the 13 coastal states/UTs of India encompassing tropical cyclones hazard, vulnerability, and risk assessment. This based web-DCRA & DSS application, developed on Geonode platform, includes the coastal stretches of 13 States and UTs, which lie up to 10 m elevation with reference to mean-sea level along the coastline.

The Web-DCRA has provision to estimate risk individually from cyclonic wind, storm surge, and flooding from cyclone induced rainfall as well as composite risk from all the three components. The web-DCRA has three major components- Digital Risk Atlas, Risk Analyzer, and Hotspot Analyzer. It contains all the layers of hazard components; exposure elements of population and assets at risk; administrative boundaries at the levels of state, district, sub-district, city, and village; and risk assessment. The risk analyzer provides capability to decision makers to update exposure, vulnerability and reassess risk at state, district, sub-district, city, and village level. The risk analyzer also provides capability to generate revised exposure summary and detailed reports and risk assessment report at various administrative levels at a click of button. The hotspot analyzer provides the decision makers tools to conduct a micro-level risk analysis of a small area; say village or a ward of a city, and generate outputs that help in disaster risk mitigation and response planning.

The Web-DSS application takes real-time input data, namely cyclone track details and rainfall from IMD to generate real-time analysis of an impending cyclone. An advanced two-dimensional depth integrated (ADCIRC-2DDI) storm surge model generates wind and storm surge hazard using IMD's cyclone track details on real time basis. HEC-RAS and HEC-HMS flood models estimate the flood based on cyclone induced rainfall. Finally, the application would provide the composite loss from cyclonic wind, storm surge and cyclonic induced rainfall flood for the real-time event. This application would be helpful to provide early warnings to low-lying areas, guide evacuation of local population, and rescue operations in the event of any cyclone crossing the coastal regions of India.

Stability Indices Based Thunderstorm Prediction over Andhra Pradesh

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Thunderstorms are usually associated with sudden rainfall, blustery winds along with lightning and thunder. These are one of the major devastating disasters, which our country is facing in recent times. They develop on a spatial scale which vary between a few meters and a few kilometres and its temporal scale from a few minutes to a few hours. They result in huge loss of lives and crops. Andhra Pradesh (AP) region is vulnerable to severe thunderstorms during the hot period of pre-monsoon season. The lack of an effective thunderstorm warning system is often cited as a major reason for the number of deaths over the country. The mean flash rates for every district in AP has been calculated from TRMM-LIS satellite data. The Prediction of thunderstorms over Andhra Pradesh (India) has been attempted for every 15minutes time interval using INSAT-3D& INSAT-3DR satellite data along with WRF model data for the time period 2017 and 2018. In two years, seven severe thunderstorm cases were identified using Real-time satellite images, Doppler Radar Images and IMD daily gridded rainfall data. Atmospheric stability indices such as K Index (KI), Lifted Index (LI), Total Totals Index (TTI), Total Precipitable water (TPW), Humidity Index (HI) and Wind Index (WI) associated with the severe convection system over Andhra Pradesh during pre-monsoon season was identified to provide guidance to convection and thunderstorm activity. These stability indices have been calculated by using satellite data for identifying the thunderstorm activity. Advanced Research Weather Research and Forecasting (ARW) model was used to derive stability indices at a high spatial resolution of 3 km and temporal resolution of 15 Minutes. The output during the first 12 hours was discarded as model "spin up" and the output of the subsequent 24-hour period was stored at 15 minute intervals. These indices give us a clear indication of development of Convective system before 3 -4 hours. INSAT-3D and INSAT-3DR satellite, WRF model have shown the prediction of thunderstorm with accuracy over the region. We calculated statistical metrics for WRF and INSAT-3D satellite, KI parameter has shown good correlation for both the cases. The results of this study indicate the predictability of thunderstorm activity by using INSAT-3D and INSAT-3DR satellite data plays an important role in disaster management.

Understanding and Combating Earthquake Hazard in India

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India was among the first few countries to have prepared Seismic Zoning Map (modified a few times since then) and Design Response Spectra for different seismic zones which are recommended for use through Bureau of Indian Standards. Experts regularly meet to recommend new or modified by-laws. In last 10-15 years, Probabilistic and Deterministic Seismic Hazard Maps have been prepared. However, these need improvement to be adopted for general use.

Seismic Zoning Map of India divides India into zones II,III,IV and V having potential of earthquakes of MM intensities VI (M5), VII (M6), VIII (M7) and ≥IX (M ≥8), respectively. This map is prepared on the basis of intensities experienced at places and their tectonic belts. The plate boundary Himalayan belt is assifned zones IV and V. The Andaman-Nicobar belt and intraplate Kutch are assigned zone V. In the intraplate Peninsular India, Koyna - Latur area is assigned zone IV. The Indo-Gangetic plains, Saurashtra peninsula, the west coast region, part of east coast region, the Narmada belt and Godavari basin are in zone III. Other parts of Peninsular India are in zone II.

Great earthquakes in Himalaya-Andaman belt and Kutch have caused devastation. Some large and moderate earthquakes in Peninsular India have also caused great loss of life and property. India is among top ten countries in terms of earthquake hazard. Moreover, risk is high due to non-compliance of adopting earthquake-resistant features in majority of constructions. During the present decade the tall structures are better designed, probably in response to large scale awareness programs launched by some organisations. Now geotechnical investigations are extensively done for seismic microzonation and site-specific seismic hazard assessment for important structures.

India has exemplary record of Disaster Management for cyclones, floods and earthquakes more so in last few decades. Disaster Management in all the aspects of Rescue, Relief and Rehabilitation has been institutionalized. The Rescue and Relief teams are well-equipped and trained at Central and states level.

Still there is lack of awareness / willingness to adopt earthquake-resistant features in constructions. The Society and engineers need to be motivated, legislations need to be strict, unsafe houses need to demolished and unsafe important structures retrofitted to combat the earthquake hazard. This is especially needed in the Himalayan region and Indo-Gangetic plains as a great earthquake is due in Himalayas.

Deterministic Seismic Hazard Mapping in Gujarat, India

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Earthquake strong ground motions in Gujarat are estimated considering 19 active faults and using the modified-stochastic finite-fault modeling based on dynamic corner frequency (Motazedian and Atkinson 2005). The simulations have been carried out at large number of base rock sites located on a grid as well as at surface by incorporating the site amplification functions estimated at 32 important cities. The scenario hazard maps are prepared based on the spatial distribution of resulting PGA and SA values. The characteristic site frequency having maximum SA for each site has been estimated, contoured and found to be in agreement with the local geology (Chopra et al. 2013). The cities on alluvium show low characteristic frequency, whereas cities situated on rocks show high frequencies. The simulated PGA values have been converted into modified Mercalli intensity (MMI) values using the empirical relation, which are contoured to show the spatial distribution. All the cities in the Kachchh region are expected to observe the PGA values of the order of 500 cm/s^2 at the surface in case earthquakes occur from major faults in Kachchh region. The cities of Saurashtra can expect accelerations of less than 200 cm/s^2 at surface. In the mainland Gujarat the expected accelerations are less than 50 cm/s^2. The analysis based on SA shows that the single-story and double-story or small structures are relatively safe in the mainland Gujarat region, but the expected SA for 3–4-story buildings in cities situated in mainland such as Ahmedabad, Gandhinagar, Mehsana, Surat and Bharuch is more (*100 cm/s^2) in comparison with single-story buildings (*50 cm/s2). It was found that a total of 3.7 lakh houses in Kachchh district are vulnerable to total damage in case of large earthquake of M 7.5 in Kachchh. In Saurashtra, most vulnerable sites are Rajkot, Jamnagar, Surendernagar, Morbi, Junagadh and Dwarka, where 3.2 lakh buildings are likely to be affected during a severe earthquake. The buildings in Radhanpur and Bharuch in the mainland region are most vulnerable due to their proximity to active regions.

The nineteen identified active faults are: 12 in Kachchh, 5 in Saurashtra and 2 in Mainland Gujarat. The locations and strike of faults are determined from various published seismotectonic maps. The corresponding dips are determined from the fault plane solutions available of historical earthquakes in the region and aftershock data. The depths are constrained from historical earthquakes. The maximum magnitude assigned to each fault is based on the regional tectonic environment and past seismicity. The maximum magnitude assigned are 7.2 to 8.0 in Kachchh, 6.5 along Narmada fault and 6.0 in rest of Saurashtra and Mainland Gujarat.

The site amplification functions at 32 sites are estimated using spectral ratios between the recorded horizontal and vertical components of the earthquake waveforms of local earthquakes with magnitudes 2.5–4.3. The frequency-dependent amplification thus obtained for every site is used in the stochastic simulation to obtain ground motion at surface.

Earthquake Hazard in the Central Himalaya: Elaborating the past to explore the future

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The timing and size of the last great earthquake in the central Himalaya continues to excite scientific interest. Here we review the available database on seismotectonics and paleoseismology from the region to determine the timing and faulting parameters of the last major earthquake on the frontal thrust of the central Himalaya and how the overlapping segments in the region have been behaving in terms of generating large and great earthquakes. The Indian sources hint at a restoration phase for the mid-14th century monuments located in Delhi and a contemporaneous destruction to the ancient temples located in the central Indian Himalaya. The constraints generated from such earthquake proxies and the data from multiple trenches across the frontal thrust in the central Himalaya converge on a mid-14th century rupture that extends for a length of ~600 km of the central Indian Himalaya, with an average slip of 15 m, consistent with moment magnitude of Mw ≥8.5. The regional data from Nepal and India, in general, indicate evidence for a medieval cluster of great earthquakes (14th, 13th and 11th centuries) spreading across the overlapping segments along the central Himalayan front, followed by quiescence extending to the present. The medieval cluster of great earthquakes within the central Himalaya indicates episodic nature of earthquake occurrence separated by long temporal gap of 700 to 1000 years. With a rupture length of ~600 km of the central Indian Himalaya, and an average slip of 15 m this earthquake is consistent with moment magnitude of Mw ≥8.5. An earthquake of similar size is overdue in any one of the segments within the central Himalaya, considering the long-elapsed time.

Application of probabilistic and Deterministic seismic hazard assessment along the Son-Narmada-Tapti Lineament

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Precise seismic hazard assessment in a region is indeed a seminal opportunity to reduce the risk factor due to future big or catastrophic earthquakes in that region. Generally seismic hazard in a region is estimated either by Probabilistic seismic hazard analysis (PSHA) or the deterministic seismic hazard analysis (DSHA). The PSHA method is used more extensively than DSHA. However, we cannot totally rule out the use of DSHA method for assessment of seismic hazard in a region. Earlier, author has estimated the seismic hazard assessment in the Son-Narmada-Tapti lineament (SONATA) in the Central India using PSHA method for magnitudes of earthquake greater than 4.0 which has been published in the SCI Journal. In the present study an attempt has been made to find out the seismic hazard using moderate to big magnitude earthquakes by DSHA methods in the SONATA region. Five moderate to big magnitude earthquakes (viz., the 1927 Son Velley earthquake of Mw 6.5; the 1938 Satpura earthquake of Mw6.0; the 1956 Balaghat earthquake of Mw6.5; the 1970 Bharuch earthquakes of Mw5.6; and the 1997 Jabalpur earthquake of Mw6.0) which are located along the east-west direction in the close vicinity of SONATA are used in this study.

The study area is bounded between the latitude 19-26^{o}N and longitude 73-86^{o}E, divided into 2665 grids of grid dimensions 0.2^{o} x 0.2^{o} (~20kmx20km). The ground motions are estimated from source to farthest site using standard attenuation relationship. The variation of ground motion is obtained among the surrounding grids for each earthquake locations. Result shows that the ground motion parameters along the E-W grids are more prominent than the N-S directional grids. After juxtaposing all data over the study area, ground motion parameters along E-W direction of SONATA are obtained. Finally, the peak ground acceleration parameters are converted into MMI unit (using Trifunc and Brady 1975). The maximum MMI and PGA are obtained VIII and 0.292g respectively near Jabalpur and its surroundings. Structural design response spectra are also generated in the seismic intensity ranges between IV and VIII at 5% damping on soft soil, soft rock and hard rock. These seismic hazard parameters can be used for future structural development and disaster mitigation in the Central India.

Active and Passive Geophysical Investigations for Site Characterization in the Seismically Active Intraplate Region of Western India - Implications for Risk Mitigation

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In Gujarat, several cities located more than 300 km from the epicentre have experienced damages due to past destructive earthquakes in the Western India. Most of these sites are resting on unconsolidated soils. The intensity of VII was reported in the Ahmedabad megacity during the 2001 Bhuj earthquake. To study the possible causes of damages and site characterization of big cities in the Gujarat state, we employed an integrated approach, comprising of PS-logging, multichannel analysis of surface waves (MASW), single and array microtremor measurements, and broadband earthquake data recording. We estimated shear wave velocity through an integrated approach at about 600 sites covering all major geological formations and different tectonic settings in the Northwestern Deccan Volcanic Province (NWDVP) of India. We validated our estimated results with the available reliable geological, geotechnical and geophysical data. The objective of this study was also to assess various methods of measuring the shear wave velocity (V_S) and develop correlations for the reliable estimation of Vs for different soils of Gujarat, Western India. In this context, we characterized several individual sites and many cities such as Gandhinagar, Ahmedabad, Surat, Bharuch, Anjar, Bhuj, Dwaraka, and Dholera, based on V_{S30}, following NEHRP classifications and site amplifications. The estimated results infer that V_{S30} for Deccan traps and granitic rocks is in the range 760–1500 m/s, thus they are classified as B-class, as per the NEHRP classification scheme. The sediments of Tertiary, Cretaceous, Jurassic, and Paleoproterozoic have V_{S30} values in the range of 360-760 m/s; and hence, assigned C-class. Further, the Quaternary soils are characterized as D-class, since they possess V_{S30} ~ 180–360 m/s. Moreover, Rann sediments and the Holocene tidal flat are classified as E-class, as the V_{S30} values are less than 180 m/s. We infer that the E- and D-type soils have significantly higher seismic amplification than those in the B- and C-category. We noticed that the buildings on D - and E-classes soils suffered higher damage than those on the B- and C-classes, during the past large earthquakes. Our study shows that V_{S30} is a good proxy for soil characterization in NWDVP.

Seismic hazard assessment in parts of Krishna-Penna basins in Andhra Pradesh, India using GIS and Geophysical techniques

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Seismic hazard assessment requires integrated approach and identification of high risk zones and suggests safety standards and measures. Seismic microzonation is one of the methods to identify the local seismic hazard zones and can be used for mitigation planning, earthquake resistance design and retrofitting of old structures. Seismic hazard may be expressed in terms of the probability of earthquake occurrence within a specific area with a given intensity, and based on this estimated hazard, the risk may be assessed. The Krishna-Penna (KP) basin is located in Andhra Pradesh (AP). This basin includes Ongole town and the capital of AP i.e. Amaravathi and Vijayawada. As per seismic zonation map of India, this region comes under zone III (BIS, 2002) which indicates that these areas are less prone to earthquake. The basin has experienced several micro to moderate earthquakes, including the three earthquake of moderate magnitude (~Mw 5-5.8) from the past to recent years.

In this study, we have collected available information on geology, tectonics, seismicity and geotechnical data and integrated them in a geographical information system (GIS) technique to generate a first order seismic hazard map of the area. In the integration part geology, assessment of ground motion parameter (Peak Ground Acceleration (PGA)), local site effect parameters (predominant period and amplification factor) and liquefaction of map of the region are important. These all layers were performed to follow pair-wise comparison using analytical hierarchy process (AHP) which assigns weights to each thematic layer in a 1 to 9 scale depending on its contribution to the seismic hazard. Along the river basin thick sediments have been found and these have low shear-wave velocities and can be categorized as Type C and D as per the NEHRP classification. In view of this, high amplification of seismic waves and liquefaction are expected in this region during a large local or regional earthquake. The VS30values and the PGA estimated through a probabilistic approach are used to estimate the local site amplification. The central part of the study area is highly populated, which makes it an even higher risk zone. The results of this study will help administrators in land use planning and also serve as a primary reference for any seismic microzonation or mega-engineering project proposed in the region.

Stochastic modelling of strong ground motions from M>5 Uttarkashi earthquakes

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The western Himalayas including the states of Jammu & Kashmir, Himachal Pradesh and Uttrakhand experiences moderate to large magnitude earthquakes including 1905 Kangra earthquake of M=7.8, 1991 Uttarkashi earthquake of M=6.8 and Chamoli earthquake of M=6.8 in 1999 are to name few. Studies based on geodetic data and statistical analysis of seismicity have pointed out that sufficient amount of stress is being accumulated in the Himalayan plate boundary which may result in great earthquake at any time. Hence, high seismic activities and infrastructural developments in the major cities around Himalaya are always of major concern when one think of imposed seismic hazard and its mitigation. Any kind of seismic hazard (deterministic or Probabilistic) analysis depends upon the ground motion prediction in terms of peak ground accelerations (PGA), peak ground velocities (PGV) etc. The accurate estimation of ground motions parameter governs the performance of seismic hazard map and consequent risk estimation.

Thus keeping in mind the importance of accurate estimation of ground motion parameters we simulated two earthquakes which occurred in Uttarkashi with magnitude M>5 on 06/02/2017 and 06/12/2017. We adopted stochastic modelling technique. The source is assumed as w^{-2} circular point source. The reported source parameters like stress drop (40 bars), elastic attenuation (Quality factor), corner frequency and seismic moment are used for simulation. The stochastic spectra is generated between band of 0.1 and 25 Hz. The modelled spectra is compared with the observed Fourier amplitude spectra obtained from recorded waveform data and converted back to the time domain. The stochastic time series is also compared with observed waveforms in terms of amplitude (PGA) and duration. The good agreement between observed and modelled peak ground accelerations shows that the global reported parameters are appropriate for modelling. These preliminary results obtained are encouraging and can also be helpful in simulating strong ground motions in terms of PGA for hypothetical earthquake for e.g. M=7.0 magnitude.

Effect of Earthquake on River Sedimentation

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When a moderate or large magnitude earthquake occurs in the catchment area of river, it carries a huge amount of sediment, debris, uprooted trees, parts of destroyed dwellings, stone, boulders etc. All these flow in the river. In case there is any dam downstream then the whole material is deposited in the dam. There have been so many such cases in the Himalayan region. The 15 August 1950 Assam earthquake of magnitude 8.7 had raised the bed of river Brahmaputra by about 4.5 meters. Similarly the formation of Lake Barapani is attributed to 1897 Assam earthquake. In 1975 there was an earthquake in Lahul Spiti Vally of magnitude 6.5. During the earthquake an artificial dam or blockade of height about 40 meters was formed. The river blockade on River Para Chu a tributary of Sutlej river. The blockade gave way after about a week or so. Ultimately, the entire sediments were deposited in Bhakra reservoir. The generation of sediments due to earthquake is called as seismo-sediment and the process as seismo- sedimentation. earthquake are known as seismo-sediments and the process is called Seismo- Sedimentation.

Studies of similar such events have helped in concluding a mathematical formulation about deposition of seismo-sediments.

The formula is S = RPTF

where S is the total amount of seismo-sediments, R is average rate of silting of the river, P is the probability of occurrence of earthquake, T is the time span in years and F is fraction which could be in the range of 0.1 to 0.5

Cluster analysis of global tomographic models to investigate the mantle structure beneath Indian Ocean Geoid Low

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Geoid height is an indicator of mass anomaly within the earth's mantle. The largest geoid anomaly of -106 m is observed in the north Indian Ocean and is almost twice of the other geoid lows. The cause of this unusually large amplitude and the mechanisms that generally govern the variation of global geoid lows is not fully understood. In this study we analyzed several latest tomographic models (GyPSuM-P, LLNL-G3D-JPS-P, SEMUCB-WM1, S362WMANI+M, S40RTS, etc.) using K-means clustering. K-means clustering identifies geographic regions by grouping together similar velocity profiles. We identified model-independent velocity signatures at all depth ranges that correspond to salient tectonic features like low velocity zones, high velocity slabs at depths of 800–1600 km and graveyard slabs. Cluster analysis of the upper mantle (depth 350 km to 800 km) show two different low velocity structures of magnitude -0.3 to -0.5% Vs and -0.7% to -1% Vs, respectively, beneath the Indian Ocean Geoid Low. The smaller magnitude low velocity structure corresponds to mantle upwellings that reside within the upper mantle beneath the north Indian Ocean, NE Pacific, West Atlantic and Ross Sea geoid low regions and cause the -30 to -60 m geoid contours. However, the extreme low velocity structure has a different origin and could be tracked through the mid mantle to the core mantle boundary where its location coincides with the position of the African Large Low Velocity Shear Province. The combination of these two low velocity materials probably causes the Indian Ocean Geoid Low. We also observe how the presence of high velocity materials within the upper-to-mid mantle influence the reduction of geoid amplitude in some regions like the Indian Shield.

HIMALAYAN CRYOSPHERE CLIMATE INTERACTIONS, CONSEQUENCES AND FUTURE TRENDS (HCCF)

Contrasting Behaviour of Mass balance and Frontal Retreat of glaciers in Indian Himalayan Region (IHR)

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Glaciers are dynamic, self-regulating and highly sensitive to the climate. Changes in glacier mass is a key parameter for assessing the glacier's health, water resources, climate change, sea level rise and environmental appraisal. With around 9,575 glaciers, within the jurisdiction of the Indian states: an estimated glacier ice cover of about 36,000 km^2 and an overall ice volume about 2,000 km^3 is significant. The Himalaya is characterised by its huge areal extent & varied climatic conditions that make inconsistency in mass changes process and comparatively differ to the rest of mountain glaciers in the world. The current trends show that most of the Himalayan glaciers are retreating with a rate fluctuating between 05 and 20 m a^{-1} and specific mass loss by 0.15 to 1.0 m a^{-1} . In this study, a ground base mass balance and frontal (snout) retreat of two Bench Mark (BM) glaciers, Dokriani and Chorabari in the upper Ganga basin, Central Himalaya, India, computed for the period from 199/92 to 2015/16. The Dokriani (7.02Km^2)and Chorabari (6.6km^2) are well developed medium sized glaciers, representing two major glacierized basins in upper Ganga River catchment. The key features of both glaciers having similar morpho-geometry and climatic condition (warm & humid summer and cold and dry winter). Beside the notable parameters, Chorabari glacier is extensively debris covered with having small accumuation area (~43%) and flows north to south, where as the Dokriani is less debris covered having large accumulation area about 67% of total glacier area and flows NNW direction for about 2 km then turns towards WSW direction. Thus, these morphogenic features significantly changes the regulating processes of glacier dynamics that resulted a contrasting behaviour.The study shows that both glaciers are retreating and having negative mass balance trend. The most interesting results is that the Dokriani glacier is retreating with average rate of 18.5m/yr, whereas the Chorabari glacier has just half of the Dokriani and is 9.5m/yr, But Mass balance is just reverse of the snout retreat i.e. for Chorabari glacier 0.72 m w.e.a^{-1} is almost double compared to the Dokriani Glacier i.e 0.43 m w.e a-1 during the study period. This suggest that the surface morphology equally play important role in mass changing processes of the glaciers.

Monitoring of Himalaya-Karakoram Cryosphere and Associated Hazards

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The Himalaya-Karakoram (H-K) has one of the largest concentrations of glaciers outside the poles. The meltwater generated from these glaciers is of interest for several purposes such as drinking water and irrigation. These glaciers also generate hazards in the downstream areas (e.g., debris flow and glacial lake outburst floods (GLOF's)). It is, therefore, crucial to monitor H-K glaciers for water resource management and hazard mitigation. Glaciers in the Karakoram reveal irregular behavior as compared to central and eastern Himalaya. Terminus fluctuations of individual glaciers lack consistency, unlike other parts of the Himalaya. Since the 1970s, total ice mass remains stable or indicate a slight increase. Such anomalies are addressed through a comprehensive mapping of surge-type glaciers and surge-related impacts, based on multiple satellite images, DEMs, ground observations, and archival material since the 1840s. Surge cycle timing, intervals and mass transfers are unique to each glacier and largely out-of-phase with climate. However, the mass balance of central and eastern Himalayan glaciers reveal mass reductions in recent decades, that destabilizes the pro-glacial area and influence the occurrence of glacial hazards. Therefore, some case studies of glacial hazards in the central Himalaya (e.g., Gangotri and Chorabari glaciers) and Karakoram (e.g., Kumdan group of glaciers) have been highlighted. Ice-dammed lakes formed by advancing and/or surging glaciers have resulted in several floods (~150) in the Karakoram region. Whereas, in central and eastern Himalaya, the GLOFs are attributed to the failure of moraine dams due to rapidly retreating or thinning of glaciers. Hence, regular monitoring of glaciers situated in the H-K region is imperative to understand the impact of climate change.

Isotopic characterization of precipitation and glacier melt from glaciers monitored by Centre for Glaciology in Central Himalaya, India

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The use of stable water isotopes has been ubiquitous in catchment hydrology that has led to major advancements in understanding the processes involved in the global hydrological cycle as well as the local hydrometeorological phenomenon. The high altitude regions (above 3000 m asl) of the Himalaya have a very sparse network of hydrometeorological stations. Thus, the isotopic signature of precipitation (rain and snow), ice, proglacial streams at high altitude regions of the Indian Himalaya is not available. Furthermore, the relationships of isotopic signature of precipitation with meteorological parameters is absent for correct interpretation of time series data generated from archives such as Himalayan ice cores, high altitude lake sediment cores, tree rings, etc. Therefore, an attempt to characterize the isotopic signatures in different components of the hydrological cycle and decipher the role of summer and winter precipitation on glacier melt using stable isotopes (δD, δ18O) coupled with existing hydrometeorological observations has been carried out at Bangni, Chorabari, Dokriani, Dunagiri and Gangotri glaciers in Central Himalaya. The isotopic composition of various components of hydrological cycle i.e., precipitation (rainfall and snowfall), glacier surface ice and glacier melt have partly overlapping isotopic ranges. δ18O, δD and d–excess composition indicates that precipitation during pre-monsoon (May/June) and post-monsoon (September/October) seasons have mixing of local moisture with that from westerlies. While during monsoon (June–September) rainfall-runoff contributes to the meltwater stream with snow and glacier melt. The depletion pattern of snow cover area (SCA) imply that most of the solid precipitation in the region results from westerlies, while during summers the precipitation from the Indian Summer Monsoon (ISM) is in the form of rainfall even over higher altitudes. Further, regression analysis has been carried out in order to establish interrelationship between the precipitation isotopic signatures and meteorological variables such as air temperature, relative humidity, and precipitation. Temperature and precipitation have good correlation with the isotopic signatures of precipitation, suggesting that both temperature and amount effects prevail in the study region.

MARINE GEO-SCIENCES AND OCEAN SYSTEM (MGS)

High resolution bathymetric mapping of the Indian Exclusive Economic Zone

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As per the provisions of the UNCLOS, India has Exclusive Economic Zone (EEZ) of more than 2 million km^2. India has exclusive legal rights to explore, exploit and utilize all the natural living and non-living resources in this region. Indian EEZ is also considered as a perfect storehouse of scientific issues related to the Indian peninsula. Realizing the need to be cognizant about Indian EEZ for the optimum utilization of the resources available and to geo-scientifically enhance our knowledge about the scientific issues related to the Indian Peninsula, the *Ministry of Earth Sciences (MoES), Government of India* launched a major scientific programme to generate a comprehensive high-resolution bathymetric map for the entire Indian EEZ by utilising the state-of-the-art technologies of Multibeam swath-Bathymetric Echosounder Systems (MBES). The research vessels of MoES were augmented with advanced wide swath MBES systems and deployed for systematic acquisition of the bathymetric data. The datasets collected in the Arabian Sea and Bay of Bengal were utilized in identification of seabed and geomorphological features in the region. Also site-specific sediment sampling, concurrently undertaken during the course of these surveys, were utilized in understanding the sediment characteristics, provenance, dynamics etc. and also the potential of the seabed resources. Many seabed features such as Seamounts, knolls, canyons, channel levees, submarine landslides etc. have been mapped and identified utilizing the data. Attempts were also made to define these features after referring to the '*Undersea Feature Terms and Definitions*' of IHO–IOC publication B-6 "*Standardization of Undersea Feature Names*". It is also pertinent to mention that many of such seabed features provide important clues to the mineral resources in the region, such as Cobalt and Ferro-Manganese rich crusts etc. The endeavour would help in providing some clues in understanding the evolutionary history of the Indian Peninsula, and also to assess the prospects of optimal sustainable utilization of living and non-living resources in the Indian EEZ.

Carbon and nitrogen isotope ratios of chemosynthetic biota from the active cold seep sites off Krishna-Godavari basin: implication in methane seep ecosystem

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The benthic biota discovered from the multiple active cold seep sites off Krishna-Godavari basin survive either directly on chemosynthesis (methanotrophy and/or thiotrophy) or heterotrophy (consumption of chemosynthetic or other detrital biomass). Characteristic endosymbiont bearing and chemo-heterotrophic faunal communities identified from the cold seep sites (Mazumdar et al 2018) include genus *Bathymodiolus* (family: Mytilidae, Subfamily: Bathymodiolinae), *Calyptogena* (family:Vesicomydae), *Conchocele* (family:Thyasiridae) and *Acharax* (family: Solemyidae). Intact relict shells of *Calyptogena magnifica* are recorded from the gas flare sites. The chemosynthetic bivalves imbibe H_2S and CH_4 using specialized body parts (foot) and transfer the same to the symbionts (thiotrophic and/or methanotrophic bacteria) hosted by bacterocytes in gill tissues, where H_2S and/or CH_4 are oxidized by the symbionts using oxygen from the overlying seawater). Oxidation of the chemical species generates the required energy for the synthesis of the body mass. Detrital organic particulates can also be ingested by these organism and associated heterotrophs subject to the type of feeding habit. Analyses of the carbon, nitrogen, and sulfur isotope ratios of the soft body mass thus hold the key to comprehend the range of metabolic pathways in the benthic biota of cold-seep regions. In the present study C and N isotope ratios were generated for the gills, mantel, foot tissues of bivalves; peduncle, scutum, and cirri of goose barnacles; whole tissue of polychaetes including tube of siboglinidea/ *Branchipolynoe seepensis* and cheliped/ carapace of galatheidae crabs. Our data shows remarkable spread in □^{13}C (-70 to -17‰ VPDB) and □^{15}N values (-3.9 to 14.8‰ Air) for the soft tissues. We propose both chemosyntheses as well ingestion of detrital carbon as the C and N sources. Sulfur extraction and isotope ratio analyses are being carried out in order to distinguish between methanotrophic and/or thyotrophic pathways.

Effect of Shale Anisotropy in Modification of Rock Stress Vector in Krishna-Godavari Basin, India

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This paper presents a stress analysis in an anisotropic medium in shallow bathymetry of 9 Krishna-Godavari basin, India using finite element modelling. Thomsen anisotropic parameters (such as: ε, γ and δ) have been estimated from dipole shear sonic log using ANNIE model to obtain the better understanding of anisotropy. The dimensionless anisotropic parameters reveal vertical transverse isotropy for the Palakollu Shale and Raghavapuram Shale in the study area. Stress modeling using finite element method is carried out in 2D post stack seismic section using conventional well log data. The stress orientation clearly responds tochanges in the anisotropic rock properties of Palakollu Shale, Tirupati Sandstone and Raghavapuram Shale formations. The contrasts of Young's modulus (1.52 to 2.55) along with contrasts of stress magnitude (1.72 to 2.28) between layersare the major factor torotate stress trajectories. Orientation of the maximum horizontal stress mostly varies from 40°N in Palakollu Shale to 17°N in Tirupati Sandstone to 20°N in Raghavapauam Shale. The model predicted stress orientation in Raghavapuram Shale matches with the orientation of derived breakout stress orientation of N20°E. The model predicted stress orientation in Raghavapuram Shale mostly follows the regional stress direction of this basin.

One million years sediment record of provenance, diagenetic and paleoclimatic changes in the Andaman Sea

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A high resolution rock-magnetic and geochemical study was conducted on a sediment core retrieved from the Andaman Forearc Basin (AFB) to document the variability in sediment provenance, diagenetic conditions, weathering and monsoonal history over the past ~ 1 Myr in the Andaman Sea. Sediment record of Hole NGHP-01-17A can be demarcated into two distinct zones based on the rock-magnetic and geochemical signatures. Higher magnetic susceptibility in zone-1 (Z1: 110 kyr to present, 0 - 10 mbsf) is possessed by fine-grained magnetic particles supplied to the basin as a result of increased chemical weathering controlled by strengthened monsoonal activity. The zone-2 (Z2: > 110 kyr, 11 - 50 mbsf) is marked by much lower magnetic susceptibility and presence of coarse-grained magnetite suggesting increase in physical weathering in source regions due to weaker monsoon. A notable shift in magnetic susceptibility and grain size at ~110 kyr can be attributed to differential contribution from the sediment sources influenced by varying intensities between chemical and physical weathering, changing monsoonal system and diagenetic dissolution of fine-grained magnetic particles. Geochemical parameters indicate that sediments in Z1 contained high iron (Fe), total organic carbon (TOC) and lower calcium carbonate ($CaCO_3$) content compared to Z2 which showed the opposite trend. Mineralogy diagnostic rock magnetic parameter (S-ratio) showed two episodes of increased inputs of anti-ferromagnetic minerals hematite and goethite at 80 - 50 kyr and 730 - 690 kyr suggesting enhanced chemical weathering in the source areas during these intervals. Geochemical tests (La-TH-Sc plot) indicated that the source of the detrital material is mainly from continental Island Arc settings. Our samples show a trend parallel to the A-CN join in A-CN-K ternary diagram suggesting variable weathering in the sources with a larger contribution from mafic igneous sources. Occurence of magnetic iron sulfide nodules accompanied by presence of authigenic gypsum in different sediment intervals below the present day sulfate-methane transition zone (SMTZ) (~25 mbsf) provide clues on the rapid shifting of SMTZ fronts positions due to variability in vertical methane fluxes at the studied site.

Crustal accretion and segmentation of the slow spreading Central Indian Ridge between 3°S to 11°Slatitudes, Indian Ocean

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The Central Indian Ridge (CIR) is a part of the major active mid-ocean ridge system trending north-south between Rodriguez Triple Junction (25°30'S, 70°E) and the equator. The CIR represents divergent tectonic plate boundary between the African Plate and the Indo-Australian Plate. The present work consists of a detailed study of the Central Indian Ridge (CIR) to understand the processes leading to the generation of the oceanic crust and its evolution. Some of the problems that are addressed from the present study are: (a) The fundamental segmentation of mid-ocean ridges, (b) crustal accretion. It is important to identify the contribution of these processes to understand the finer scale evolution of the ridge system. These studies would also help in the delineation of potential hydrothermal mineralization zones associated with active hydrothermal vent systems.

A 750 km long segment of the Central Indian Ridge (CIR) between 3°S and 11°S, has been studied to understand the processes leading to the generation of the oceanic crust and its evolution through the analysis of marine geophysical data. The 750 km long section of the CIR is characterized by rugged topography, steep valley walls, and well defined rift valley floor, all characteristics of slow spreading ridges. Based on the high resolution multibeam bathymetric investigations, we have identified twelve ridge segments and seven distinct ridge-transform intersection (RTI) highs occurring at the inside corner tectonic setup. Three of these prominent RTI highs are identified as oceanic core complexes /megamullion structures. The ridge segments are classified as magmatic and less magmatic ridge segments based on the rift valley configuration and off axis morphology. The analysis of high-resolution bathymetry and magnetic data revealed the influence of Central Indian Ocean deformation zone on the newly evolved oceanic crust. Magnetic model studies qualify the ridge as a slow spreading ridge with average full spreading rates varying from 27 to 38 mm/yr. We identified up to anomaly 3 across the ridge axis. The disposition of the magnetic anomalies suggests that the plate opening direction has not changed during the last 0-4 Ma period. Gravity data has been analysed to understand the crustal structure.

The computed mantle Bouguer anomalies (MBA) and the residual mantle Bouguer anomalies (RMBA) of the study area show significant variations along the ridge segments that are separated by transform and non-transform discontinuities. The identified megamullion structures are associated with less magmatic ridge segments. Based on our detailed high-resolution studies we propose that the oceanic core complexes are formed preferentially at the segment ends undergoing tectonic extension under sparsely magmatic regime. Both the transform faults and the non-transform discontinuities are characterized by thin crust. The along-axis crustal thickness computed from RMBA on an average is 5.23 km. The longer linear segments L and N have shown up to 7.8 km thickening of the crust towards the middle of the segment. The derived spreading rates are comparable to the slow spreading Mid-Atlantic and Carlsberg Ridges and also compare well with spreading rates derived from the MORVEL model.

A comparative study on geological setting of Central Indian Ridge and South West Indian Ridge (near Rodriguez Triple Junction) and its influence on hydrothermal system

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Seafloor Hydrothermal systems ascertain enormous significance in terms of their rich metal concentration and associated biodiversity. Previously, it was considered only fast spreading ridges (eg. East Pacific Rise) provide ideal geological conditions for hydrothermal activities. Subsequently, this view modified after series of discoveries of hydrothermal signatures along slow (eg. Mid Atlantic Ridge, Central Indian Ridge - CIR) and ultraslow spreading ridges (eg. South West Indian Ridge - SWIR, Gakkel Ridge). This study presents a comparative review of slow spreading CIR and ultraslow spreading SWIR near the triple junction area based on our observations and trying to reveal the hydrothermal potential of the region with respect to geological setting.

The SWIR, having a wide and deep axial valley, devoid of any major transform fault and shows extensive volume of exposed ultramafic rocks in the flanks at higher structural level. Signatures of recent magmatic activities are restricted in a narrow mid axial valley and mostly confined in the segment ends associated with oblique en-echelon fracture zones defined as non-transform discontinuities. The emplacement of ultramafics are considered to be driven by long lived detachment faults. A variety of microstructural shearing features are observed within the ultramafics ranging from ductile to brittle deformation regime. Mineralogical data from spinel within the ultramafics showing $Cr^{\#}$ around 17-20 suggesting extremely low partial melting of peridotites around 5-7%. The CIR, on the other hand having relatively narrow axial valley, segmented by major transform faults and behave more symmetric across the ridge suggesting a fair amount of magmatic supply. However in places exposed ultramafics are also found along with gabbro in the form of Oceanic Core Complexes (OCCs). Such zones show high magnetization in magnetic anomaly map, could be a response to the produced magnetite from serpentinization reaction and this confirmed by the mineralogical data from ultramafic rocks.

Physical and chemical water column studies shows signatures of hydrothermal activities in both CIR and SWIR region. In SWIR, due to less availability of melt and focused magmatic activity, the active hydrothermal signatures mostly restricted around ridge segments crosscutting the ridge axis. However chances of low temperature active hydrothermal activities and inactive hydrothermal deposits can be found in association with long lived – deep rooted detachment faults. In CIR, the OCCs near or within the valley with close association of magmatic features are the ideal geological conditions for hydrothermal activities. Such settings could provide a combined heat source from magmatic and exothermic heat form serpentinization also setup a fluid pathway through detachment faults.

Cenozoic sedimentation and seismic stratigraphy along the central part of western continental margin of India - constraints from deep sea drilling

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The western continental margin of India (WCMI) is one of the classic examples of magmatic rifted margins characterized by extensional tectonics and a long record of sedimentary history since its origin. The interpretation of sedimentation phases along the margin helps to map the corresponding prevailing depositional environment, thereby helping to unravel the tectono-climatic linkages in the past. In the present study, we will be presenting the structural interpretation of sedimentary sequences on closely spaced high resolution multi-channel seismic (MCS) data along the WCMI. Mapping of the MCS data revealed five major depositional sequences since Cenozoic (ranging from Paleocene to Recent). The major sediment boundaries recorded the interactions between climate and tectonics in the western Himalaya since the initiation of India-Asia collision. The sediment deposition along the basin revealed both shallow water deposition from the Indian continental shelf and presence of mass transport deposition in the deep water environment. The seismically acoustic basement appeared faulted and the near-shelf volcaniclastic sedimentation overlying the acoustic basement appeared syn-rift derived mainly from the earliest rift phases. The interpretation is well constrained by results from combined core-log and lithostratigraphic information from the International Ocean Discovery Program (IODP) Expedition 355. This high resolution mapping of the regional seismic stratigraphy will add new insights into the pre- and post-rift tectonic processes which may have occurred along the western margin. Also an attempt has been made to estimate the long sedimentary record and its distribution in the central margin through the present study.

Seafloor massive hydrothermal sulphide exploration: Indian Initiative

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Sea-floor massive sulphides are deposits of metal-bearing minerals that form on and below the seabed as a consequence of the interaction of seawater with a heat source (magma) in the sub-sea-floor region. The discovery of such systems in the deep oceanic realm along the mid-ocean ridges has kindled a lot of interest primarily on account of the high concentration of base metals (Cu, Pb, Zn) and many noble metals (Au, Ag, Pd, Pt) in them. Seafloor hydrothermal activity associated with concomitant sulfide minerals and biological resources is a major research topic with vital scientific significance and economic considerations.

The discoveries of fossil and active hydrothermal system along Central Indian Ridge (CIR) and South West Indian Ridge (SWIR) as well as evidence of hydrothermal plume and mineralization signatures in this region suggest the possibility of many polymetallic sulphide mineralization zones in the Indian Ocean region. This prompted India's aspirations to undertake a comprehensive research and exploration program, aiming in identification of new locals of hydrothermal activity, and to understand the complex physical-chemical-biological-geological scenario of the hydrothermal systems and thus entailing the genesis, environment and distribution of hydrothermal plumes and mineralization in the CIR and SWIR region.

NCPOR under the aegis of Ministry of Earth Sciences has initiated a mission-mode multi-disciplinary program on exploration of hydrothermal sulphide mineralization in parts of CIR and SWIR region. Integrated multi-disciplinary scientific and exploration strategy including geophysics, geology, physical oceanography, chemical oceanography, biological studies have been attempted. The preliminary exploration target was to track the hydrothermal plumes in the region, which subsequently lead to identification of hydrothermal vents/mineralization zones.

Detailed geological and geomorphological studies were carried out using high resolution bathymetric maps to identify major geological features viz. neo volcanic ridges, detachment faults, lineaments and probable zones were narrowed down for exploration of hydrothermal plumes. Various proxies' viz. physical, chemical, geochemical, biological were used to identify the signatures of hydrothermal plume in the water column and on the ocean floor. Analysis of the data/samples collected during the cruises, provided convincing clues on hydrothermal plumes at few locations. The significant results obtained from the above scientific studies paved way for further detailed studies in various probable sites in the region for the identification of potential sites of hydrothermal deposits in the allocated area.

An overview of the Ocean Bottom Seismometer records from the Indian Ocean Geoid Low region: Implication towards deep mantle understanding

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A regional deviation of the equipotential gravitational field, from an idealized hydrostatic ellipsoid is known as geoid anomaly. The most salient feature in the northern Indian Ocean termed as the Indian Ocean Geoid Low (IOGL) anomaly, is the lowest geoid anomaly of ~ 106m, and appears as a very long wavelength feature (> 3000 km) covering the entire Indian Ocean (Sreejith et al, 2013). The theories from seismological and numerical modelling suggests that it could be attributed to low velocity mantle structures shallower than 1000 km (Ghosh et al., 2017) or could be related to Tethyan subduction during the Mesozoic period (Spasojevic et al., 2010). However, due to inherent methodological limitations and almost no offshore seismological observations from this region, secrets of this perplexed anomaly still remains outstanding.

To understand the mantle dynamics beneath the IOGL, the first phase of Indian Ocean Seismic Array (IOSA), consisting of 17 passive broadband Ocean Bottom Seismometers (OBS) were deployed during the period of 2018-2019. The retrieval of all 17 OBS units have been successfully achieved, which could deliver crucial insights to the seismic and structural anomalies beneath the IOGL region. In general, it is observed that seismograms from OBS installed in other parts of the world are typically contaminated with noise, such as, the tilt noise and water-wave noise (for e.g., compliance noise, and microseism noise), introducing difficulties in implementation of qualitative subsurface imaging techniques.

In order to identify and extract the seismic phase information from the noisy signals, routine filters are not efficient enough to enhance the signal to noise ratio. In consideration to the technical difficulties and the expenses involved in the deployment of the OBS, several challenges still lay ahead with processing of the noisy seismograms. In this paper we discuss the typical behavior of noise in the seismograms recorded from the deep oceans and few unconventional techniques to deal with such noisy data. This would help to enhance the data repository for wider usage and interpretation.

Geomorphology and architecture of submarine channel levee system in north east of Ninety East Ridge

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Morphological investigations in the Bay of Bengal could provide evidence of submarine channel levee complexes having well-developed stacked channel-fill and over bank deposits, especially in the lower Bengal Fan. This study presents new set of high resolution swath bathymetry and sub bottom profiling data undertaken to map submarine channel levee system over north eastern part of Ninety East ridge. The identified submarine channel is having a maximum depth of -4122 m and is characterized by a slope of 8°. The channel is interrupted by Andaman forearc in the east and Ninety East Ridge in the west. These are among the most noticeable channel systems in the Bay of Bengal. The previously identified E7 (2) channel levee (B. Jena et al., 2016) in the northern region had a total length of about 405 km along the channel axis. In this study, the average depth of E7 (2) channel levee was measured to be about -135 m and channel width ranges from 2 km in the south and 9 km in the north. Similarly 52 km long new meandering patterns levee systems were also identified at a depth of 4200m between 6° 44′N, 092° 06′E and 6° 13′N, 092° 14′E which is 65 km south of E7(2) channel levee flows gently deepening and widening along the east of Ninety-east Ridge. On the eastern side of Ninety East Ridge, two elevated features E1 and E2 were observed with 240 m and 900 m respectively. Analysis of levee systems represents the active and abandoned channel loops caused due to turbidity currents and over slipping at sharp bends.

Geochemistry of ferromanganese crusts from Central Indian and Southwest Indian Ridges: constraints on hydrothermal plume signatures

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The major, trace and rare earth elements (REEs) concentrations of ferromanganese crusts from ~1000 km long stretch of Central Indian and Southwest Indian Ridges (CIR & SWIR) around Rodriguez Triple Junction are studied for their genesis and to identify influence of hydrothermal activity. The high concentrations of major (iron and manganese) and trace elements (cobalt, nickel, copper and zinc) and REE in these crusts suggest that they are of hydrogenous origin (formed from the seawater). Although the high REE concentrations are of typical hydrogenous nature, the crusts are characterized by the negative cerium anomalies ($Ce/Ce^* \leq 1$) in the shale normalized REE pattern. This is a clear indication of possible influence of hydrothermal activity. The excess cerium (Ce_{xs}) is calculated to quantify the degree of decoupling of Ce from its strictly trivalent REE. The relatively low concentrations of cerium and Ce_{xs}/Ce_{bulk} ratios (~0.8) suggest that these crusts were under influence of hydrothermal plumes. The high REE fractionation (chondrite normalized ratio of Nd/Yb = 2.5 to 4.0) with negative cerium anomalies confirms the presence of high temperature hydrothermal plume fall-out in these crusts. End-member mixing model of cerium anomaly is established to quantify the contribution of hydrothermal plumes. Based on the Ce mixing calculations, it is estimated that the hydrothermal contribution to these crusts may be about 70-80%. The present study provides evidences for the hydrothermal activity in the less studied SWIR and suggests the possibility of higher incidences of hydrothermal vents in ultra-slow spreading mid-oceanic ridges such as SWIR.

Evidence of crown crack generated submarine landslides Off Quilon, Kerala

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Seabed Submarine landslides in the continental margins have long been recognized as a major geohazard that are capable of damaging seafloor installations and even generating tsunami waves. Hence it is necessary to study the morphology of continental slopes and recognize areas vulnerable to submarine landslides to improve our understanding on the potential risks. In this context, using high resolution multibeam bathymetry and sub-bottom profiling data, we draw attention to a linear system of cracks along a 60 km long section of the outer

continental shelf Off Quilon, Kerala. The cracks are located in water depths of 350 - 500 m between Alleppey Terrace in the north and Trivandrum Terrace in the south. These cracks resembling offset of normal faults are up to 400 m wide and 30 m deep, along gentle slopes (average gradient: 2°). Their location and surface expressions can be related to 'crown cracks' that are often found on the headwalls of slides. To the north of study area, a small scale 'rotational slide' covering an area of 108 km^2 is found broken from the crack system. The failure material of this slide is well preserved immediate downslope and is in compliance with the presence of crown cracks indicating initial stages of a large-scale slope failure. Further south, where the crack system disappears, a major slide is identified. The head-scarp of this slide is high up to 150 m and is located along the trend of a fault. The failed mass of this slide has been converted into a 'debris flow' covering an area of 1125 km^2 with a run out distance of 38 km. The extents of debris flow are discernible in bathymetry and sub-bottom profiling data. Since, several failures are identified along the crack system, the unfailed slope regions in the study area could be categorized as 'landslide susceptible zones'. From a societal perspective, we need to evaluate the degree of tsunami hazard that might be posed by a major submarine landslide, if it is nucleated on the newly discovered crack system.

Watermass exchange in the Atlantic-Arctic Gateway (Fram Strait) during the mid-Pliocene Warm Period

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Arctic sea ice is an important component of global ocean and climate system which is undergoing rapid mass loss in the past few decades. Oceanic heat transport by the north Atlantic current (NAC) is found one of the important factor for this mass loss. Therefore, quantifying the contribution of poleward ocean heat transport to Arctic Ocean sea ice loss is imperative for future sea ice prediction. In order to understand role of oceanic heat transport and future sea ice conditions in the Arctic, we have reconstructed a new record of water-mass exchange between the Atlantic and the Arctic Oceans using the neodymium isotopic composition (ϵ_{Nd}) of marine sediments from Fram Strait (80°15.894'N, 6°35.430'E, water depth: 556.4 m) during the mid-Piacenzian warm period of the Pliocene epoch, the most recent geological analogue for future climate change. Our semi-quantitative water mass exchange reconstruction shows long-term secular changes from the lowest during the Marine Isotope Stage M2 "glacial" and highest during the mPWP. Orbital forcing is determined to be critical for modulating northward volume transport of Atlantic-derived water masses. Our proxy record provides critical input for improving future Arctic sea ice projections.

MINERAL EXPLORATION -CHALLENGES FOR NEW DISCOVERIES (MEC)

State-of-art Multi electrode (DIAS32 technology, Canada) Induced polarization survey in Zawar (Lead Zinc) Mines, Udaipur district, Rajasthan.

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The Study area falls in southern part of ZawarMines(Pb – Zn) area of Hindustan Zinc Limited. Regionally, Zawar Pb-Zn belt is occupied by thick pile of calcareous, arenaceous and argillaceous meta-sediments of Aravalli super group of Proterozoic age. The principal rock types are conglomerate, quartzite, greywacke, phyllite, slate and dolomite showing a wide variation in grain size mineral constituents. Hindustan Zinc Limited deployed state of the art technology “DIAS 32” multi electrode Induced Polarisation Surveyin association with DIAS geophysical, Canada in Zawar Mining Lease area, Udaipur district, Rajasthan as part of exploring the continuity ofmineralisation within study area.DIAS-32 technology has many advantages over conventional IP survey in terms of common reference voltage line, full waveform recording, easy operation, noise rejection based on CVR and multi dipole selection. Objective of this survey was to see the electrical resistivity and chargeability signature associated with lithology, alteration and mineralization. This survey was carried out with DIAS-32 acquisition system in conjunction with 10KW GDD transmitter using distributed 2D DCIP array with Pole-dipole configuration along 3 km lines with 200m line spacing and 100m station spacing. Square waveform has been used for transmitter with 50% duty cycle and with 0.125 Hz (8s cycle) of base frequency. DIAS-32 technology serves better signal to noise ratio based on common voltage reference and advanced processing techniques.CVR mode of data acquisition provides considerable flexibility in the construction of dipole from the individual time series datasets at each receiver electrode. This survey helped to identify the undercover lithology and to identify new targets for drilling based on chargeability and resistivity anomalies in study area. This paper will elaborate the technology description and the outcome of the survey.

Geophysical Investigation for Lead and Zinc (Pb & Zn) and associated minerals around Phophonga Hills, Goalpara District, Assam

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Lead (Pb) and Zinc (Zn) are the minerals which mainly occur in sulphide mineralization like Galena (PbS) and Sphalerite (ZnS). It is found in association with Iron sulphide and also occurs in its oxides. Iron sulphides are conducting in nature and can be helpful to detect the Pb-Zn deposits. The area around Phophonga Hills is mainly occupied by rocks of Assam-Meghalaya

Gneissic Complex. These rocks are of Archaean to Proterozoic age and are deeply weathered. The rocks are comprised of banded biotite hornblende gneiss and quartzo-feldspathic gneiss with pegmatite and schist. The geophysical data namely Induced Polarization (IP), Self-Potential (SP) and Magnetic vertical field (VF) have been processed and interpreted for identification of lithological contacts as well as favourable zone for sulphide mineralization. Magnetic (VF) and apparent resistivity maps reveal a wide range of variation in magnetic and resistivity values respectively over exposed formation on either side of the surveyed area. The smooth variation in magnetic (VF) and resistivity values are recorded in the central portion of the area occupied by soil/cultivated land. The contacts of exposed formation on either side of the area and soil/cultivated land in the central part have been clearly demarcated by magnetic and resistivity surveys. Some important anomalies have been delineated by the geophysical investigations. These anomalous zones have been recommended to verify the nature of the causative source.

Application of the gravity method in delineation of favourable locales for Uranium exploration in and around of Duwalgudra area, Rajnandgaon district, India

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Kotri–Dongargarh belt has emerged as a potential geological domain for uranium mineralization through effort over the last many years. Uranium mineralization in this belt hosted by volcanic rocks of Nandgaon and Khairagarh Group is structurally controlled. The structurally controlled vein type uranium mineralisation associated with N-S trending fractures/shears in metabasic and rhyolite in Bodal and Bhandaritola respectively. The present study area, near Duwalgudra is located 20 km NW of Bhandaritola, exposes predominantly Bijli rhyolite and Pitepani Volcanics, which form part of bimodal volcanic sequence belonging to Nandgaon Group and Dongargarh granite around Mongra in south-eastern part. Gravity survey was aimed to delineate subsurface geological structures that could serve as favourable locales for uranium mineralization.

Gravity data was acquired using Scintrex CG-5 gravimeter along with SP-80 DGPS system for geographical locations. Qualitative analysis of Bouguer gravity anomaly and its derivative maps aided in delineation of linear gravity lows representing one N-S and three NW-SE trending fractures. A broad gravity low of the order of -5mgal is attributed to intrusive Dongargarh granite. Intense N-S fracturing in exposed Bijli Rhyolite validated the fractures delineated from gravity data. Southernmost NW-SE trending fracture intersects the N-S fracture zone and these two fracture zones are mapped for a strike length of 6 kms. N-S trending gravity high established the continuation of basic intrusive concealed below Bijli

Rhyolite. Possibility of mobilisation and reconcentration of uranium along the fractures due to later basic intrusive can not be ruled out. Detailed gravity survey over the southernmost NW-SE fracture has facilitated in demarcating the boundaries and its extensions precisely. Further, this led to identification of two NE-SW minor cross-cutting fractures under soil cover. The deciphered NW-SE fracture zone transected by N-S and NE-SW fractures in Bijli Rhyolite intruded by basic body provide a possible target for further exploration.

Delineation of manganese ore deposits and its structural features by Potential Methods for occurrence of mineralization in Meghnagar, Jhabua District, Madhya Pradesh, India.

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Geophysical surveys employing Gravity and Magnetic methods have been carried out in Mandli-Rampura block, Meghnagar, Jhabua district, Madhya Pradesh. The survey area belongs to Aravalli Super group consisting meta-sedimentary sequences of quartzite, phylitte, dolomitic limestone and igneous rocks of granitoid and gneiss of Precambrian age.

The Bouguer gravity anomaly contours map shows the trend is WNW-ESE in the northeast part, and N-S in southwest part. In the lower part of the surveyed area, the trend of contours is in WNW-ESE direction.

The high gravity values are seen in the northeast portion with gravity value -34 mGal which are due to high density material or basement may be shallower.

The southwest portion showing low gravity values, it may be due to presence of either low density material or deeper basement. Few high gravity anomaly zones have been delineated with limited width and a strike length of anomaly 50—150 m.

The magnetic anomaly map indicate that the anomalies are bipolar in nature. Three high magnetic bands X-1, X-2 and X-3 of folding nature are traced in the lower portion of the study area, wherein magnetic variation is in the order of +150 to -250nT. Band X-2 may be the zone of our interest for the prospect, because it is passing through the open manganese mines (old working), this zone is delineating the deposit for mineralization point of view. From the Potential Method, it is evident that there is a structural break seen at Trav SW 700.

Integrated geophysical surveys as a tool to delineate structural controls for Uranium mineralization in soil covered areas of Sohla-Nimbi tract, part of North Delhi Fold Belt, Haryana, India

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The Proterozoic rocks of North Delhi Fold Belt in the state of Haryana are the north- eastern continuation of Alwar and Khetri sub basins of Rajasthan. Sohla-Nimbi tractlocated in Mahendragarh district of Haryana exposes quartzite rocks of Bayal-Panchnota Formation, which are the youngest rocks of Alwar Group of Haryana. The outcrops of Sohla and Nimbi are 5 km apart and regional strike varying from N10°E-S10°W to N30°E-S30°W with vertical to sub-vertical dips. The area in between is mostly soil covered with few isolated inselbergs. Along Sohla ridge, significant radioactive anomalies and sulphide mineralization have been reportedin highly brecciated/ sheared magnetite-hematite quartzite rocks.To map the structural disposition and sulphide mineralization along shear/ brecciation zone under soil covered area between Sohla and Nimbi, magnetic and Induced Polarization (IP)/ Resistivity surveyswere employed which facilitated in identifying structurally controlled Uranium mineralization within subsurface.

The processed magneticdatashows the presence offolded brecciated hematite-magnetite quartzite body dipping west andstriking in N10°E-S10°W direction along its axial plane having closure near Sohla. Towards Nimbi, three isolated magnetic anomalies trendingN30°E-S30°W are attributed to hematite-magnetite quartzite bodies crosscut by younger NNW-SSE and NW-SE trending faults/ fractures. Magnetic low zones delineated parallel to Sohla ridge are inferredas shear/ brecciationzones and became prominent structural control to host Uranium mineralization. IP/ Resistivity surveys overone such brecciation/ shear zoneapproximately 3.50 Km in strike length and 500-1500 m wide located between Sohla and Balanaresulted in demarcation of sulphide rich zonehaving strike length of 1.20 Km and 600 m width. Apparent chargeability values up to the order of 27 mV/V were recorded over the background of 2-5 mV/V associated with moderate to low order of apparent resistivity values. Subsequently, borehole drilled near Sohla over the high chargeability zoneintercepted Uranium mineralization in sheared/ brecciated quartzite rocksalong with sulphides.

Geophysical Study for Coal Exploration in the North-West part of Godavari Valley Coalfields, Adilabad district, Telangana –A Case Study

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The Godavari valley coalfield is well known for the occurrence of thick Gondwana sediments from early Permian to early Cretaceous times within a major NNW-SSE trending long linear basin. Pranahita Godavari valley is one of the sub-basin of Godavari valley basin which extends in the areas of Adilabad, Warangal, Karimnagar, Khammam and Godavari districts of Telangana and Andhra Pradesh covered a length of 470 km. Regional exploration for coal by scout drilling in the study area is situated in north-west of Dorli Block, Adilabad district, Telangana which is the NW part of Godavari Valley Coalfields. Geophysical investigations have been carried out using magnetic, gravity and resistivity soundings to identify subsurface geological formations & associated structures and coal disposition. High dominant magnetic anomalies have been noticed in the north-east, south-east and central part of the study area over trap rocks having more thickness, whereas, magnetic lows noticed in the southern and central part over trap rocks having less thickness. A prominent gravity high anomaly has been noticed over the south-western part of the study area which may indicating the basement high. On the basis of the magnetic and gravity radial spectrum, it can be inferred that the range of depth persistence of different interfaces viz., trap rock and underlying Gondwana sediments between 60 - 80m and 120 - 160m, which is well corroborating with interpretation of resistivity sounding data. The curves obtained from resistivity soundings (VES-1 to VES-8) have brought up five to six-layers setup depending on resistivity variation which may comprising of top sandy soil / clayey-sand, underlined by weathered / massive trap rock and Gondwana sequence consisting of Kamthis, Coal bearing Barakar Sandstone and Talchir formations.

Uncovering the Concealed Schist belt-An insight through National Geophysical Mapping

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In order to understand regional subsurface architecture and possibility of occurrence of any mineralised zone, the gravity and magnetic surveys were conducted as a part of National Geophysical Mapping Program during FS: 2018-19 in Chikmangalur and Hassan districts, Karnataka. These surveys have brought out significant findings .The study area assumes importance as it is the intervening portion of Shimoga- Bababudan and Chitradurga schist belts of Western Dharwar Craton. Geology of the area is represented mostly by older enclaves

of Sargur Antaraghatta Ultramafic Complex (AUC), Peninsular Gneissic Complex (PGC-I), metabasalt of Bababudan & Chitradurga groups and younger intrusive of Closepet equivalent granites.

The Bouguer gravity anomaly map exhibits ribbons and pockets of gravity high and low with the overall anomaly variation of around 20mGal. Circular to oval shaped low bouguer gravity anomaly is observed over the granite intrusive bodies reported at Banavar and Kadur. The Bouguer gravity anomaly also indicates a major younger granitic body with strike extension of 20 km in the form of gravity low closure in peninsular granite gneisses. This is considered as an equivalent to Closepet granite. The contacts on both sides of this granitic body are well defined in the form of high gradient zone. The eastern contact of this unmapped granitic body is Antaraghatta Ultramafic complex belt, well known for its chromite occurrences. Interestingly, the NW-SE trending western contact also seems to be significant for the presence of parallel concealed ultramafic complex. The discrete high closures in NW-SE trending linear high gravity zone which is sandwiched between the major gravity lows is identified for possible presence of ultramafic bodies with possible chromite lensoids. The Bouguer anomaly tilt derivative map reflected the best visualization with enhanced edge response of these gravity high anomalous patches and show them as a continuous linear gravity high zone beneath the cover of Peninsular Gneissic Complex. The sporadic ultramafic bodies restricted to this inferred anomalous zone act as a window, suggesting that these lensoidal patches are inter connected at depth. The residual bouguer gravity anomaly map suggests that the body lies under very thin cover of gneisses. The thickness of gneissic cover is of the order of ~ 500-800m with depth extending up to 3 km as, it was evident from the Euler depth solutions and radial average power spectrum analysis based on available data. The present results are also well corroborated with the available aeromagnetic data (Palaniappan, 1993), further confirming our observations. Thus, geophysical survey clearly suggests the possible disposition of this hitherto unknown wide and linear ultramafic complex under the gneissic cover. Hence further geoscientific studies over this residual anomalous zone is needed to establish this possible occurrence of ultramafic complex.

Evidential layers derivation using ASTER VNIR-SWIR data for Gold-Sulphide mineralization in parts of Gadag schist belt, Karnataka, INDIA

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Gadag schist belt is known for Gold-sulphide mineralization. The Gold-sulphide mineralization is controlled structurally and lithologically. In this context, ASTER (Advanced Space Borne Thermal Emission and Reflection Radiometer) VNIR (Visible Near InfraRed) – SWIR (Shortwave Infrared) bands were utilized to derive alteration zones and structures in the present study area. Lithology also have been updated using ASTER VNIR-SWIR bands, derived image enhancement products i.e. Principal Component Analysis (PCA) colour composite and False Colour Composite (FCC). Further, image spectra of alteration zones (Hydrous mineral: Al-OH, Mg-OH, etc.) derived from ASTER calibrated VNIR-SWIR bands were compared with the standard corresponding reference library spectra. Alteration zones were delineated using the image spectra of Muskovite, Kaolinite,Heametite minerals. Structures were demarcated using high pass (HP) filtered image and FCC image. Low pass (LP) filter image and PCA image colour composite were utilized to update the lithological boundaries in the study area. These are very important evidential layers which can be further integrated using different integration techniques (fuzzy logic, weight of evidence etc.) to identify potential zones of Gold-Sulphide mineralization in the present study area. It has been observed that, ASTER data can be utilized to derive these important evidential layers in any part of the world and further, these layers can be integrated to find the potential zones for Gold – Sulphide mineralization.

Delineation of subsurface structure and possible mineralization in parts of Cuddapah basin in Easter Dharwar Craton by gravity and magnetic method

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Regional Geophysical mapping employing gravity and magnetic has been carried out in part of Kadapa district of Andhra Pradesh in Toposheet Nos. 57J/15 and 57J/16. The area comprises of Archean Dharwar supergroup, Archean Paleoproterzoic Peninsular Gneissic Complex (PGC-II), Mesoproterozoic Cuddapah basin, are prominent geological domains. The oldest unit represented by quartz-chlorite-sericite schist and chlorite-sericite- schist of T-sundupalli schist belt of Dharwar Supergroup of Archean age. The objective was to delineate the subsurface structures controlling mineralization.

Regional Gravity and Magnetic surveys have brought out characteristic responses over various litho units and the dispositions of T- Sundupalli schist belt, its contact with adjoining terrain in the form of high gravity gradients. Significant low gravity zones L1, L2 identified over cuddapah group of rocks and contact of Cuddapah with grey hornblende biotite gneiss respectively. The high gravity zones H1, H2 along with high gravity gradients G1, G2 are inferred as T-sundupalli schist belt with its northern and eastern extension. These high enclaves are due to schist/contacts/shears which may contain mineralised zones. Residual gravity map clearly depicts the T-sundupalli schist belt (RGH1) and also brought out its northern extension (RGH2) in addition located a new parallel schist belt RGH3 and RGH4 in the form of exposed relics schist patches. Upward continuation of gravity data revealed the depth persistence of T-sundupalli schist belt and corroborated with magnetic signatures. Magnetic anomaly map depicts high zones over PGC-II and low zones over Cuddapah group of rocks. Radially averaged power spectrum of gravity indicated depth interface at 4 Km, 8Km representing high crustal thickness and basement which are corroborated with that of magnetic interface. T-sundupalli schist belt with its northern extension is well reflected in both x-derivative (S1) and second derivative gravity anomaly maps.

Quasi-3D Electrical Resistivity Tomography (ERT) Study for Investigating Uranium Mineralization in, South Purulia Shear Zone (SPSZ), India

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South Purulia Shear Zone (SPSZ) is an E-W trending narrow zone between North Singhbhum Mobile Belt (NSMB) and Chottanagpur gneiss complex (CGGC) in Eastern part of Indian Shield. SPSZ is a potential sector for Uranium where Uranium mineralization is associated with hydro-thermally altered veins at various places. A preliminary 2-D resistivity survey was conducted in Dandudih village of East Singhbhum District that lies in SPSZ, to explore sub-surface structures related to Uranium mineralization. For this survey, we measured three parallel profiles in NE-SW direction separated at a distance of 250m using Wenner-Schlumberger multi-electrode configuration at each profile. 2D inversion of all profiles was obtained using smoothness constrained least-squares inversion method. Quasi 3D resistivity imaging was used to map the extent of a buried anomaly in the study area. In this technique, we have combined 2D inverted sections of parallel profiles, measured during the survey, into one data set to obtain 3D inversion for the understanding of results. Quasi 3D resistivity imaging results provide a spatial analysis of subsurface situations, thus giving advancement over 2D resistivity imaging sections. Results show the presence of multiple conducting bodies, that are deep and steeply dipping in the north direction. With interpretation results and prior studies, we may say that these low resistivity values are associated with hydro-uranium anomaly zones. This preliminary study expresses the efficiency of quasi 3D electric resistivity tomography to identify altered hydro-thermal uranium zones. However, only one method is not enough to outline the lateral and depth extents of anomalies and hence directs future exploration in this region.

Geophysical Exploration for delineating the Stratiform Manganese Mineral deposit within the Neoproterozoic Pranahita-Godavari Basin, Adilabad-District, Telangana

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The stratiform manganese mineral deposit confined within the Neoproterozoic Penganga limestone of Pranahita-Godavari basin, Adilabad-District, Telangana is exposed as long linear belt of ~35 km long and ~ 20 to 30 m wide zone, trending in NW-SE direction. In this region, the chemically precipitated manganese deposit is developed in oxide and / or carbonate facies environment. Todorokite is the main manganese oxide ore and occurs as thin layer (~ 1 m thick) within massive limestone unit of Penganga Group. The earlier geological works in this region were mainly confined to establish the strike extension of the mineralized zone. As there exists ambiguity about its lateral extension and the associated structural controls of mineralization; the detailed geophysical surveys comprising of gravity and magnetic are conducted at around the Goatkuri-Guda mine area, near Adilabad for delineating the manganese mineralization.

The gravity and magnetic studies have brought out the underlying basement configuration dipping from SW to NE direction. However, a significant steep gravity gradient at the central part reflects the basement fault (?) trending in NW-SE direction. Similarly, the regional anomaly patterns are used to delineate the structural fabric of overlaid on Penganga formations. Based on the regional anomaly character the study area has divided into two blocks. In the northern block, the general NW-SE regional trend replicates the regional geological strike varying from WNW-ESE to NW-SE direction. However, the southern block is occupied with a predominant NE-SW trending regional magnetic high, associated with discrete gravity high and lows anomalies and it formed orthogonal structural relationship with the regional geological strike direction. The contact between these two blocks is interpreted as a major fault, trending in NE-SW direction.

Further analysis has been made to delineate the disposition of layered manganese mineralization exposed in western part of the area. The NW-SE trending discrete residual gravity highs are recorded over the known mineralized zone and indicate its limited lateral extension. A few such similar characteristic linear high anomalies observed in the eastern part of the area are demarcated as parallel manganese mineralization zones in this area. It is further interpreted that the basement fault (?) demarcated in the central part of the area could restrict the lateral extension of the stratiform manganese mineral deposit in this region.

Inferred Contact of Dharwar Craton and Southern Granulite Terrain in Krishnagiri Area Based on Gravity and Magnetic (T.F.) Data and its Significance in Mineral Potentiality

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Regional Bouguer Gravity and Magnetic (T.F.) data across the Dharwar craton and SGT (Southern Granulitic terrain) have been analyzed to estimate the deeper crustal configuration. Rocks belonging to Eastern Ghats Supergroup, the Sargur-Satyamangalam Group, the Peninsular Gneissic Complex are marked in the area. They have been intruded by both basic and acid dykes, Syenite and Carbonatite bodies of Dharmapuri Alkali complex. Linear quartzite bands of Khondalite group, Charnockite, Pyroxene granulite, pink granulite,

represent the oldest rocks in the eastern area and associated rocks of the Charnockite Group. In the north-eastern part of the study area the survey have brought out gravity gradients trending in NW-SE over contact of Dharwar group of the rocks with PGC basement and moderate to high gravity anomaly over Gneissic basement entailing Kolar Schist Belt. The E-W trending Gravity gradients may possibly suggest the contact of PGC basement with Southern Granulitic terrain near Krishnagiri. With the help of different derivative maps of Bouguer Anomaly, Gravity high axes, fracture zones and linears have been inferred for understanding the disposition of volcanic suite of rocks (Dykes) which could be the possible conduits. A clear division of Gravity Gradients (trending NW-SE & bulging NE-SW) in zone Z1 in North-Western part of the study area possibly reflects a deep mafic intrusion in the upper crustal levels. The Magnetic (T.F) anomaly map depicts Magnetic linears in the NE-SW direction in the form of attitude of clusters of high Magnetic value which may be inferred as the presence of mafic intrusion in the upper crustal levels which is in corroboration with the Bouguer Anomaly Map. Although the high frequency magnetic response may be attributed to the shallower features of the subsurface, their alignment is in collaboration with the bulging of the Bouguer gravity contours. The sudden change in Magnetic anomaly response from Low to high (trending N-S) may reflect the lithological changes in North-western portion over Krishnagiri. The attitude of magnetic contours in the central & southern portion of the study area respectively may reflect the inferred contact of Dharwar Group with PGC basement and SGT (Southern Granulite Terrain). The bipolar nature of Magnetic anomalies may mark the intervening Kolar Schist Belt. Quantitative interpretation of Bouguer anomaly suggests the prominent anomaly response at depths of about 8 Km probably suggesting the shallow PGC and SGT contact. The shallow Euler depth solutions in the NW-SE trending Dharwar group of the rocks whets the inferred intrusion in the upper crustal levels. Most of the Euler depth solutions are occurring over the possible conduits where high gravity and magnetic gradient is observed. Surface manifestations of the deep conduits over these gradients may signify possible mineral prospects in the near future.

ADVANCES IN HYDROCARBON AND ALTERNATE ENERGY RESOURCES

Carbon Capture Utilization & Storage Advances and Initiatives towards Climate Integrity

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The increase of CO_2 level in the atmosphere have caused alarming changes in the climate change such as global warming, extreme weather conditions, sea level rise and shrinking of glaciers etc., which have great implications on global food security and economics. The UNFCCC (United Nation Framework on Convention of Climate change) have addressed the issues that strong desirable and achievable commitments are necessary to race against climate change by developed and developing nations. The fossil fuels burning add to ~ 80 % of CO_2 in the atmosphere, and is the principal cause of CO_2 built up. The energy dependence on fossil fuel and CO_2 emissions have to be curbed to keep the global temperature rise below 1.5 degree centigrade.

Storage of CO_2 in underground geological formations is one of the viable alternatives for environmental remediation. The options are: Geological storage in depleted oil reservoirs for enhanced oil recovery (CO_2 -EOR); Storage in gas reservoirs for enhanced gas recovery (CO_2-EGR); and Sequestration in the Basalt formations & Saline aquifers. However, geological storage is highly cost intensive for developing economies as the purified and liquefied CO_2 from thermal power station have to be transported to geological storage site.

The innovative carbon storage advances have been: Bio- carbon capture utilization and storage (Bio-CCUS); Getting geothermal power with CO_2 instead of water in the arid areas where water is scarce; increasing the fertility of ocean and soil by carbon dioxide uptake and direct capture of CO_2 from air, converting CO_2 into cement, caustic soda etc.

India's initiatives towards carbon storage and review of new CO_2 storage overtures will be presented and discussed.

Porosity Mapping from Inversion of Post-stack Seismic data in Cauvery basin, India

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The Cauvery basin extending along the east coast of India, has been formed as a peri-cratonic rift basin. The basin exhibits a series of parallel horsts and grabens structures trending NE-SW direction. A seismic section oriented in the direction of NE-SW passing through well "M" is considered for porosity prediction in the Cauvery basin. Post-stack inversion of seismic data is normally carried out to derive acoustic impedance (AI) in an area. We have been used here a methodology to invert post-stack seismic data into porosity from given porosity log. The post-stack inversion for porosity estimation is performed by using an estimated porosity wavelet, low frequency model and model based inversion. Total porosity estimated from the density log for the depth interval of 700 -1600 m has been used as input for porosity inversion from the seismic data. The total porosity ranging from 20 to 60% has been used as input for porosity inversion for the 2D post-stack seismic data. This prediction is applied to the dataset having moderate correlation between AI and porosity. In the Cauvery basin, the porosity along seismic section ranges from 40 to 60% in Kamalapuram formation, 20 to 40% in Karaikal Shale and 20 to 30% in Niravi formation

Sub-Basalt Imaging Using Locally Generated Converted Waves (PSSP Waves): A Case Study from Indian West Coast

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The major impediments of sub-basalt imaging (PP waves), are weaker transmission of PP energy, while penetrating basalt section and beyond, with very high absorption and scattering of PP waves. These problems are very severe for basaltic layer which has varying degree of undulations with multiple flows and having inter layered sediments. The generation of reverberating energy and unwanted noise trend, interfering with very weak PP sub-basalt reflections further complicate the imaging problem. Basalt has very high velocity compared to surrounding sediment. Hence the point of critical reflection angle is reached at small incidence angle (lesser offset in CMP gather). Because of the high value of Vp/Vs, strong locally generated converted waves from basalt top are noticed while analyzing 2D data with longer offset. The usage of locally generated converted waves, (from interface of sediment and basalt) have also been suggested by various researchers to solve specific problems.

In our study area multi component OBN or OBC data are not available. But we noticed reasonably strong converted waves generating from basalt top in VSP data and explored the option of Sub-basalt imaging using PSSP waves in 2D long offset seismic data. We have performed modelling study. The quantitative, response of one-dimensional model at the well location validates the presence of PSSP waves within the offset range of 2.5 Km to 8 Km. The synthetic gathers, derived from another modeling study along a strike line, have confirmed existence of PSSP waves at an offset 2500 M, onwards, from basalt top along with PP waves.

We could isolate PSSP waves from PP gathers, using a logical imaging process on 2D data (streamer data of 12 Km long cable) and performed time and depth imaging. In this paper we present, time and depth imaging of PSSP waves which provide better reflection continuity below basalt and clear fault trends which could hardly be seen in vintage data of PP image section. Hence PSSP imaging methodology can be attempted as alternative option for focused exploration of sub-basalt reflectors.

Identification of basement depth beneath the Jaisalmer Basin using Magnetotelluric data

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The Jaisalmer Basin, one of the prominent among the four subs-basins of Rajasthan basin in the NW part of India, is a highly prospective sedimentary basin as indicated by oil and gas occurrence made in some parts of the basin. This pericratonic basin, which forms the eastern flank of the Indus shelf, carries thick sediments that chiefly deposited during the Paleozoic-Cenozoic period. Deep drilling and conventional exploration studies failed to map the basement under the basin due to its thick sedimentary column. Therefore, deep penetrating magnetotelluric geophysical tool was chosen to investigate the basement depth and morphology beneath the basin. Two-dimensional resistivity structure derived from MT data at 24 sites along a profile across the Jaisalmer Basin successfully imaged the highly resistive Precambrian basement underlying the sediments. MT model shows considerably deep basement at a depth of ~ 10 km in the western part of the profile and becomes very shallow (100 – 500 m) at the eastern margin of the basin. A sharp change in basement depth from ~10 km to ~4 km is seen at a place west of Jaisalmer. The resistivity structure also characterizes the sedimentary formation that shows range of conductivity varying from high (1-20 Ωm) to moderate (>20 Ωm to <200 Ωm) values. Some of the prominent faults in the study area are also identified in the MT model through their low resistivity nature.

Tomographic Imaging of Hydrocarbon bearing Sub-volcanic Mesozoic Sediments in the Deccan Volcanic Province (DVP) of India

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Imaging of sub-volcanic Mesozoic sediments below the Deccan Trap (basalts) covered regions of India for hydrocarbon exploration is a very challenging problem presently faced by the oil industry, which is also a global problem. The main issue is the poor penetration and significant loss of seismic energy due to scattering, attenuation, absorption and mode-conversion of seismic wave when it encounters a highly heterogeneous and rugose basalt interface. The conventional (near-vertical) seismic data-acquisition, processing and modeling/inversion techniques adopted by the oil industries fail to image the potential hydrocarbon bearing Mesozoic sediments (reservoir) hidden below the impervious basalt. To overcome this challenge of imaging hydrocarbon bearing Mesozoic sediments hidden below the Deccan Trap, I have used robust tomographic imaging of dense wide-angle seismic data acquired in the Deccan Syneclise region of India along the 90 km long Sinor-Valod seismic profile. The tomographic image could able to decipher (< 1.0 km thick) the presence of sub-volcanic low-velocity-layer (LVL) Mesozoic sediments (4.3-4.5 km/s velocity) hidden below the two flows of high-velocity-layer (HVL) Deccan basalts (2-3 km thick and 5.0-5.5 km/s velocity) underlain by the basement (5.9-6.1 km/s velocity) extends down to maximum 3.5 km depth. The tomographic image is further validated and constrained by 2-D elastic finite-difference full-wave modeling using staggered-grid scheme, ray-trace inversion of wide-angle phases from different layers showing top and bottom basalts and pre-stack depth migration (PSDM) with flattening of common-image-gathers (CIGs) of the wide-angle reflection data acquired along the seismic profile. The robustness of the tomographic velocity model derived is assessed through numerous tests like velocity perturbations, Chi-square estimates, RMS traveltime residuals, uncertainty estimates, Ray-density/Hits and series of checkerboard resolution tests.

Optimizing near-surface noise suppression and workflow for depth conversion using high-resolution seismic data

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Seismic data has unique importance among all other geophysical data sets due to the fact that it provides most continuous and higher resolution information of the subsurface structures at shallower and deeper levels. Appropriate processing of such seismic data is essential to produce realistic subsurface image and confident interpretation. De-noising is the heart of processing. Noise type analysis prior to the start of processing plays a key role in choosing the appropriate filters and the de-noising flow. High resolution shallow seismic data becomes a good example for presence of several types of near-surface noise and poses challenge for noise suppression. A perfectly noise suppressed data could produce a clear velocity semblance for estimation of velocity section suitable to generate a best stack and can be used to generate a first guess of interval velocities. Still, the former velocity section does not represent the true velocity of the subsurface and cannot produce reliable depth estimates. The velocity section derived from seismic needs to be calibrated to the sonic log, which is an elongated procedure and still the thin horizons detected on time section are ambiguously projected on depth section.

This study, presents an example of choosing a right de-noising flow to suppress near surface noise, pitfalls of general seismic processing approach, a simple time to depth conversion procedure to produce reliable depth estimates of the horizons of interest and the complications involved in generating depth section. The study is based on the case studies, which utilized high resolution shallow seismic data from Indian coal fields.

Identification of Rock type based Spectral Decomposition analysis of Carbonate reservoir for Hydrocarbon exploration

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Hydrocarbon exploration from carbonate reservoir is challenging task respect to clastic reservoir. However, statistics show that maximum storage of crude oil and gas is in carbonate reservoirs such as about 60% of oil and 40% of gas are present in carbonate rock globally. The objective of this study is to identify the rock type from post-stack seismic data of onshore carbonate reservoir in India. Rock type identification is an essential part of the development of the geological model. This task carries out mostly by petrophysicist with the help of wireline log data or core data. Significant uncertainty comes when the identified rock types from well log or core data correlate with spatial control data such as seismic. The uncertainty level reaches a higher degree in complex geological setup. We have conducted the study in a reservoir where lithology is mixed with carbonate and clastic rock, but the presence of carbonate rock is high than clastic. The spectral decomposition approach provided a holistic view of the reservoir. We have carried out spectral decomposition study for rock typing purposes in our study area with optimized use of Mexican Hat wavelet at 17Hz. The necessary seismic interpretation and its related attribute analysis did not provide a subtle level of information of carbonate reservoir. However, the spectrally decomposed volume has produced an enhanced image of the carbonate reservoir. To correlate seismic acoustic property with petrophysical property post-stack inversion study has carried out. The inversion study has captured the variation of the petrophysical property of a specific rock type based on seismic response. We considered the spectrally decomposed seismic volume as a seismic input parameter of the post-stack inversion study. Three wells are used for the inversion study where one far well is considered as blind well to validate the result. The impedance variation in reservoir formation over absolute acoustic impedance volume has captured the rock types of carbonate reservoir. The impedance variation has obtained through attribute analysis in the carbonate reservoir. Initially, the two broader lithotypes were captured. However, after completion of the study, we have identified four rock types with a finer level of study which is calibrated with far distance placed blind well data. Less uncertainty has produced from this study during the propagation of rock type character away from well. Multiple rock type identification from the seismic property and good correlation with well data have produced a robust geological model in our study area. The outcome of this study has captured the extension of hydrocarbon-bearing facies with suitable petrophysical property.

Denoising of well log signal using multilayer decomposition algorithm for Reservoir Characterization

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Reservoir characterization is an integrated study of well log and seismic data where well log plays a vital role for unboxing the reservoir feature at subtle level. Minor changes of well log data can effect enormously for characterizing the reservoir. Identify of proper well log signal which is representing the reservoir is challenging task. Petrophysicist does necessary well log conditioning before analysis. Still in few cases, noises in well log data are observed even after data conditioning. The current work has focused on denoising of well log data through a multilayer decomposition algorithm. This algorithm leads to wavelet transformation of well log signature. Noise components of well log data suppress the low-frequency part as well as high-frequency part of well log signature from signal which diminishes the vital information substantially of subsurface geology. The filtering procedure is essential step for well log data processing. However this can be applied in particular range of frequency which produces the limitation of Fourier transformation in this study. The wavelet transformation using multilayer decomposition algorithm has the property to reflect the information of the signal in both time domain and frequency domain. The multilayer decomposition process has carried out based on optimized mother wavelet selection. The experiment has shown that the wavelet named 'Sym8' with the threshold rule 'heursure' with 5-level decomposition is useful for the denoising the signal using the wavelet transform of the current field well log data. The comparison study is performed between pre and post denoising analysis of well log data, which shows distinguish changes in the shape of the well log data. The proper denoise well log data will provide errorless measurement of petrophysical and rock physical property of subsurface geology which will contribute to integrated study with image data such as seismic.

Determination of Geomechanical Properties of a Carbonate Reservoir Rock Using Geophysical Well Log data

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Carbonate reservoirs have complex depositional environments and diagenetic processes that control the spatial distribution of their mechanical properties. These changes in the mechanical property of rock can cause challenges in the reservoir's development. Thus the understanding of the geomechanical properties of the reservoir becomes an essential task towards hydrocarbon exploration such as wellbore stability analysis, evaluating rock drillability, estimating reservoir compaction, and surface subsidence. These properties

involve building an earth model for getting a holistic view of geomechanical changes in the reservoir. In this work, we have determined the geomechanical properties of a conventional carbonate reservoir by using geophysical well log data. The properties are estimated using empirical relationships using velocity and density of the reservoir formation derived from well log data. Geomechanical properties of rocks are can also be measured from the core sample; however, we have measured these properties based on well log data inform of dynamic measurement using compressional sonic and density well log data. The core sample-based property which is a static part of the geomechanical property is estimated based on empirical relationship from measured well log-based dynamic property. In this study, we have identified five different geological formations with different lithologies. Two significant carbonate rock type is identified from these five zones through shale rich lithology of the formation. The geomechanical parameters such as Young's modulus (E), bulk modulus (K), shear modulus (G), unconfined compressive strength (UCS) and Poison ratio (V) are estimated in this study. The results show that as we go down the borehole depth, there is a general increasing trend is observed for Young's modulus (K), unconfined compressive strength (UCS), shear modulus (G) and bulk modulus (K) whereas for Poison ratio (V) it is reverse.

Improvement of the wide angle refracted phases using super virtual interferometry (SVI)

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Wide angle refraction tomography is a useful technique to delineate the detail shallow subsurface velocity distribution. Recording of refracted phases at very far offset either require a strong source or we need to increase the signal strength suppressing the random noise. In super-virtual interferometry (SVI) cross-correlation between consecutive receiver responses is carried out to obtain the virtual head-wave arrivals, which are then convolved with the initially recorded traces to get the super-virtual trace. Here, we have generated few synthetic common shot gathers (CSGs) using forward modeling over a three-layer velocity model with a spherical anomaly and a complex five layer velocity model. SVI technique is applied on the gathers which has resulted in an improved SNR of refracted phases at the far offset. We have further tested this technique on a field dataset acquired from IIT Kanpur. In future SVI technique will be applied on the datasets we have recently acquired using remotely acquisition unites (RAUs) and a thumper source from the Himalayan frontal thrust, followed by the tomographic analysis of the datasets. This technique will also have significant implications in delineating velocity-depth models for shallow-land or marine hydrocarbon-bearing reservoirs.

Lithology identification using Wavelet analysis of well log data

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An integrated study between seismic and well log data is always desirable for characterization of sub-surface geology. This approach faces challenges to get fruitful result due to two reasons – 1. quality of dataset and 2. Sub-surface heterogeneity. However good scaled result between seismic and well log response provides robust model of sub-surface geology. The complex geological tectonic setting with mixed lithology is a classic example of most sedimentary onshore basin in India. The wavelet transformation and study-related wavelet on seismic data is standard practice for identification of hydrocarbon-bearing reservoir facies. Our focus of this study emphasizes the signal response of well log data in a chaotic lithology scenario for hydrocarbon-bearing reservoir facies. The method of wavelet analysis involves the decomposition of a signal into different frequency and scale components which provides the multi-scale analysis to demarcate the underlying structural features. The low-frequency component of wavelet response derived from well log data is vital for providing information about lithology variation at a deep level. The study is conducted strating from removing of unwanted noise involved in well log data which leads to suppress the required signal in well log data. The corrected wavelet signal of well log data is used for further transformation with the help of different established wavelets such as Haar, Daubechies, Morlet, and Mexican Hat. Conventional well log data such Gamma-ray (GR), Neutron porosity (NPHI), Density (Rhob) and Resistivity(shallow and deep) are used for this study. The analyzed wavelets of well log data response are decomposed through CWT (Continuous Wavelet Transform) algorithm to capture the detail variation of wavelets. This study is significant for further analysis with seismic data. The variation of decomposed signal of well log data is captured with minor to significant changes of lithogy of the reservoir.

Application of L1 Norm based Total Variation to enhance Seismic Image

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The induction of noise is inevitable while acquiring the Seismic data, and eliminating it is essential to enhance the image quality. At the primary level processing procedures, noise removal is done by various standard filter applications on to the data and applied on to the data of image as a whole. Filters reduce the noise but at the same time smoothens the edges to a greater or lesser degree. Thus in present study, it is proposed to improve the seismic image based on signal fluctuations at local level using the concept of total signal variation minimization. The fluctuations in signal are estimated by the computation of the L1 norm of image gradient.

Minimization of variations in seismic signal due to noise at the local level using L1 norm produces many desirable features, such as better contrast, and also gives control over noise feature disappearances during optimization of L1 norm total variations method. This proposed technique detects the pixels contaminated by noise and preserves formation layer boundaries in the seismic image. The regulation parameter proposed in the method, well suits in handling and effectively removing the non-Gaussian noises. The empirically proposed method produces the image working on noise variations at local level, removing the noise, and enhancing and preserving the formation features.

Application of this techniques reduces the total variation of signal, produces an image, which is a close match to the original seismic image while preserving the boundaries of layers. Apart from visualization of quality improvement of seismic image at micro-visual level, the performance metrics peak signal to noise ratio (PSNR) shows significant improvement. The proposed total variation method with L1 norm is remarkably effective at simultaneously preserving layer boundaries while smoothing away noise.

CYCLONE FANI

Extremely Severe Cyclonic Storm, Fani

The extremely Severe Cyclonic Storm (ESCS) "FANI" crossed Odisha coast close to Puri with maximum sustained wind speed of 175-185 kmph gusting to 205 kmph on 03rd May 2019, after its origin as a low pressure area (LPA) on 25th April. It was one of the rare cyclone as:

- It developed near the equator. Last such genesis near equator over the north Indian Ocean occurred in January, 2005(Cyclone, Hibaru).
- Fani was the most intense cyclone to cross Odisha coast during pre-monsoon season of satellite era(1965 onwards).
- It had one of the longest life(8.5 days) and longest track(3030 km) as it recurved clockwise and moved across coastal Odisha, West Bengal, Bangladesh and Assam.

However, the prediction of Fani was an excellent demonstration of country's scientific capability in forecasting tropical cyclones. India Meteorological Department(IMD) monitored and predicted the cyclogenesis from 18th April onwards, even before the formation of LPA on 25th. Since 25th April, IMD continuously monitored, predicted and updated warnings about its track, intensification, movement and associated adverse weather like heavy rain, wind and storm surge utilising various observations including satellites, ships, buoys, Radars and global and regional numerical models.

During TC Fani, there was almost zero error in landfall point and time forecast about 3 days in advance. It enabled disaster managers to take timely actions to minimise loss of lives to 64. India received appreciation globally including UNDRR and WMO for pin point accuracy in prediction of Fani.

DWR Monitoring of Cyclones: Status and Future Plans with reference to Cyclone FANI

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Cyclones are synoptic scale severe weather systems affecting a large population near the coastal regions of India in Bay of Bengal and Arabian Sea. Strong winds and high storm surge are the main features of the cyclones which create a lot of damage to the property and cause human casualties. For real time monitoring of the severe weather phenomena and cyclones and Disaster Mitigation, 25 no of Doppler Weather Radars (DWR) are installed by India Meteorological Department (IMD). Out of these DWRs, 11 S Band DWRs are installed in the coastal area of India to cover the entire East and West coasts of India. Among these, seven DWRs are installed at Gopalpur, Paradeep, Kolkata, Visakhapatnam, Machilipatnam, Chennai & Karaikal at the East Coast of India to monitor Bay of Bengal region and four at Kochi, Goa, Mumbai and Bhuj at West Coast to cover the Arabian sea. The first DWR of IMD was installed in year 2002 at Chennai and the second DWR at Kolkata in 2003. These radars are "**High Tech**" Doppler facility radars capable of providing "**Three Dimensional Structure of the Cyclone**", **Strong Winds** in the cloud wall region and "Quantitative Precipitation Estimate" associated with the cyclone within the range of 400 km radius. These DWRs are operational round the clock and take observations at every 10 minutes interval. The accuracy of DWR in measuring Eye Diameter is very high along with the Radial Velocity in the wall cloud region of the cyclone. DWR is capable of monitoring the "Landfall time and location" of the cyclone on the coast very precisely. Additionally, more C & X Band DWRs are planned in the NW Himalayan region and NE region of India. Since installation of these DWRs, many Cyclones such as SIDR, OGNI, PHAILIN, HUDHID, GAJA and FANI have been successfully tracked by DWRs at different locations in the coastal region.

IMD has plans for modernization of DWR Network further by augmenting C band DWRs in addition to existing S Band DWRs on the coast. These include four C band DWRs at Port Blair, Mumbai & Ratnagiri in Maharashtra and Balasore in Odisha. Fig 1 & 2 show the observed images by DWR Visakhapatnam before the landfall of the system at Puri (Odisha). The system was very accurately monitored and tracked by DWR.

Extended Range Prediction of Cyclogenesis with Special Reference to Cyclone FANI and Future Plans

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The extensive coastal belt of India is very vulnerable to the deadly storms known as cyclonic storms. The tropical cyclones (Surface wind speed exceeding 33 Kts) over North Indian Ocean (NIO) after crossing the coast cause damages to life and property over many countries of south Asia including India. The combination of a shallow coastal plain along with the world's highestpopulation density coupled with low socio-economic conditions in the region surrounding the BoB has resulted in several land falling cyclones becoming devastating natural disasters.

In India, many studies have demonstrated the usefulness of cyclogenesis forecasts in the short to medium range using global and regional models. However, very recently, the forecasting of genesis of tropical cyclones over NIO using coupled models. Pattanaik et al., (2013) and Pattanaik & Mohapatra (2014) in their recent studies have demonstrated that the forecast of dynamical parameters like the low-level vorticity, low-level circulation, vertical wind shear, ocean heat content etc. are responsible for the genesis of the tropical cyclone and the multi-model ensemble (MME) based extended range forecast (2 to3 weeks) indicate very well the genesis of the system and associated rainfall distribution during cyclone seasons of 2010 and

2011. Similarly, the ERF of cyclogenesis for extremely severe cyclonic storms "Chapala" and "Megh during 2015 were also captured reasonably well.

India Meteorological Department has recently implemented a coupled modeling system based on Climate Forecast System (CFS) coupled model for operational use. This coupled modeling system is run once in a week in the real time with 16 ensemble members for generation of operational ERF products. The model is also run during the hindcast period for 16 years from 2003 to 2018. The cyclogenesis forecast based on operational ERF has shown useful skill up to two weeks on many cyclone cases. With regard to the extended range forecast of genesis of Extremely Severe Cyclonic Storm "FANI" over east-central equatorial Indian Ocean and adjoining southeast Bay of Bengal (26 April – 04 May, 2019) it could able to capture in week 1 forecast, whereas it was not captured properly in the week 2 forecast. It is to be mentioned here that further work is in progress in collaboration with Indian Institute of Tropical Meteorology (IITM), Pune to update the GPP calculation based on additional model varialbles and the initial results have suggested improvement from the earlier GPP considered in the forecast.

Performance of high resolution regional model in prediction of track intensity and landfall of cyclone Fani and future scope

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The extremely server cyclonic storm Fani during pre-monsoon season of 2019 (26 April – 04 May)over Indian region portrayed many distinct features which made it a classic storm for atypical study. The cyclone had traversed nearly 3030 km with one of the longest track spanning nearly 20^o latitude overBay of Bengal. It had initial north-northwesterly movement but exhibited clockwise turning thereafter before landfall. Due to rapid intensification (RI) in between over oceanic area during 29 and 30 May, it evolved from the cyclonic storm (CS) to extremely severe cyclonic storm (ESCS) stage within 30 hours. The cyclone even maintained the cyclonic storm intensity for almost 21 hours evenafter landfall.

In this study, the real-time forecast performance of high-resolution regional coupled HWRF-HYCOM (Atmosphere-Ocean) model had been assessed for the Fani cyclone. The modeling systemwas customized for the cyclones over North Indian Ocean (NIO) basin. Theatmospheric initialfirst guess and time varying lateral boundary conditions were taken from the Global Forecast System (GFS) of India Meteorological Department (IMD) and the HYCOM based Real Time Ocean Forecast System (RTOFS) of Indian National Centre for Ocean Information Services (INCOIS) had provided initialized ocean condition. The regional

GSI (3dVar) data assimilation was also employed to produce improved initial condition after vortex initialization using all available observed storm characteristics.

The model generated 5 days forecasts four times daily at 00, 06, 12 and 18 UTC from 26 April to 03 May 2019. The basic performance evaluation had been completed verifying forecast data with the best track data as made available by Cyclone Warning Division (CWD), IMDalso recognized as Regional Specialized Meteorological Center (RSMC) by WMO for the specified region. Different diagnostic assessment had been carried out to establish the capability of the modeling system in the portrayal of prominent features of the storm. The results showed that the model captured the clockwise recurving of the storm from the cyclonic storm stage but could not indicate the same in the forecasts generated from initial conditions at depression stages of the storm. The model reproduced the RI fairly well but with moderate overestimation. The structural reorientation of the storm during the intensification had been studied and qualitatively compared with the observations.

The positive impact of ocean coupling had only been noticed in the intensity forecasts. It hadalso been observed that the landfall point error along with track error of the model had been reduced significantly while GSI assimilation system has been employed with INSAT-3D satellite radiances.

Forecast of storm tides and associated inland inundation for Fani cyclone using a coupled model for surges, tides and wind waves

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Storm surges associated with tropical cyclone have immense socio-economic impact on coastal communities of India. This has increased the urgency to more accurately predict and forecast storm surges and associated coastal inundation. Keeping this in view, the Indian Institute of Technology Delhi developed a high-resolution grid for the east coast of India, which is used in a coupled ADCIRC+SWAN model. The ADCIRC is a finite-element based, depth-integrated shallow water model that can be used to predict storm surges and for other coastal applications. The SWAN model is a third-generation wave model that computes short-crested wind-generated waves in the coastal regions. The coupled model is employed to simulate the effect of wind waves on storm surges and local tides. Wind and pressure fields are generated using the dynamic wind model of Jelesnianski and Taylor, which make use of cyclone forecasts from Indian Meteorological Department (IMD). The model set up was then used to generate forecast of storm tides and coastal inundation with a lead period of 72h to 24h. Here, we demonstrate the simulations made during Fani cyclone, which crossed the Odisha coast during 26 April - 4 May 2019.The model simulations are also carried out using Land use/Land cover (LULC) data taking best track information from IMD for computation of coastal inundation

Operational Storm Surge and Coastal inundation prediction during ESCS 'Fani'

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The high population density along the Indian coast necessitates a real-time storm surge early warning system. Keeping in view of this, the Earth System Science Organization (ESSO) - Indian National Centre for Ocean Information Services (INCOIS) initiated the Storm Surge Early Warning System (SSEWS) for Indian coasts in collaboration with India Meteorological Department (IMD). INCOIS uses the ADCIRC (Advanced Circulation) model for the storm surge computations. It is a finite-element based, depth-integrated shallow water model that can be used for real-time modeling of storm surges and other coastal hazards such as Tsunamis. As part of real-time forecast, an automated Decision Support System (DSS) was developed on multi technologies with Geographic Information System (GIS) engine. The DSS enabled the visualization, analysis of the inundation and respective surge heights and their associated impact on the coast. The enhanced Jelesnianskii and Taylor dynamic wind model scheme is using for the cyclonic wind forcing.

A 24x7 real-time storm surge and inundation forecasts were issued during Extremely Severe Cyclonic Storm (ESCS) Fani. Fani is the most intense pre-monsoon cyclonic storm that made landfall along the Odisha coast in the month of May. INCOIS closely monitored the associated storm surge and inundation and shared the respective advisories to IMD in real-time for the smooth operations. The hardening and innovative deployment of tide gauges and other ocean observatories helped us for the real-time monitoring and validation of model input and outputs during ESCS Fani. Timely joint advisories of IMD and INCOIS together resulted in successful handling of ESCS Fani.

Recent Advances in the Application of Satellite Observations for Monitoring and Prediction of Tropical Cyclones

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During recent years there have been an increase in the frequency of occurrence and the severity of tropical cyclones over the North Indian ocean basin. For several decades, satellite observations have been playing crucial role in monitoring and prediction of tropical cyclones and conversely, tropical cyclones have remained one of the important considerations in defining the characteristics of the sensors for meteorological satellites. In the recent times there have been considerable advancements in the satellite observations in terms of sensor technology, characterization of satellite sensors (e.g. spectral, spatial and temporal coverage and resolution) and emergence of new trends and techniques in satellite meteorology. Some of the examples of these recent trends include the development of millimeter wave sensors for retrieval of atmospheric thermodynamic profiles and cloud microphysics and Global Navigation Satellite System (GNSS) meteorology for limb sounding and water-vapor content retrieval of atmosphere and reflectometry of the ocean surface. Space-borne observations from microwave scatterometers provide valuable inputs for assimilation in NWP models and are known to have a significant impact on the prediction of tropical cyclone track and intensity. These observations also unambiguously reveal the low level circulation patterns related to cyclogenesis. Researchers are making efforts to design the models functions that may be helpful in the retrieval of very high magnitudes surface winds using scatterometer observations.These observations have specific significance to the tropical cyclones where the extreme atmospheric conditions make it difficult for conventional satellite sensors to yield accurate observations of weather parameters. Microwave satellite observations from sensors like Synthetic Aperture Radar (SAR), which were mainly designed for land applications, also have relevance to the study of tropical cyclones because of their high resolution capability to sense ocean surface winds under heavy cloud cover and precipitation. SAR observations are also potentially useful for assessment of post-landfall flooding and structural damage. This presentation will provide a brief overview of the above developments and highlight some cases of tropical cyclones where the satellite data were helpful in monitoring, prediction and understanding.

Uncertainty in rainfall of cyclone Fani (2019) as evident from analyses and model products

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Most of the TC related research over North Indian Ocean has been focused on improving track and intensity predictions, leaving behind the verification of rainfall products. Rainfall products are available from different sources, ex., TRMM, GPM, and INSAT-3D (IMR and HEM products). These rainfall analyses/observations are useful to verify the numerical guidance of rainfall. The rainfall prediction in 4-5 days' lead will be of utmost importance for disaster mitigation practices. The state-of-the-art numerical models are comparatively better for track and intensity prediction. However, the skill of different models is different for track and intensity prediction. As rainfall depends on track and intensity prediction, there exists uncertainty in rainfall amounts and distribution among the numerical models. It is apparent that the rainfall analyses also show significant uncertainty. Therefore, in this presentation, the rainfall uncertainty associated with a recent TC (Fani, April 2019) in different observational datasets and global/regional models are discussed.

Tropical Cyclone (TC) Fani, an extremely severe cyclonic storm (ESCS) formed over the Bay of Bengal (BoB), is the most intense storm that crossed the Odisha coast during the pre-monsoon season in the past three decades. The maximum sustained wind speed of FANI in its life span is 115 knots. Fani has undergone through a rapid intensification phase from 03 UTC 29 April over west-central BoB. It crossed east coast of India at Puri, Odisha with 100 knots intensity. Fani has traveled almost 3030 km in its lifetime, one of the longest tracks over BoB.

To address the rainfall uncertainty of TC Fani, the TRMM, GPM, IMR, and HEM rainfall products are considered along with the rainfall products from GFS, ECMWF, WRF, and HWRF models. These rainfall analyses are compared with IMD rain gauges (obtained from RSMC report of Fani) to identify the best rainfall analyses. The model's rainfall forecast is then verified with the best rainfall analyses to understand the uncertainty of models in terms of radial profiles, distribution of categorical rainfall and forecast length. The preliminary results indicate that TRMM and GPM rainfall analyses are better than HEM and IMR analyses. IMR overestimates the rainfall for any intensity stage within inner core. Uncertainty in the models will be discussed during the presentation.

Tropical Cyclone Forecasts using High Resolution Global Models: Recent Improvements in India due to Ensemble Forecasting

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The Indian subcontinent, with a total coastline of about 7516 km and almost 40% of the population living within 100 of this coastline, is exposed to nearly 10% of the world's tropical cyclones making it one of the worst cyclone-affected areas. On average, the Bay of Bengal and Arabian Sea are affected by about 5-6 tropical cyclones each year out of which 2 to 3 cyclones may reach the intensity of a severe cyclonic storm. There are two definite seasons of tropical cyclones in the North Indian Ocean (NIO) i.e., from May to June and from September to the middle of December.

In the last decade or so there have been many advances in the field of numerical weather prediction (NWP) which have resulted in an improvement in the forecasts of tropical cyclone tracks. However, even with all the progress, there are still challenges in the accurate prediction of the tropical cyclone tracks and intensity which is mainly due to the limit of predictability of weather by NWP models. Leading NWP centres all over the world now depend on "Ensemble Forecasting" to address the issues of forecast uncertainty. An ensemble weather forecast is a set of forecasts that present the range of future weather possibilities. Multiple simulations are run, each with a slight variation of its initial conditions and with slightly perturbed weather models. These variations represent the inevitable uncertainty in the initial conditions and approximations in the models. They produce a range of possible weather conditions.By generating a range of possible outcomes, the method can show how likely different scenarios are in the days ahead, and how long into the future the forecasts are useful. The smaller the range of predicted outcomes, the 'sharper' the forecast is said to be. Good ensemble forecasts are not just as sharp as possible but also reliable.

Two High resolution Global Ensemble Models have been operational since June 2018 in India. Global Ensemble Forecasting System (GEFS) and NCMRWF Ensemble Prediction System (NEPS) have been used to forecast tracks and intensity of the cyclones. This has resulted in an improvement in these forecasts mainly due to the quantification of the inherent uncertainties associated with the numerical weather prediction systems. The paper compiles and provides an overview of the recent progress in Tropical Cyclone Track and Intensity Forecasts in India.

Performance of Ensemble Prediction System in Predicting Track and Landfall of cyclone "FANI" and future scope

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The GEFS T1534 (~12.5km) ensemble prediction system has been implemented since June 2018 for operational weather forecasting in India. While the deterministic GFS T1534 shows good potential in capturing extreme weather events, the GEFS ensemble system shows a better fidelity in producing probabilistic forecast for high impact weather events. In this study, we discuss the track and landfall probability of extremely severe cycloning storm "FANI" during 26 April – 3 May 2019. During the cyclone "FANI", the GEFS ensemble prediction system predicted the genesis with a longer lead time and also predicted the landfall location and time with longer lead (3 to 4 days) with reasonable accuracy. The ensemble track and strike probability derived from the T1534 (12.5 km) ensemble prediction system, shows coherence and less spread suggesting higher reliability of the forecast. Accurate ensemble prediction system with reasonable probability helped in taking timely measure of shifting people and minimizing the loss of life and properties. The performance of ensemble prediction system and the track and landfall strike probability is found to be particularly accurate in case of cyclone "FANI". Though the ensemble prediction system has generated a reliable forecast, there is a need to improve individual member to improve the landfall time error. The present paper discusses the salient features of the stat-of-he art prediction system based on GEFS T1534.

ANNI TALWANI MEMORIAL GRANT FOR WOMEN RESERACHERS

Dynamics of the Upper Mantle beneath the Northwest Himalaya and Ladakh-Karakoram Zone Based on SKS Splitting

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Abstract:

The northwest Himalaya and Ladakh-Karakoram zone is the western extremity of the Himalaya-Tibet orogen and provides a unique opportunity to study the interaction between the two continental plates. The dynamics of the upper mantle has been studied with the help of teleseismic earthquakes recorded by 29 broadband seismological stations which extend from the Himalayan frontal thrust(HFT) to the Karakoram shear zone(KSZ), covering all the important tectonic features of the Himalayan collision belt and trans Himalaya. We have used core refracted and radially polarized SKS waves to understand the anisotropic structure of the upper mantle. Whenever a polarized light travels through an anisotropic medium, it splits into two rays and the faster ray always orients parallel to the lattice preferred orientation of the mantle minerals. We have obtained 213 good splitting results by analyzing the SKS splitting of 133 teleseismic events. Transverse energy minimization method has been used to obtain the splitting parameters i.e fast polarization direction (FPD) and delay time. The study shows that the FPDs are aligned in the NE- SW direction almost throughout the upper mantle of the Himalayan collision belt up to the Ladakh batholith. However the trend of anisotropy near the KSZ follows a NW-SE trend. Delay time for most of the selected events is above ~1s, confirming a mantle origin for the SKS splitting. The FPDs are parallel to the absolute plate motion of the Indian plate, so we conclude that the upper mantle anisotropy of this region is controlled mostly by the movement of the Indian plate over the asthenosphere, with an exception for a few stations where the effect of lithosphere is overwhelming the splitting, originated from the mantle. The FPDs observed near the KSZ are oriented parallel to the strike of the fault and therefore the anisotropy of this region is the result of a lithosphere scale deformation controlled by the KSZ. Previous studies along this profile show that the crustal anisotropy is following the trend of the tectonic features (NW-SE) which is opposite to the general trend of anisotropy in the upper mantle. So, we could say that the Indian upper mantle is not accommodating the crustal shortening due to India -Asia collision.

1. Introduction

The Himalaya-Tibet orogenyistheresult of India-Asia collisionand convergence since ~70 Ma and provides a unique opportunityto study the interaction between the two continental plates(Molnar and Tapponnier, 1975).The collision and convergence processes created significant topographic variations: crustal shortening and development of large folds and thrusts (Molnar and Tapponnier, 1975). A large part of mantle lithosphere had been consumed since the onset of the collision (van Hinsbergen, 2011). To account for the effects of collision and convergence in the mantle lithosphere several competing mechanisms were proposed that include underthrusting of Indian mantle lithosphere beneath Tibet (Ni and Barazangi

1984; Tilmann et al.,2003; Rai *et al.* 2006), delamination, roll back and breakoff of Indian lithospheric mantle (Razi et al., 2014, Chemenda et al. 2000), lithosphere detachment (Kosarev *et al.* 1999), underplating (Nabelek *et al.* 2009) andsubduction of the Asian lithosphere (Kind *et al.* 2002).Most of these mechanisms and hypothesis are proposed based on studies primarily in the Central and SE part of Tibetan plateau.A number of experiments have been donein the Tibetan Plateau by several international projects (e.g. INDEPTH and Hi-Climb) (Nelson et al., 1996; Huang et al., 2000; Schulte-Pelkum et al., 2005; Nabelek et al., 2009; Chang et al., 2015, 2017). In contrast, limited numbers of seismologicalstudies were carried out in the western part of the Himalaya-Tibet orogeny (e.g. Rai et al., 2006; Oreshin et al., 2008; Hazarika et al., 2013, 2014; Wu et al., 2015). Due to the lack of comprehensive geophysical data, the fate of the underthrusting Indian mantle lithosphere beneath the Himalaya-Karakoram-Tibet is still not clear.The issues related to the depth extent of the Karakoram fault (KF) and crust-mantle coupling/decoupling is still unresolved.

The northwest (NW) Himalaya and Ladakh-Karakoram zone(LKZ) is the western extremity of the Himalaya-Tibet orogenythat bears a signature of the collision process in the form of well-exposed suture zone (Indus Suture), exhumed block that experienced deep subduction (e.g. Tso-Morari Crystalline Complex), a magmatic arc(Ladakh Batholiths, LB) and an intra-continental Karakoram Fault (Honegger et al, 1982).This part of the orogenic system (Fig. 1) covers all the geotectonic units starting from the Himalayan thrust belt system in the south to the Trans Himalayan zone (eastern LKZ) in the north and provides distinctive opportunity to unravel the geodynamic processes that control the structure and evolution of this diverse geological province.

Most of the current issues on geodynamic processes focus on linking the deformation/strain in the crust to deep lithospheric mantle processes (Savage, 1999; Sol et al., 2007; Chang et al., 2017). Seismic anisotropy study is an effective way to address such issues. Shear waves travelling through anistropic media splits two quasi *S*-waves with different wave speeds. The faster *S*-wave manifests the anisotropy direction (ϕ) and time different between fast and slow *S*-waves (δt) quantifies the thickness and strength of anisotropic layer. The lattice-preferred orientation (LPO) of mantle minerals (e.g. olivine), is the major dominating factor in producing anisotropy in the mantle (Crampin, 1984).Shear wave splitting measurements in various continental settings suggest that anisotropy resides in the asthenosphere due to progressive simple shear at the base of the lithosphere (Bormann et al., 1993, 1996; Silver, 1996; Savage 1999). Few studies have suggested fossil anisotropy,which is frozen in a cool lithospheric mantle during some recent tectonic events (Silver and Chan, 1991; Silver 1996). The mantle flow can be controlled by obstacles like lithospheric keels (Bormann et al., 1996; Fouch et al., 2000), cratons (Heintz and Kennett, 2006) or subduction slabs (Margheriti et al., 2003). It is essential to understand the cause of anisotropy to unveil the geodynamic evolution of a region. Moreover, understanding the linkage between crust and mantle deformation is one of the important issues for exploring the linkage between surface geological expressions and underlying deep subsurface processes.

Shear wave splitting of core refracted phases e.g. SKS, SKKS,and PKS is a powerful tool to investigate mantle anisotropy parameters (Silver and Chan, 1991). Significant studies were carried out in the central and eastern part of the Tibetan plateau to characterize deformation in the mantle (e.g. McNamara et al., 1994; Hirn et al., 1995; Sandvol et al., 1997; Wu et al., 2015). However, such studies are extremely limited in the Himalaya(e.g. Singh et al., 2006; 2007; Oreshin et al., 2008; Heintz et al., 2009; Hazarika et al., 2013; Saikia et al., 2018). Investigation of mantle anisotropy is vital for understanding the geodynamic evolution of the Himalaya. In this study, we emphasized mantle anisotropy study along a profile passing across the NW Himalaya and the eastern LKZ based on *SKS* splitting data (Fig. 1). The study provides new information on the seismic anisotropy and mantle strain/deformation beneath a profile extending from the Himalayan Frontal Thrust to the KF, which has significant implication in understanding the geodynamic evolution of the region.

2. Data and Method of Analysis

2.1 Data

The broadband teleseismic data used in the study were recorded by 28broadband seismological stations located along an approximately NE–SW profile passing across the Satluj valley of NW Himalaya and eastern LKZ (Fig. 1). The stations belong to three different networks (viz. Lower Satluj, Upper Satluj/Kinnaurand Ladakh networks) operated by Wadia Institute of Himalayan Geology, Dehradun, India.We have used teleseismic data recorded during 2013-2014 by 8 stations of the lower Satluj (LSAT) network (RMGR, CKKN, GARH, KGHT, SADH, DIGA, RMPR, and TAPR) located from the IGP to the HH.The upper Satluj (USAT) network is comprised of 10 stations (BNJR, SARA, PULG, MUDH, SPLO, KHAB, RACK, LOSR, KAZA, and HURL) that covers part of the Lesser, Higher and Tethyan Himalaya. Data recorded during 2008-2011 by this network is used. There were total 10 stations inthe Ladakh-Karakoram network (TSMR, NDDR, NYOM, MAHE, CHUM, CHUL, MERK, SPAN, PHOB and DRBK) operated during 2009-2011.Data from this network largely samples the ISZ, Ladakh batholiths and KFZ. Each seismological station of the three networks is equipped with similar instrumentation i.e. Trillium-240 sensor and TAURUS data logger of Nanometrics. Time synchronization was done by attaching a GPS antenna with the data logger. The sampling rate of the stations of the USAT network is 100 samples per second (SPS) whereas stations of LSAT and Ladakh network are set at 20 SPS.

We select *SKS* waveforms of teleseismic earthquakes with body wave magnitude M ≥5.5 and epicentral distance : 84^{o}-120^{o}.The SKS phases recorded at distances shorter than 84 are generally not well isolated from *S* arrivals and hence are not used in this study. The information of the earthquakes are obtained from USGS Catalog (http://neic.usgs.gov). About 300 earthquakes were recorded by the seismological stations out of which only 107earthquake data has been selected with higher signal-to-noise ratio (SNR> 4). The SNR is estimated following Bai et al., (2009). Most of the earthquakes are from the Circum-Pacific belt. Some earthquakes, arriving from NW and SW back-azimuths are useful to study azimuthal variations.

2.1 *SKS* Splitting analysis

The *SKS* phase leaves the source as an *S*-wave, converts to *P*-wave in the outer core and, finally, propagates again as an *S*-wave from the core-mantle boundary (CMB) to the surface. The *P* to *S* conversion at CMB causes *SKS* phase to be radially polarized. Therefore, any energy on the transverse component is attributed to the presence of anisotropy. The advantage of using the *SKS* phaseover other shear waves is that it offers good lateral resolution due to its near-vertical incidence at the receiver and is well recorded at larger distances. Furthermore, SV polarization at the CMB neutralizes source effects allowing the presence of energy on the transverse component (SH) to be interpreted as due to anisotropy beneath the receiver site.

The phase arrival times of *SKS* phases are computed using the IASP91 Earth reference model (Kennett et al., 1995).The waveforms are band-pass filtered with corner frequencies of 0.08 and 3.0 Hz to enhance the dominant period of the *SKS* phase and also to reduce background noise. Waveforms covering ~15-25 s time window around the *SKS* phases are extracted from teleseismic waveforms. We have applied transverse component minimization method of Silver and Chan (1991) for analyzing selected *SKS* waveforms and obtained splitting parameters (□□□□*t*) for individual waveforms. This is the most commonly used splitting measurement method for broadband data (Vecsey et al., 2008; Wuestefield et al., 2007;Long and Silver 2009).The method performs a grid search over all possible values of □ and □*t* up to a reasonable maximum delay time value (~4 s) by rotating and performing time-shifts of the horizontal components appropriately. The energy on the corrected transverse component, *Et*(□, □*t*) is measured during the grid search producing a contour plot of transverse component energy for all possible pairs of splitting parameters. Finally, a pair of splitting parameters is obtained that successfully corrects for the effects of anisotropy by minimizing the energy in transverse component and produce linear particle motion after correction for anisotropy. The 95% confidence region (2□□for □, and 2□□□□for □*t*) has been determined following Silver and Chan (1991). The quality of results is accessed based on minimum energy on transverse component and the linearization of elliptical particle motion observed after correction for anisotropy. The accuracy of the resulting splitting parameters depends on (i) correct estimation of the arrival time of *SKS* phase, (ii) signal-to-noise ratio of *SKS* phases and more importantly (iii) fast or slow polarization direction should not coincide with the back azimuth direction (Bai et al. 2009).

3. Results & Conclusions

The upper mantle anisotropy beneath the northwest Himalaya and eastern part of the Ladakh-Karakoram zone has been investigated based on shear-wave splitting of core-refracted *SKS* waveforms recorded at 28 seismological stations. Based on this study the following conclusions are made:

(1) The study reveals considerable strength of anisotropy (with □t ~0.75-2.96 s) originated primarily in the upper mantle.

(2) The fast polarization direction (FPD) of anisotropy in the frontal part of the Himalaya are parallel or sub parallel to the Himalayan arc suggesting effect of localized lithospheric deformation fabric, caused by Indian-Asia collision.

(3) The FPDs at most of the stations located over the Lesser, Higher and Tethyan Himalaya follows Absolute Plate Motion (APM) direction of the Indian plate suggesting dominance of asthenospheric flow in aligning minerals in the sheared lithosphere-asthenosphere boundary layer.

(4) Complex pattern of anisotropy is observed in the Indus Suture Zone. This complex anisotropy may be combined effects due to shearing of Indian plate over asthenosphere and lithospheric deformation due to India–Asia collision.

(5) The FPDs in the KFZ are parallel or sub-parallel to the strike of the Karakoram fault. It can be envisaged that the strike-slip or transpressional deformation in the KF extends up to the lithospheric mantle accommodating the India-Asia collision and facilitating extrusion in the Tibetan Plateau.

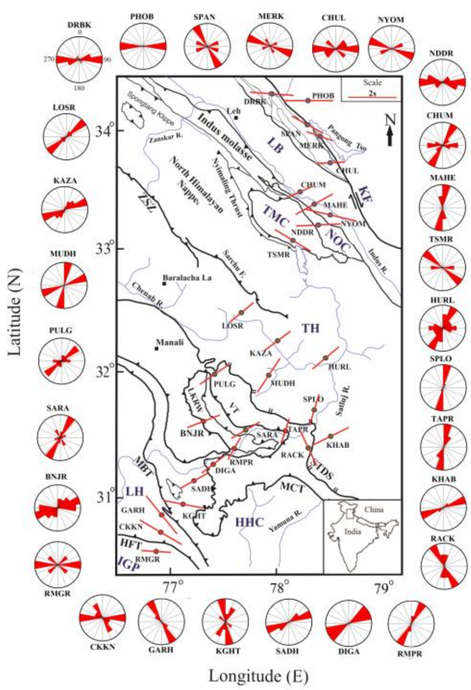

Figure 1. Simplified tectonic map of northwest Himalaya and Ladakh-Karakoram zone modified after modified after Mahéo et al.,2004; Epard and Steck, 2008; Hazarika et al., 2014. Predominant Fast Polarization Direction (FPD) measurements obtained from 28 seismological stations (red dots) are represented. The orientation and length of the bar plotted over the red dots indicate predominant FPDs and splitting delay time (□*t*), respectively. The inset at the right bottom shows map of India where the study area is marked by a rectangle. The FPDs computed at each stations are presented in the form of rose diagram. Longest pie slice is for the most frequent direction of anisotropy for that corresponding station. Bin size is 30 for each of the plots.

Validation of LAI (Lithosphere Atmosphere Ionosphere) Coupling Theory of Seismo-Electromagnetic Phenomenon of Earthquake Precursors

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Abstract

The geophysical shell scheme (lithosphere, air, ionosphere) is regarded an over - the-counter complicated dissipating nonlinear system in which earthquake planning might be viewed as an autonomous method which leads to a critical state of the structure. This article brings together latest scientific progress in knowing the issue of seismo-ionospheric connections. The primary fields of modern studies are La (Lithosphere) Ionosphere Coupling, major ionosphere variants and the statistical characteristics that enable the use within practice. This study relies on three key fields: the verification of the La (Lithosphere Atmosphere) Ionosphere couplement. The layout model in this studyThe geophysical shell-system is regarded an affordable, non-linear complex system with dissipation in which earthquakes can be regarded as an autonomous technique which contributes to the critical status of the system. The system is based on an earthquake-planning system. This article presents the most recent science in the knowledge of the seismo-ionosphere bonding problem.Present study relies on three primary fields: the Validation of La (Lithosphere Atmosphere) Ionosphere Coupling, the primary phenomenological characteristics of earthquake-related ionospheric differences, and their statistical characteristics that enable them to be used in practice. The concept template for this model is a walkways the traditional earthquake and ionospheric precursors. Throughout this respect, the scaling law and the relationship between the geochemical precursors, the anomalous electrical field engaged in ionospheric variations initiated and the ionospheric irregularities themselves are major factors in the earthquake readiness zone. Confirmed Seismo-Electromagnetic Phenomenon Theory of Earthquake Precursors ionospheric forerunner sesimo and the statistical parameters are used to create a method for information processing and other statistical processing methods which can be used in earthquake prediction in the temporary manner.lastly, for national and international surveillance and feasible short-term forecast of damaging earthquakes, a feasible scheme of ground-based readings and satellite monitoring is suggested.

Keywords: Earthquake, ionosphere , seismoelectromagnetic,LAIC

1. Introduction

Many earthquake accounts have been followed by unusual events incorporating magnetism and electricity since the early days. These results, however, were subject to a surplus of precise measurements and 30 measures. It is not the case nowadays as a range of separate trials in seismic areas weighing many different parameters are well equipped. In fact, 32 telescopes can be viewed from infrared up to 33 radio waves in a broad range of frequencies. The parameters of these satellites can be contrasted with land and satellite information around the earth.

Simultaneously, designs have been created to illustrate this connection between the 37 lithosphere-atmosphere-ionosphere. There is plenty of proof that the ionosphere could function as an indication of the pre-earthquake procedures in the Earth's lithosphere. One of the significant instructions of present research is to study the alteration of the ionosphere before seismic events. It resides on the grounds of knowing the procedures in the structure of lithosphere-ionosphere, which ultimately implies the option of predicting hurricanes, in specific through ionospheric surveillance. The issue of acknowledging the ionospheric disruption induced by earthquake planning procedures on the backdrop of many other nature disasters becomes very genuine in this respect. It is understood that the ionosphere is a very variable environment where the features of its parameters are measured both regularly and irregularly.

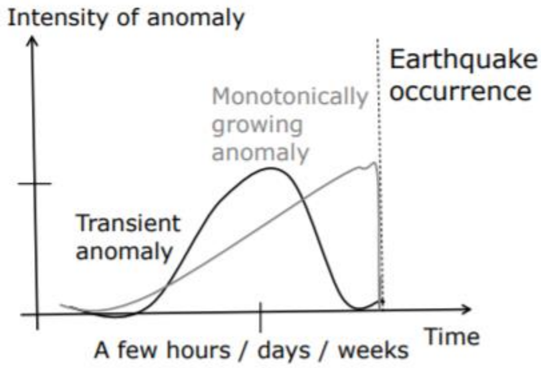
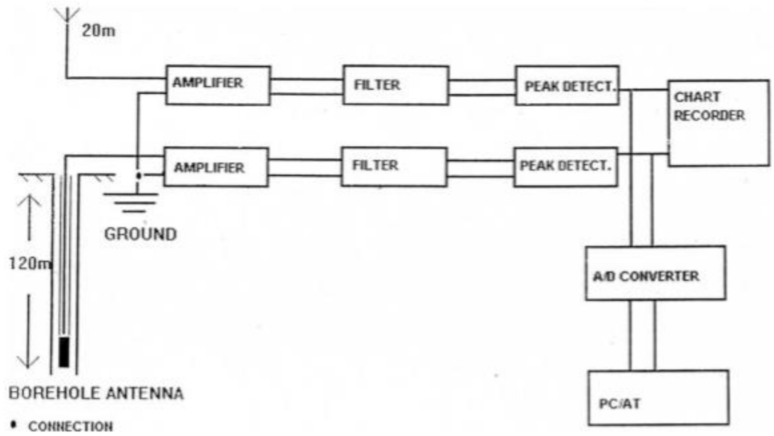


Fig. 1 [10] Two types of time-series of reported precursors

Many factors, including wind and geomagnetic operations, meteorological occurrences and anthropogenic sources, affect the global state of the ionosphere. It also encounters usual variants in the season, day-to-day and diurnal. It is therefore very essential to obviously define and distinguish the ionospheric stresses connected with seismic activity from the regular space weather differences. For the periods of low solar and geomagnetic activity, most, if not all, case studies and statistical analysis were conducted.Here we attempt to differentiate the pre-seismic TEC changes from the impacts of the magnetic storm using the GPS measurements and the numerical UAM calculations Enhanced radon ionisation before earthquakes is a small part of the full balance of ionisation, and a short-term earthquake prediction is used to identify the natural processes initiated by earthquake preparation The Lithosphere – Atmosphere – ionospheric couplage (LAIC, Lithosphere Atmosphere – Ionosphere Coupling) System described in this paper provides a comprehensive understanding of processes involved for creation of anomalous land and ionospheric occurrences before serious storms.According to author, a sequence of essential laboratory outcomes and most exciting theory of the seismo-electromagnetic phenomenon of earthquakes are presented some days before the earthquakes are examined. precursors of lithosphere-ionosphere combination designs. Earthquake phenomena that happen following earthquakes have less relevance. First, some significant laboratory findings are analyzed in the paper, which demonstrate the connections between the lithosphere and the ionosphere. The seismo-electromagnetic hypothesis of an earthquake precursor designs lithosphere-ionosphere coupled with a sequence of fundamental laboratory outcomes a couple of days ago according to the views of the writers, before earthquakes are examined in the current job.

Advance coupling mechanisms for lithosphere-atmosphere-ionosphere Earthquake Precursors

Now, the physical bonding processes at seismic activity will be evaluated in the lithosphere-atmosphere-ionosphere scheme.



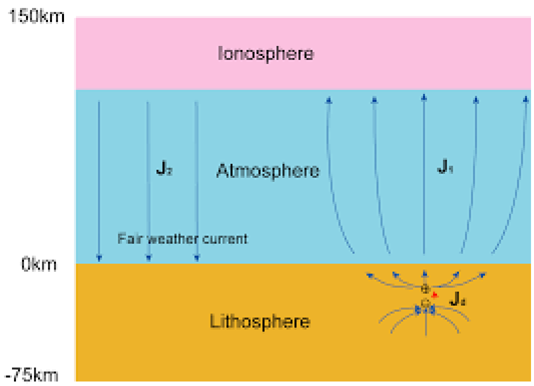


Figure 3: Lithosphere Dynamo

Proposed Methodology

In the current job, an effort is produced to clarify and assess the most exciting and Earthquake Precursor Seismo-Electromagnetic Phenomenon Theory of significant designs of lithosphere-atmosphere-ionosphere bonding prior to earthquakes. In some designs it is presumed that natural acoustic and acoustic-gravity bubbles are enthusiastic and propagate through the atmosphere to ionospheric levels in the near-Earth atmosphere above the region of earthquake preparing where they trigger disturbances in the electrical field and shifts in the density of the loaded ions.Other designs indicate that ionospheric fluctuations are the result of changes in electrical areas and flows induced by lithosphere or near-Earth atmospheric electrical procedures.The characteristic spatial scales of ionospheric events before an earthquake are between 200-300 km and a few thousand km, and the characteristic time scales are between a few minutes and a few day.. It is impossible to take into account only one of the models explained and to neglect any model.The true lituosphere-ionosphere coupling may be the result of the operation of several different mechanisms, the combination procedures in the atmosphere-thermosphere-ionosphere scheme receive more and more interest from the science society. Among the many fresh subjects that are constantly debated in scientists, the function of the worldwide electric circuit in ionosphere variation is small; the effects of galactic solar beams on the worldwide visibility of a satellite (black and red waves) and the globe cloud effects. One of the latest topics is the locking scheme which causes a few week / day / hour before moderate / strong / miga-earthquake events anomalies in diverse almost-earth buildings starting with the boundary wind area into our planet's magnetosphere.Furthermore, many of the different standard and anthropogenic occurrences were recent demonstrated to have similar behaviors and impacts on atmosphere and ionosphere. For instance, radioactive pollution from atomic power plants during disasters (Three-Mile Island, Chernobyl, Fukushima) produces heat anomalies comparable to those recorded from satellites before earthquakes through the Ion Induced Nucleation (IIN).

At the same time EM events (electromagnetic current changes in the atmosphere, variation of ionosphere strands) indicate a connection between the heat atmosphere and the atmosphere and ionosphere EM events. The bonding processes were suggested by several communities of researchers. The Lithosphere-Atmosphere-Ionosphere Coupling model was one of those efforts widespread. However, many parts of the model have a qualitative nature and do not allow quantitative modeling to take place in different geophysical conditions.This scenario obviously shows the separate absence of understanding about the binding of the atmosphere-ionosphere, particularly when we imagine the impacts from below on the ionosphere. The existing Global Electric Circuit concept only asserts the presence of a potential difference between the floor and the ionosphere but does not provide any tools to assess how the modifications in the electrical characteristics of the near-ground atmosphere fluid will be reflected in the ionosphere. However, the previous findings have been created during the last century of research of the bonding procedures:Ionization performs an significant part in many natural procedures, such as stimuli of cloud exposure by galactic cosmic rays, creation of short-term wind precursors, hurricane and typhoon patterns, generating radio wave propagation anomalies in the close ground wave guide. At least three primary causes of ionization should be regarded: normal soil radioactivity, galactic and solar cosmic rays, thunderstorm discharges, anthropogenic radioactive emissions (atomic experiments, radioactive holes and nuclear power plant accidents, etc.). Ionic induced nucleation as a catalytic exothermic process performs a important part in the combination of ambient heat and electrical theory.

Combining the declared absence of understanding in the binding mechanisms and proven information, we can formulate the primary objectives of the current initiative: to assess ionization procedures in the close surface environment and troposphere to assess the dependencies of major environmental components from the ionization frequency and weather circumstances. Considering the responses of elevated plasmachemistry after main ion creation and ion cluster formation and their temporal and unique dynamics. Considering the implications of Ion Induced Nucleation–development of big hydrated clusters and complexes, i.e. heat impacts, meteorological impacts, and atmospheric electrical impactsTo estimate the energy effectiveness of intensive ionization in formation of the anomalous fluxes of the latent heat and infrared emission .To assess the impacts of intense ionization and consequent ion-driven nucleation of electrical characteristics of the boundary layer of the atmosphere. To produce a full model for the atmosphere and ionosphere, bringing into consideration differences in the thermal characteristics of the boundary layer.The accomplishing of the goals mentioned above would lead to creation of the complex atmosphere-ionosphere model, which will unite existing separately the Global Electric Circuit model and different ionospheric models. To assess the energy efficiency of efficient ionization in the creation of latent heat and infrared emission anomalous fluxes. To assess the impacts of extensive ionization and consequent ion-induced nucleation of the electrical characteristics of the border surface of the environment. To generate the full atmosphere-ionosphere system having into account the differences of the electrical characteristics of the border surface of the environment.It would be the true advance in our understanding of the atmosphere-ionosphere system's bonding processes.

At around the same period, considering the global effects of physical radioactivity and cosmic galactic rays, the approach of thermodynamics throughout the atmosphere will also be created. To meet this scientific challenge, we greeted the many other significant experts involved in the proposed model development and verification plan. The practice of the team would be engineering in two respects: one theoretical modeling and the other is the validation data evaluation of acknowledged typical ionization effects cases using ground and satellite sensors. The extended satellite databases and different kinds of ground results is being used as a baseline as opposed to the theoretical modeling.

Most of the above-mentioned effects were registered by specific spacecrafts and ground-based studies. With the help of the LAIC model, we have sensible reasons.The next move now requires to be taken by the scientific society–to quantify the impacts outlined in the manner of first major designs and to check these designs using ground-based and aerial surveillance of ionization impacts due to anomalous variation of air and ionosphere. In this document, we concentrate on journals that meet the previous identifying requirements: First, quantitatively defied is a applicant of the forerunner, namely anomaly.Second Two anomalies and earthquake time series are built within set thresholds such as minimum magnitude, region, and lead time. Third To achieve a statistical correlation, a statistical process that involves four relationships that consider all earthquake combinations-no earthquake versus anomaly and no anomalies are implemented, e. G. Correlation of phi. Forth Consistency is maintained for correlations under different thresholds. Fifth Before big earthquakes, big anomalies occur.

Results Analysis

Seismologists have developed earthquake computer models and the subsequent floor tremor. The films include opinions of maps as well as thorough opinions of perspectives. The colours show the shaking's maximum strength at each place so far. For a more comprehensive explanation of the colour system, see Explanation of Colors. From the view, a ratio of 1000 multiplied the deformation of the floor to show how the ground flows when the seismic waves

propagate through the floor. There are two motions for the films. Normal range films (960x540) typically have a volume of less than 20 MB. Usually the HD (1920x1080) variants are 30 MB or zip more in size and showed at its best high resolution displays.
Overall, due to the rare events of the big event, it is hard to demonstrate a statistical connection between the forerunner and the big event. In specific, a range of much bigger earthquakes are needed to demonstrate the causation needed by the identity requirements 5, which, according to the Gutenberg-Richter relationship, are also fewer. Furthermore, it may be undetectable the occurrences of earthquakes in the ocean and far from the place of earth surveillance. Supposing that on the ground-based facility a range of precursors are detectable, it could require a thousand years of long-term. These possible precursors of the atmosphere-ionosphere last for a few hours to a few days Ahead of the mainshock. Some of the precursors are therefore detectable by satellites because the satellite's orbit testing is less than the precursor length.

In addition, satellite monitoring may contain the entire region of effective seismicity when satellite inclination exceeds 60 degrees. Here we concentrate on the pre-seismic strength reduction of VLF electromagnetic waves that is noted by the sun-synchronous DEMETER satellite during the night. The events happened within 500 km of epicentral distance from either the sub-satellite stage inside 4 hours of the mainshock with far more than magnitude 5.0.Within 500 km of epicentral distance from either the sub-satellite point, the occurrences occurred within 4 hours of the mainshock with much more than 5.0 magnitude. It is possible to detect over 100 events with such a size of over 5.5 of this orbit all through the 2.5-year operation. If three dedicated and low-cost nano-satellites are simultaneously introduced to recognize this precursor as a piggyback, an increase in orbit phases due to satellite changes expands the number of observed events to contribute to statistical analysis. In other cases, the comparison between results of more than 6 and 5 required by identification criteria 5 states the cause between the incident and the anom recognized

Conclusion

A critical assessment of current laboratory information and theoretical designs regarding the binding of lithosphere atmosphere-ionosphere during preparing moments for the earthquake is provided in the evaluation. Up to now, there is no usually agreed theoretical hypothesis that would allow the findings of ionospheric storms that occur a few days before even severe earthquakes to be interpreted. At the other hand, there were no mistakes in the various recent hypotheses-not The assumption of the creation of acoustic-gravity bubbles, the theory of the alteration of electrical conductivity in the near-Earth setting by radon injection, the theory of the creation of the Earth ionosphere and not the electromagnetic hypothesis which lithospheric changes of the electro-magnetic field are transferred directly onto the ionosphere though the atmosphere. It must therefore be stated that, in reality, separate procedures clearly act in principle, and only a few of them are mentioned in this assessment.

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On degeneration of the Shafat glacier (1971-2017), western Himalaya and plausible controls

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Introduction

Possessing a unique geometry, every glacier behave heterogeneously towards the climatic conditions. Their comprehensive behavior, is thus, necessary to be evaluated in detail to develop a complete picture of glacier response. Remote location, rugged terrain, problems related to logistics and inhospitable climatic conditions limit the continuous monitoring of these glaciers. Therefore, remote sensing can be used as a best tool to compliment field studies spatially and temporally. Comprehensive glaciological studies, considering multiple glacier parameters are meager in the Himalayan region, particularly the Ladakh Himalaya. Therefore, this study is an attempt to understand the multidimensional variability of the Shafat glacier parameters (area/length/ debris cover/ surface ice velocity (SIV) / surface elevation change (SEC)), for the period 1971-2017 and correlate them to the climatic (temperature and precipitation) and non-climatic (debris cover, topography, glacial lakes) variables. Shafat is a north-south trending glacier in the Suru sub-basin, J & K, India (Fig 1a). Emerging from the Nun-Kun group of mountain peaks, the glacier has an altitude range of 4110-6736 masl and an average slope of 24.5°. It is a partially debris covered glacier, with the total debris coverage of 25% (2017).

Dataset and Methodology

To accomplish our objectives, we have manually delineated the glacier and debris cover boundaries for the period 1971-2017 using high-medium resolution satellite imageries of Corona-KH4B (1971), Landsat ETM^{+} (2000) and Sentinel multispectral imagery (2017). State of art methods have been used for estimation of glacier parameters and associated uncertainties. The parallel line (Fig 1b) and energy balance approaches were utilized for estimation of frontal retreat (Shukla and Qadir, 2016) and debris thickness (Schauwecker et al., 2015), respectively. SIV was assessed using the sub-pixel image correlation technique (Leprince et al., 2007) using Landsat series sensors: TM/ETM^{+}/OLI (1993/94, 1999/2000 & 2016/17). SEC was computed from the Geodetic method (digital elevation model (DEM) differencing) using Advanced spaceborne thermal emission and reflection radiometer (ASTER) DMO product (2017) and Shuttle radar topography mission (SRTM) DEM as reference.

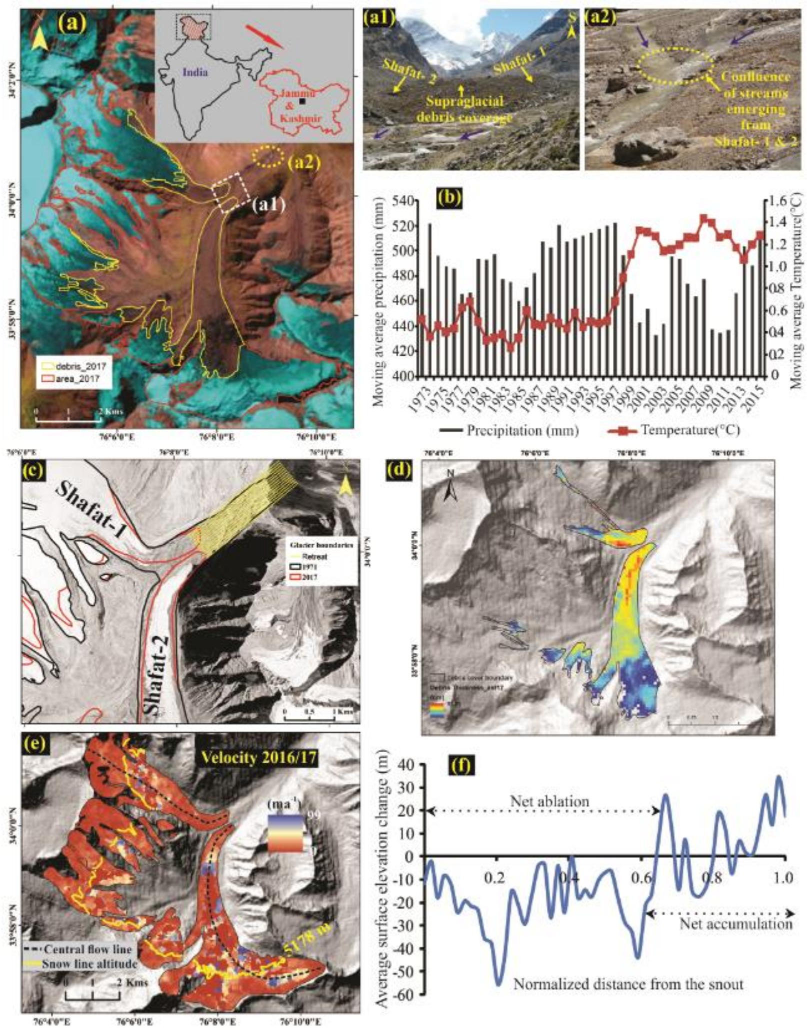

Figure 1. (a) Location map of the study area. The Shafat glacier (snow/ice and debris cover) boundary overlain on the Landsat Optical land imager (OLI) imagery acquired on 19 Sep 2017 using false color composite (FCC: R: Short wave infrared (SWIR), G: Near infrared (NIR), B: Red. (a1) & (a2) Field photographs (2017) depicting the snout of the Shafat glacier and confluence of meltwater streams from two tributary glaciers (Shafat-1 & Shafat-2), respectively. (b) 5 years moving average of the mean annual precipitation (mm) and temperature (°C) recorded for the glaciated valley obtained from high resolution climate research unit (CRU) time series (TS) 4.01 during the period 1971-2017. (c) Glacier boundaries (1971 & 2017) overlain on the declassified Corona KH-4B imagery of 21 Sep 1971 showing frontal retreat of the glacier during the period 1971-2017. (d) Variations in the debris thickness of the Shafat glacier derived from ASTER 2017 imagery using modified energy balance approach.(e) Spatial variations in the surface ice velocity of the Shafat glacier for the image pairs: 2016/17. (f) Spatial variability in the surface elevation estimated using the geodetic method for the period 2000-2017.

The uncertainty associated with the glacier parameters were assessed using standard methods (Paul et al., 2017).

Results and Discussion. Results reveal a degenerative pattern of the Shafat glacier during 1971-2017 period. The glacier area has reduced by 8% from 34.6 ±0.13 (1971) to 31.9 ±1.6 (2017) km^2, with an average growth in the supraglacial debris (SGD) by 1.52 times. Meanwhile, the glacier has retreated by an overall 438 ±32 m (retreat rate of 26 ±0.7 ma^{-1}), with an average debris thickness of 10.4 cm in 2017 (Fig 1c,d). Besides, the phenomenon of glacier disintegration has also been observed post 2000, in which the main trunk separated into two glacierets, i.e., Shafat-1 and Shafat-2 (Fig. 1 a1, a2). The differential distribution of SGD might have facilitated the enhanced degeneration, resulting into the glacier disintegration. Moreover, the overall shrinkage and retreat of the Shafat glacier is synchronous with an increase in minimum (T_{min}) and maximum (T_{max}) temperature by 38% and 6%, respectively during the period 1971-2017 (Fig. 1d). The annual average precipitation has also increased during this period, however, insignificantly (1%). The glacier has also slowed down by an average 5% from 10.33 ±3.68 (1993/94) to 9.83 ±1.83 ma^{-1} (2016/17) (Fig. 1e). However, an increase in glacier velocity has been observed during 1993-2000 (18%), with a pronounced decrease (19%) thereafter from 2000-2017. The decline in glacier velocity during 2000-2017 is accompanied by surface lowering of nearly 0.82 ±0.15 $m.w.e.a^{-1}$ during the period 2000-2017 (Fig. 1f). The debris accumulation was more (65%) during 2000-2017 as compared to that during 1971-2000 (54%). Also, glacial lakes of variable sizes (0.003 to 0.03 km^2) have formed after 2000. These results indicate towards the negative health of the Shafat glacier, with an enhanced degeneration post 2000. The prime driver for overall glacier response can, thus, be ascribed to the climatic conditions prevailing in the glaciated valley. However, the pronounced glacier changes in the last two decades (2000-2017) may be attributed to the differential distribution of debris coverage and associated glacial lakes.

Keywords: Shafat glacier, Suru sub-basin, glacier response, climate change

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Constraints of crustal anisotropy behaviors from Silghat, Northeast India from the analysis of shear wave splitting effects

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Abstract

Crustal anisotropy is explored by means of shear-wave splitting of local earthquakes beneath the Silghat region that occupies the north-western part of the Mikir hills near the Assam valley of Northeast India. An active strike-slip fault i.e. Kopili Fault orienting in NW-SE direction separates the Mikir Hills from Shillong Plateau, adding complexity in geodynamics and seismicity in the North-eastern province of India. Thus, we made an effort to understand crustal anisotropy beneath Silghat. Splitting of S-waves can be analyzed by aid of the splitting parameters- the Fast polarization direction (Φ) and Delay Time (δt) between the Fast and Slow axis, deduced by using an automated cross-correlation technique following certain criteria in choosing the good quality S-wave arrival without being contaminated with other refracted phases. Here, we analyzed local shallow focus earthquake events resulting a little variation of delay times, signifying the presence of moderate crack density in the study area. The Φ at most of the cases are aligned nearly parallel to the strike of the Kopili fault and in some cases, Φ is parallel to major lineaments traversing the region in NE-SW and E-W orientations revealing the FPD of this region as parallel to the local tectonic structures and stress field. Hence, the reason behind the seismic anisotropy in crust is predominantly due to the aligned cracks, micro-cracks and pore spaces developed from the local stresses and in some extent the consequences of tectonic forces governed by the strike-slip mechanisms in the study area.

Keywords: Seismic anisotropy, Shear wave splitting, Northeast India, cross-correlation technique, direct S-waves

INTRODUCTION

Seismic anisotropy is a powerful tool to decipher the deformation pattern of any tectonic region from a stable region and explains the focal mechanism of that region by splitting into two orthogonally polarized waves with different velocities, depicted by the two splitting parameters i.e. the Fast Polarization Direction (FPD) (Φ) and the delay time (δt) between the fast and slow shear waves within an anisotropic medium that existing basically in the crust and upper mantle. The crustal anisotropy as a consequence of shear wave splitting (SWS), induced due to the shape preferred orientation (SPO) of the layering mineral (such as fluid filled cracks and micro-cracks) with contrast to their elastic properties (*Savage et al.2010)*. The Northeastern region (NER) of India is the most varied region possessing a complex geodynamics since late cretaceous (*Evans, 1964*). The Mikir hills is separated from the Shillong plateau by NW-SE trending seismically active strike-slip fault i.e. Kopili fault, that had produced two large intraplate earthquakes in 1869 and 1943 (M_w>7). The seismo-tectonic study *(Angelier and Baruah, 2009)* has been carried out to understand the probability of large scale earthquakes and stress developed in this region. Our prime efforts are made to characterize the splitting parameters beneath Silghat (SIL) station, located at the northern end of Mikir hills nearby the Assam valley to decipher the present day plate motions and characteristics stress patterns in this particular area.

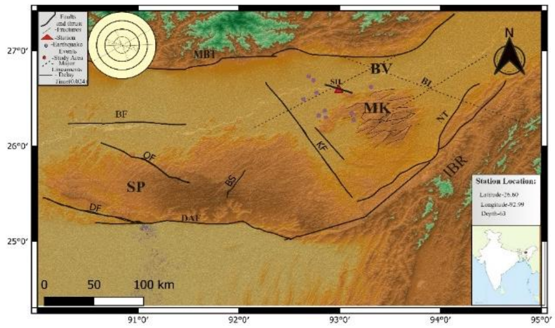

Fig-1: Tectonic map of the study area, Silghat (SIL) showing faults and lineaments along with the station location and earthquake events. Inset India map in the right bottom corner shows the area marked by red dot; Inset spoke diagram in the upper left corner plotted between the Delay time (0.01-0.04s) vs FPD for individual results. The average delay time and FPD are represented on the station as an inverted triangle. MBT- Main Boundary Thrust; BV- Brahmaputra Valley; BL- Bomdila Lineament; NT- Naga Thrust; IBR- Indo-Burman Range; MK- Mikir Hills; KF- Kopili Fault; BS- Barapani Shear; DAF- Dauki Fault; DF- Dapsi Fault; SP- Shillong Plateau; OF- Oldham Fault; BF- Brahmaputra Fault

Data and Methodology

The earthquake data of Silghat broadband seismic station are acquired by CSIR-NEIST-Jorhat, Assam from the year 2012-13. The seismograms of epicentral distance ≤ 100km and depth ≤ 45km are considered to ensure crustal anisotropy due to SWS. The magnitude duration of 1.5-3.8 M_D are recorded revealing the shallow focus earthquake confined within the region (Annual Seismological Bulletin, NEWSN).

We have adopted the cross-correlation technique for SWS by the means of rotation by 1^o of horizontal components (EW and NS components) through 180^o azimuthal coverage to find the best possible correlation above 80% (Fig. 2). In this continuation a band-pass Butterworth fourth Order is used for all the waveforms to improve the signal-to noise ratio (SNR) with a threshold SNR of 4. They are thoroughly scrutinized by the following criteria for analysis of good quality shear wave for crustal anisotropy without being contaminated by other reflected converted phases:

i. The incident angle of S-waves must be ≤45° *(Nutlli, 1961 and Piccinni et al., 2013).*
ii. The amplitude ratio of S and P waves must be greater than 4; each event is examined.
iii. The arrival time difference between the P and S waves must be less than 10 sec.

Results

The SWS gives the splitting parameters of 10 events, only those seismograms are retained which qualify the above mentioned criteria and of minimum error of FPD and delay time. In the study area the average FPD is ~108° with an average Delay time of 0.024 second.

EVENT ID	EVLA	EVLO	EVDP	FPD	Error in ϕ	Delay Time	Error in δt	X-Correlation	BAZ
2012.09.24-07.04.20.SIL.	26.32	92.79	37.6	89	20	0.04	0.02	0.9131	213
2013.01.31-12.45.49.SIL.	26.37	92.85	44.5	113	19.3	0.02	0.024	0.9929	209
2013.03.17-11.15.49.SIL.	26.69	92.74	36	100	20	0.02	0.021	0.933	292
2013.03.18-23.15.49.SIL.	26.62	93.31	34.5	107	15	0.02	0.007	0.994	86
2013.05.21-15.46.30.SIL.	26.27	93.14	43.7	156	20	0.02	0.017	0.9153	158
2013.06.05-16.46.30.SIL.	26.49	92.64	40.8	60	19	0.04	0.017	0.9755	251
2013.06.12-10.16.30.SIL.	26.56	92.77	34.5	161	19	0.02	0.017	0.9049	259
2013.06.18-03.46.30.SIL.	26.3	92.86	45	58	14	0.03	0.011	0.9691	201
2013.08.01-14.16.30.SIL.	26.34	93.12	42.7	141	19.6	0.01	0.015	0.8958	156
2013.10.05-17.46.30.SIL.	26.73	92.69	40.6	91	9.4	0.02	0.016	0.9867	296

Table-1: *List of events showing individual splitting parameters ϕ and δt. EVLO-Event longitude; EVLA-Event latitude; EVDP-Event depth; FPD-Fast polarization direction; BAZ-Backazimuth.*

Discussion and Conclusion:

From the splitting parameters, it is inferred that the fast polarization directions (FPD) of the study area is orienting in NW-SE direction which is nearly parallel to the active strike-slip Kopili fault *(Bora et al.,2018)* and some are parallel to the strike of the major lineaments traversing the study area (*Fig.1*). The minor variation in delay time shows the area is encountered with moderate crack density. Hence, Seismic crustal anisotropy in this region is predominantly due to aligned fractures generated by local stresses and in some extent the consequences of tectonic forces governed by the strike-slip mechanisms in the study area.

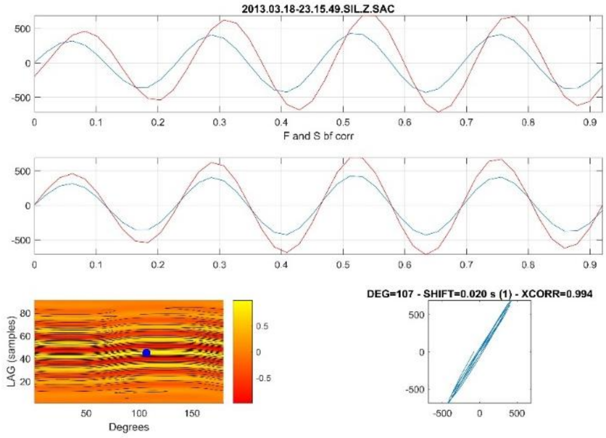

Fig-2: An example of SWS of the earthquake event ID 2013.03.18-23.15.49.SIL.by using Cross-correlation technique before and after horizontal rotation showing maximum correlation-coefficient of 99% with a delay time of 0.020s and FPD 107°.

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Scapolite and Tremolite occurrences surrounding the Cu mineralisation in the metasediments of the SE extension of Khetri Cu belt, North Delhi Fold Belt.

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Abstract

The presence of Scapolite and Tremolite minerals have been recorded from the metapelitic units of the Ajabgarh Group of rocks towards the South eastern fringe of the Khetri copper belt. From the field and petrographic evidences we can see that the Scapolite mineralizations are closely associated with the epigenetic Copper mineralisation whereas the tremolite mineralization seems to have not much relation to it. This may be due to the activity of the Cl^- anion, as it an essential component for the formation of Scapolite, acts as carrier for the basemetal mineralisation i.e. a ligand. The chlorine might have migrated from an external source or it may have been a part of the country rocks. But an external source is not a possibility in this area as there is no evidence of an evaporate deposit nearby. The close proximity of Carbonate veins indicates the movement and loss of volatiles due to the activity of the hydrothermal fluids which might have led to the enrichment of the Cl^- anions for the Scapolite formation. Also, Tremolite occurrences indicate that the rock has not endured terribly high temperatures to fix the Mg^+ cation whereas Scapolite occurrences require high temperatures as is indicated by the presence of Na-metasomatism in the area. Thus the Cu mineralization has formed in close proximity to the Scapolite minerals rather than the Tremolites.

Keywords

Scapolite, Tremolite, copper, hydrothermal, chlorine.

Introduction

Scapolite and tremolite occurrences are reported from the metapelitic sequences of the Ajabgarh Group of rocks dominating the Nim ka Thana subbasin which is a southeastern extension of Khetri Cu belt, North Delhi Fold Belt. Copper mineralisation i.e. both primary and secondary copper sulfide phases are present within the area, spatially associated with the alteration assemblages present within the region. The area has been affected by metasomatism which is distinctive from the alteration assemblages present within the region. Scapolite is a common mineral in metamorphic rock that has altered during the interactions with the crustal fluid (Kullerud et.al, 1999) and so is tremolite. Scapolite is an isomorphous mixture of the meionite ($Ca_4Al_6Si_6O_{24}CO_3$) and marialite ($Na_4Al_3Si_9O_{24}Cl$) end members. Progressive replacement of plagioclase by scapolite is a common phenomenon. This process by which feldspar is altered to scapolite is called scapolitization. Hence scapolite is assumed to be a altered product of feldspar (ekstrom et al. 1972). Tremolites ($Ca_2Mg_5Si_8O_{22}(OH)_2$) are formed at greenschist facies condition due to the moderate temperature for the fixation of the Mg^+ cation. In the study area the scapolites area formed in close proximity to the copper mineralisation rather than the tremolites depicting the activity of the Cl^- anion in the mineralisation.

Methodology

Polished sections of different lithologies hosting scapolites and tremolites from surface sections were studied for petrological studies. Leica DM27 microscope was used in the Mining/Ore Geology Laboratory, Department of Applied Geology, Indian Institute of Technology (Indian School of Mines), Dhanbad, India. Representative sections were studied using Electron Probe Micro Analyser (EPMA), CAMECA SX-5 for major and minor elements including F and Cl, equipped with five wavelength dispersive spectrometers, facility available at Central Research Facility (CRF), Indian Institute of Technology (Indian School of Mines), Dhanbad, India. It was used to understand the mineral chemistry and the mineral phases on selected polished sections. EPMA analysis was carried out using the wavelength dispersion mode with a beam current of 15nA, excitation voltage of 15kV with a beam size of 5µm. Peak and background time are 10s and 5s respectively.

Results

Scapolites are coarse grained elliptical to rounded scapolite rich band developed along the foliation plane of the biotite rich metasediments (Fig.1.a). Elongated or Broom shaped tremolite grains developed along the quartz vein interface within the dolomitic marble (Fig.1.c,d). From the field studies we can identify that the scapolites are in close proximity to the copper mineralisation rather than the tremolites. Petrographic studies show the development of elongated tremolite grains within the dolomite rich zone in the metapelites (Fig.1.d). From the petrographic studies and mineral chemistry using EPMA and respective BSE images we can see that the scapolites (Cl% -1.06-2.21%) are scattered or amoeboidal in shape and have grown in close proximity to the carbonate rich zone in the metapelites (Fig.1b, 2a, 2b). Also, the scapolites in the study area are marialitic-meonitic in composition leaning towards the marialite end (Fig.3).

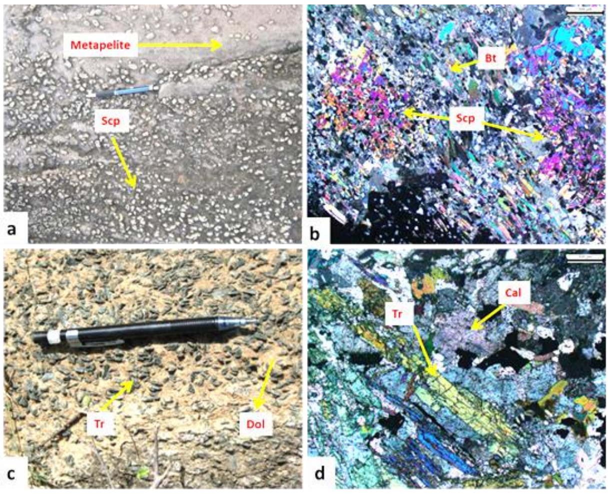

Fig.1. Field and photomicrograph of the alteration phases a) Coarse grained elliptical to rounded scapolite rich band developed along the foliation plane of the biotite rich metasediments; b) microscopic view of the scattered development of scapolite grains in the metapelite; c) tremolite grains developed along the quartz vein interface within the dolomitic marble; d) elongated tremolite grains within the dolomite rich zone along with opaque minerals (magnetite) as seen under microscope.

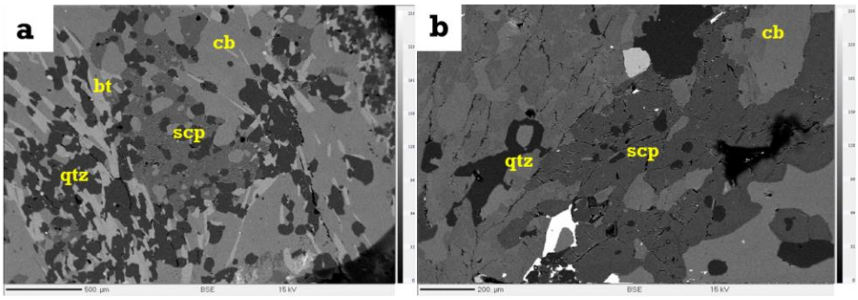

Fig.2. BSE images showing a) Scanty or partial developed or anhedral growth of scapolite within the metapelite indicating the development stage of scapolite because of the fluid interaction, b) scanty or ameoboidal growth of scapolite within a carbonate rich zone.

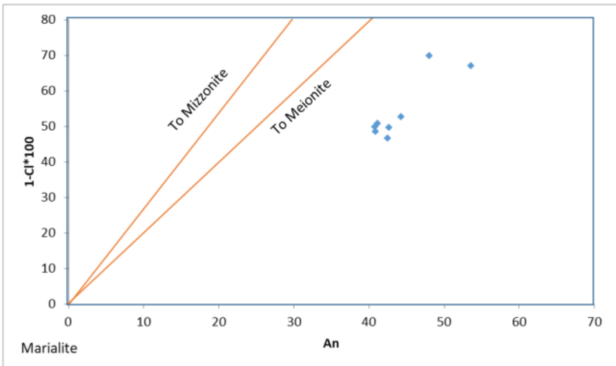

Fig.3. Scapolite characterization plot showing that most of the scapolites from the study area fall in the marialite-meionite zone

Discussion and Conclusion

The altered zones are represented by the ubiquitous occurrence of scapolite and tremolite in a metasediments of the area.This study shows that the scapolites have formed in close proximity to the copper mineralisation rather than the tremolites. The chlorine rich solutions have penetrated the rocks through the hydrothermal fluid leading to a high activity of Cl in scapolitization. The occurrence of carbonates in the nearby vicinity in the form of veins, indicates the high activity of CO_2 as most of the sections carry this mineral. Calcite presence has a kind of buffering effect on it possibly leading to the constant composition of the scapolites in the vicinity. The implication of this is that the Cl^- anion present in the scapolites acts as a kind of ligand i.e. a carrier for the deposition of the copper mineralisation (e.g. Seward et al., 2014; Williams-Jones and Migdisov, 2014), as is also suggested for the thick Cu mineralisation in the scapolitised metasedimentary rocks of the Khetri region in the near vicinity (Knight et al., 2002; Kaur et al., 2014; Baidya et al., 2017, Kaur et al., 2019). Also, the scapolites in the study area are marialitic-meonitic in composition leaning more towards the marialite end.

Acknowledgement

The authors are thankful to the Director, Indian Institute of Technology (Indian School of Mines), Dhanbad for providing support and analytical facilities. The authors would like to thank Geological Survey of India (GSI) for extending necessary support during field studies. JPS would like to thank IIT(ISM) Dhanbad, for providing the financial support in the form of research fellowship for her Ph.D. work. PRS thanks DST for FIST Level-II funding for the Department of Applied Geology, IIT (ISM) Dhanbad, India.

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POSTERS

LITHOSPHERIC STRUCTURE AND GEODYNAMICS

Surface Wave Tomography of Archean Cratons

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Cratons are separate continental regions that have been stable since the Archean. They are characterized by thick lithosphere(150-250 km), cold geotherm and is chemically different from the surrounding asthenosphere. Several seismic tomography studies have shown that cratonic keels are not uniform and consist of layering (mid-lithospheric discontinuity) and compositional heterogeneity within the cratonic lithosphere. Recently, Garber et. al., 2019 compared several seismic tomographic models and found much discrepancy among them. In order to design a more accurate methodology of seismic tomography, we target the study area of North American craton where we have massive seismic dataset with good azimuthal coverage. Surface waves are excellent tools for the lithosphere study and using these data we can model isotropic as well as anisotropic property of the lithosphere; and further this model will be used in spectral element method to verify the model.

Here we present a very early preliminary result of this study using the fundamental mode of Rayleigh wave dispersion curves, measured using a frequency-time analysis method (down to 8sec). For this we measure 80,000 paths of group velocity. These are undergone frequency-time analysis to obtain dispersion curves and picking is done on them. The dispersion curves so obtained are regionalized and then inversed to obtain geographical distribution dispersion curve. We measure the dispersion data from 8 to 200s where short period dispersion are more sensitive to the crustal region, which help us to model a much accurate crustal part and lithosphere model.

The process of picking of the dispersion curves is under progress and 20000 paths are performed till date.

Delineation of sub-surface structure at East-Indian geothermal province (Odisha Region) using gravity and magnetic data sets

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Geothermal provinces in non-orogenic are less uderstood due to lack of exposed geological structures in the vicinity of hot springs. Further, very less studies have been carried out over such hot spring regions owing to its low enthalpy nature and low economic productivity. The present study aimed at understanding a similar geothermal system in East-Indian geothermal province using gravity and magnetic methods. The study area consists of two hot spring regions namely, Atri and Tarabalo separated by a distance of ~21 km. The prime objective is to dellineate detail subsurface feature of the regions thereby to develop a probabilistic model for such type of hot spring zone and infer about its link with delineated subsurface features. In the present study, edge and depth enhancement techniques were used to delineate the regional and local faulting pattern as well as their depth extent in the study area. The NW-SE trending low gravity and magnetic anomaly zones can be infered as the trace of regional fault which act as the main source recharge and discharge (water circulation) of these hot springs. The geophysical observations help to infer four key aspects about the geothermal system of the region: (1) depth of the source may be extending beyond 4-5km, (2)the source may be placed remotely from the place of hot spring and might be feeded by some sill type features due to underplating as described by Behera et al. (2004), (3) the regional fault may act as the main path for the flow of fluid, and (4) the local fault and fissures connecting the regional fault hot fluid to the region. Thus, the study provides a better understanding about the sub-surface configuration of the two hot spring regions.

Petrology of Archean Anorthosites from Holenarsipur Greenstone Belt, Western Dharwar Craton, South India

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The Dharwar Craton (DC) of South India is one of the typical Archean terrains, which preserves rocks between the ages of Paleo to Neoarchean. Based on distinct lithologies, DC is divided into older Western and younger Eastern segments. Western Dharwar Craton (WDC) is made up of older TTG basement, volcano- sedimentary sequences viz., older Sargur supracrustals and younger Dharwar Super Group and Neoarchean granite intrusions. The Holenarsipur region is considered to be the nucleus of DC, which is located at the southern part of WDC. The Holenarsipur Greenstone Belt (HGB) preserves the older Sargur supracrustals, dominated by mafic- ultramafic schists, amphibolites and minor gabbro-anorthosite suites. The Doddakadannur anorthosite complex (DAC) is situated at the southern arm of HGB, which is exposed as N-S trending sheets over an area of one sq km, having an intrusive contact with amphibolites. The whole region has undergone upper amphibolite facies metamorphism. Based on the relative proportion of plagioclase and mafic minerals, these rocks are classified into, i) anorthosites (> 90% plagioclase), ii) gabbroic anorthosites (80-90% plagioclase), iii) anorthositic gabbro (70-80% plagioclase) and iv) gabbro (35-50% mafic minerals). The anorthositic rocks composed of irregular porphyritic calcic plagioclase, bordered by fine-grained recrystallized granular plagioclase and hornblende as essential minerals. Apatite, quartz, magnetite and euhedral garnet are accessory minerals. The associated amphibolites exhibit distinct planar fabric, essentially made of hornblende and quartz. Magnetite and euhedral garnet are the accessory minerals. Fine- grained anorthosites exhibit granoblastic texture with triple junction, indicating recrystallization under equilibrium condition. Though DAC has undergone medium to high- grade metamorphism, these rocks preserve typical cumulate texture of Archean anorthosites, in which plagioclase and hornblende forms the cumulus and intercumulus phases respectively. The adcumulate nature of these rocks indicates the crystal fractionation and settling from a parental melt. The lack of internal igneous layering suggests the absence of in-situ fractionation and thereby eliminates the possibility of comparison with other Archean layered complexes elsewhere. The cumulate texture, association with mafic-ultramafic assemblages in greenstone belts and lack of internal layering suggests that DAC is an atypical Archean megacrystic anorthositic complex.

Quantification of TEC variation from a seismically active site in the Equatorial ionization Anomaly crest of Indian sector

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In the present study we quantify the variation in Total electron content (TEC) at Equatorial Ionization Anomaly (EIA) crest due to Equatorial Electrojet(EEJ) and Equatorial counter Electrojet (CEJ) occurrences, in the Indian sector using GPS derived TEC data from Desalpar (DSP), Badargadh (BDG) of Kutch, Gujarat, and ground magnetic data from Minicoy (MNC), Lakshadweep.

Using one year of (2015) data from the sites day to day and seasonal trend of TEC and EEJ has been analysed, highest amplitude of EEJ and TEC observed during Equinox seasons and lowest amplitudes are observed during Winter Solstices. The occurrences of large amplitude CEJs at MNC in June-July month have significantly reduced TEC at DSP and BDG. To quantify the variation of TEC at DSP and BDG due to CEJ at MNC, TEC from MNC also have been used. The ration of $TEC_{DSP/BDG}$ to TEC_{MNC} shows higher values for strong EEJ days (>45nT) and low values for strong CEJ days (<-10nT), during magnetically quiet days (Kp<3). Influence of Prompt penetration electric field and Disturbance dynamo effects on EEJ and TEC also being discussed in the study.

Dynamics of the Upper Mantle beneath the Northwest Himalaya and Ladakh-Karakoram Zone Based on SKS Splitting

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The northwest Himalaya and Ladakh-Karakoram zone is the western extremity of the Himalaya-Tibet orogen and provides a unique opportunity to study the interaction between the two continental plates. The dynamics of the upper mantle has been studied with the help

of teleseismic earthquakes recorded by 29 broadband seismological stations which extend from the Himalayan frontal thrust(HFT) to the Karakoram shear zone(KSZ), covering all the important tectonic features of the Himalayan collision belt and trans Himalaya. We have used core refracted and radially polarized SKS waves to understand the anisotropic structure of the upper mantle. Whenever a polarized light travels through an anisotropic medium, it splits into two rays and the faster ray always orients parallel to the lattice preferred orientation of the mantle minerals. We have obtained 213 good splitting results by analyzing the SKS splitting of 133 teleseismic events. Transverse energy minimization method has been used to obtain the splitting parameters i.e fast polarization direction (FPD) and delay time. The study shows that the FPDs are aligned in the NE- SW direction almost throughout the upper mantle of the Himalayan collision belt up to the Ladakh batholith. However the trend of anisotropy near the KSZ follows a NW-SE trend. Delay time for most of the selected events is above ~1s, confirming a mantle origin for the SKS splitting. The FPDs are parallel to the absolute plate motion of the Indian plate, so we conclude that the upper mantle anisotropy of this region is controlled mostly by the movement of the Indian plate over the asthenosphere, with an exception for a few stations where the effect of lithosphere is overwhelming the splitting, originated from the mantle. The FPDs observed near the KSZ are oriented parallel to the strike of the fault and therefore the anisotropy of this region is the result of a lithosphere scale deformation controlled by the KSZ. Previous studies along this profile show that the crustal anisotropy is following the trend of the tectonic features (NW-SE) which is opposite to the general trend of anisotropy in the upper mantle. So, we could say that the Indian upper mantle is not accommodating the crustal shortening due to India -Asia collision.

Estimation of Amplification Factor of Bhavnagar Region, Gujarat using Geotechnical Data.

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Through the present study the site characterization of Bhavnagar region, Gujarat state is carried out using the standard penetration resistance test ‘N Value’ (SPT N) and shear wave velocity, geotechnical dataset. This is a theoretical approach as it uses geotechnical data such as shear wave velocity, damping ratio and thickness of sediments. The soil type specific relationships between SPT N value and shear wave velocity were used to generate shear wave velocity profiles at each borehole site. The site response analysis conducted using linear approach with software DEEPSOIL showed that the local site conditions play an important role in the transmission of ground motion from the bedrock to the surface to estimate the Site.

Amplification Factor at that location of Bhavnagar, Gujarat. The Gujarat state of India falls under three seismic zones V, IV, III of the seismic zoning map of India, Bureau of Indian Standard. The Methodology to carry out present study can be summarized in five main steps are following:

1. To study and extract the useful geotechnical information like SPT N value, rock type and thickness of the rock column from the given well log data.
2. To find the Shear wave velocity using correlation equation between SPT N value and shear wave velocity.
3. Generation of Time History from the spectral acceleration available at the bedrock to generate the ground motion at the bedrock.
4. Generation of Ground motion at the surface soil through the 1-D site response analysis using DEEPSOIL software.
5. Estimation of Amplification factor i.e. ratio of the Peak Ground Acceleration (PGA) at surface to the PGA at the bedrock.

The study area is divided into nine different borehole location for each of which Amplification Factor is estimated. The SPT N value used to evaluate the shear wave velocity at depths. Vs at surface vary from 135 to 295 m/sec. In the National Earthquake Hazards Reduction Program (NEHRP) site classification scheme, site classes D and E are prevalent and D is dominating in the Bhavnagar region. PGA at bedrock is estimated to be 0.08g. The same vary in the range 0.08g to 0.125g at the surface. Amplification factors vary from 1.0 to 1.56. At the site, where the Amplification is large (>1.5), lie in the site class E in NEHRP. The study area falls under seismic zone III as assigned by Bureau of Indian Standards (BIS), where a maximum PGA of 0.16g can be expected.

Group velocity dispersion characteristics and one-dimensional shear velocity structure of the Rajasthan Craton

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During 2014-16, a semi-permanent network of four 3-component broadband seismographs was operational in the Rajasthan Craton. The reliable and accurate broadband data of the 2015-2016 different regional earthquake sequence from these four stations of this network enabled us to estimate the group velocity dispersion characteristics and one dimensional regional shear velocity structure of the region. First, we measure Rayleigh- and Love- wave group velocity dispersion curves in the period range of 7 to 100 sec and then invert these curves to estimate the crustal and upper Mantle structure below the Rajasthan Craton. We observe that group velocities are of variable nature within the craton. This could be attributed to the heterogeneous crust-mantle structure in Rajasthan resulted from the magmatism episodes associated with the Proterozoic Collision and 65 Ma Deccan volcanism. Our best model in Rajasthan reveals a two-layered crust, with a 15-km thick upper-crust (UC) of average shear velocity (Vs) of 3.10 km/s and a 25-km thick lowercrust(LC) of average Vs of

3.417 km/sec. Our modeling detects a drop in Vs (~1-2%) at 79-120 km depths, underlying the Rajasthan, representing the probable seismic lithosphere-asthenosphere boundary (LAB) at 79 km depth. Therefore, this 1-2% drop in Vs could be attributed to the presence of partial melts(magma) in the upper mantle related to magmatism episode associated tothe Proterozoic collision and the 65 Ma Deccan volcanism as also suggested by existing geological and seismological evidence.

Enhancing signal-to-noise ratio of converted seismic wave data using the Seislet Transform

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Seismic waves that are recorded for seismological investigations usually disturbed by noise of various origins. Such noise may influence the imaging and modeling which ultimately leads to misinterpretations of the data. In order to improve the signal-to-noise ratio of P-to-s converted wave seismological data, here, we suggest using a novel sparsity enhancing tool, that is, the Seislet Transform, to process receiver function data by applying regularization in the seislet domain. Basically, Seislet Transform generates multiscale orthogonal basis functions that are oriented along varying local slopes of dominant seismic phases in the input data. The key elements of the Seislet Transform are the prediction and update operators, which are based on the principle of wavelet lifting scheme combined with a local plane-wave destruction filter. Thus, in the Seislet framework signal can be effectively compressed in the small scale and random noise spreads in the whole transform domain as a result of which improvement of the signal-to-noise ratio can be achieved by simply applying a thresholding operator. The application of Seislet Transform on both synthetic and field data from Hi-CLIMB network and station HYB from Indian shield demonstrate the improvement of the inversion results over the original data sets.

Widespread crustal magmatism in the Kachchh region– Evidence from shear wave velocity contrast across Moho

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The Kachchh region in Gujarat located in the western part of India covered by Deccan Volcanic Province is one of the seismically active regions in India and has witnessed damaging intraplate earthquakes in past. Due to the absence of detail high-resolution crustal studies, a general consensus on the nature of the crust and its relation to the local seismicity remains elusive. Here we investigate the shear wave velocity contrast ($\delta\beta_M$) across Moho using receiver function waveforms using a newly proposed methodology. The results reveal that $\delta\beta_M$ varies spatially from 0.15 to 0.86 km/s all over the Gujarat region. For Kachchh region $\delta\beta_M$ varies from ~0.15 to 0.58 km/s; for Saurashtra region from ~ 0.44 to 0.86 km/s and for Mainland Gujarat it is from ~ 0.32 to 0.74 km/s. The tectonic correspondence shows that the concentrated seismic zone is characterised by lower $\delta\beta_M$. The bulk crustal thickness (H) and bulk V_P/V_S ratio show an anti-correlation relation i.e., lower $\delta\beta_M$ corresponds to the larger crustal thickness and mafic material above the Moho. The Kachchh region is characterized by low $\delta\beta_M$ variation across the Moho compare to the Saurashtra and Mainland region. The scaling relations support the evidence of the magmatic body present at lower crust to upper mantle level that caused the crustal growth in this regions. Such mafic body in the lower crust is capable to accumulate enough strain to generate the crustal level seismicity. The shallow seismicity is primarily due to the movement of the faults.

Anisotropic Pn traveltimes tomography beneath the Indian Plate and its surrounding regions

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We present new high resolution Pn- tomography image and anisotropic models beneath the Indian shield, its surrounding regions and Bay of Bengal. The velocity information for the uppermost mantle from the Indian subcontinent is hitherto not attempted. For this purpose high quality 4850 Pn phases have been used from the 118 seismological stations deployed in the Indian Shield and Andaman -Nicobar Island regions. The data show that the average uppermost mantle P-wave velocity for the entire Indian subcontinent is ~8.168 km/s. The anisotropy effect has also been incorporated in the inversion scheme. It is observed that the incorporation of anisotropy improves the image compared to the isotropy model in few regions. The results clearly reveal interesting features which corroborate with the prevalent geology of the region. The high Pn velocity corresponds to the central part of the Indian shield. In contrast the sedimentary basins like Indo-Gangetic plain, Bhuj in western India and southern Indian granulitic regions corresponds to the lower Pn wave velocity. Some of the new features have been resolved here that were hitherto not known. The fast anisotropic directions within the shield are variable suggesting the remnant anisotropy within the uppermost mantle. While in Himalaya and Burmese arcs the direction are consistent with the eastward material flow directions.

Local Trend Analysis of Irregular pulsations (Pi2:6-25 mHz) at low latitude Station of Desalpar, Kachchh. Gujarat

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Geomagnetic pulsations are studied using ground magnetometer data from the date of installation of Induction coil magnetometer, at Desalpar MPGO, ISR, Kachchh, Gujarat. We are here by reporting the morphology of Pi2 pulsations bursts (6-25 mHz) and its local time variations during 2013. The investigation is carried out to address the effect of sun earth interaction on these Pi2s. The observed quiet and disturbed periods Pi2s using Desalpar magnetic data are compared with the 1Hz fluxgate magnetic data of Intermagnet low latitude stations i.e., HON, and PHU. The peak-to-peak amplitude are in the range of 0.34nT during quiet time (22nd Jan 2013; Kp=0) and 0.9nT during the disturbed days (28th Feb 2013; AL=-109nT). The local trend analysis has been carried-out by classifying the data into 3hour local time bin (LT=UT+0530). Pi2 periods and occurrence rate during the local time in 2013 shows maximum number of events in early morning and midnight times, and very less number of events during the noon times. This might be because of the Tail currents at the magnetic reconnection during the night time. The numbers of events in D component have been noticed in comparison with H component. Whereas, the observed periods of H-component are more when compared to D-component. The periodicity of Pi2 has been enhanced during 18-19 LT. The Periodicity in H component is being increased from 6LT and attain maximum during 18-19LT and then decreased after that. The maximum amplitude is noticed during the 6LT. D component amplitude have noticed most of the greater than H component in 2013. These results are tested from background solar wind IMF parameters.

Scaling law between seismic moment and corner frequency of small earthquakes in Koyna- Warna region using Spectral Ratio Technique

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The precise determination of the stress drop and scaling of source parameters are important for seismic hazard assessment. Here, we investigate the scaling law between the different source parameters of mostly low magnitude earthquakes of reservoir triggered earthquakes of the Koyna-Warna region, in the west coast of India. A large number of P-waveforms have been used, recorded at the surface (2238 waveforms) and borehole (2663 waveforms) networks during the period 2005-2017 and 2015-2017 respectively. The borehole seismometers are deployed at a depth of 981-1522 m from the surface. Theretrieved spectra are inverted to

estimate the source parameters using Spectral Ratio Technique which effectively eliminate source and path effect compared to conventional spectral fitting method. The inversion results yield optimal fit between theobserved and theoretical spectra for □2. Scaling relationship between the corner frequency and moment satisfy self-similar scaling of conditions. We further discussed the source dimension and stress drop for the triggered earthquakes in the region.

Upper crustal structure and composition from P- and S-wave velocity modeling along the Perur-Chikmagalur 3-C seismic profile of Dharwar Craton, India

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We present 2-D upper crustal P- and S-wave velocity models (Vp and Vs) along the 200-km NE-SW trending Perur-Chikmagalur 3-C seismic profile of Dharwar Craton (DC) using ray-trace inversion of first-arrival refraction and reflection traveltimes. The velocity models reveal alternate horst and graben structures at shallow depth (0.5-2.5 km) filled with weathered volcano-sedimentary rocks having low Vp (5.2-5.5 km/s), Vs (3.2-3.3 km/s), Vp/Vs (1.62-1.65) and Poisson’s ratio (0.19-0.21) along with granite and gneissic rocks of increased velocity exposed in the horsts. The steeply dipping Chitradurga Shear Zone (CSZ) has been imaged extending down to the depth of 6-8 km with anomalously high Vp (6.8 km/s), Vs (3.8 km/s), Vp/Vs (1.8) and Poisson's ratio (0.28) comprising mid-to-lower crustal rocks exhumed to shallow depth due to intense shearing and transpression between the Eastern Dharwar Craton (EDC) and Westen Dharwar Craton (WDC). It is associated with complex suturing and oblique convergence due to NE-SW compression and inter-wedging of different blocks in the CSZ. We found major compositional distinctions between the EDC and the WDC blocks. Rock compositions of Neoarchean EDC are rich in felsic granites having relatively low Vp (6.2 km/s), Vs (3.55 km/s), Vp/Vs (1.74-1.75), Poisson's ratio (0.25) as compared to its counterpart Mesoarchean WDC dominated by greenschist facies-gneisses of mafic/ultra-mafic composition having relatively high Vp (6.35 km/s), Vs (3.60 km/s), Vp/Vs (1.74-1.76), Poisson's ratio (0.25-0.26) in the upper crust. A distinct zone of detachment imaged at 8-12 km depth acts as a major unconformity having eastward-dipping low-velocity-layer (LVL) sandwiching Dharwar-schist-belts and Archean-gneisses within the upper crust.

Estimation of coda – Q from synthetic and digital seismograms using linear and non – linear techniques: A comparative approaches

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A comparative study is carried out to fit the single – scattering model of coda wave generation to experimental data. A comparison between the non- linear (Gauss-Newton) technique and the technique used in seismological practice (log-log, linear model and least square fit) are made. Two types of data are used during the study: (1) a synthetic coda generated by white Gaussian noise modulated with an attenuation factor, exp(-kt), and a geomechanical spreading factor; (2) digital seismograms provided by three events recorded in there different seismic stations namely Tezpur (TZR), Dokmok (DMK) and Seijusa (SJA) that occurred in Tezpur region in Assam, India.

There are no significant differences are observed in the values of Q_c inferred by both the techniques, when the signal to noise ratio of the final part of the coda is greater than or equal to 5 for synthetic coda. But the log-log technique produces systematic overestimate values of Q_c if the signal to noise ratio is less than 5. If the whole data of digital seismograms are considered, the values of Q_c are shown overestimates in log-log technique when compared with the non-linear (Gauss-Newton) technique.

The Q_c dependence on the lapse time is less pronounced when the Gauss-Newton technique is used. This effect is more evident when different coda durations are obtained by fixing the start time of coda analysis and increasing the end time of the same coda. This pattern is observed for all three events in Tezpur region; when a linear technique is used, a lapse time dependence is observed but when the non-linear method is used the dependence is less significant.

2-D inversion of 3-D MT data: An example from central India

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In the complex geological formations the MT response are generally three-dimensional (3D), sometimes it is interpreted as 2-D due to non-availability of 3-D modeling capabilities. The volume current and boundary charges for secondary field in the 3-D environment control the validity of 2-D inversion for 3-D data. Joint inversion of TE and TM mode data for a 3-D structure produces the top of the conductor, but the depth to the base of the conductive structure is over estimated. In TE mode, neither volume currents nor boundary charges pertain as sources for a secondary electric field, therefore, dealing of TE mode for 3-D structure overestimate both the conductivity and the depth to the bottom of the structure. In the case of 2-D TM mode, the electric field is normal to resistivity contacts; boundary charges will be induced as sources for secondary E-fields, and inclusion of boundary charges in both 2-D TM and 3-D formulations lead to an agreement of 2-D TM and 3-D results. Since dimensionality analysis shows the 3-D structure for the lower frequency range in central India, the approach of 2-D TE+TM inversion may leads to misinterpretation, therefore, we considered TM mode inversion in addition to TE+TM mode. The regional geological structure, as well as major tectonic boundaries i.e. Central India Shear (CIS), Tan Shear Zone (TSZ), Narmada-Son Lineament (NSL) show the strike direction is ENE-WSW. Hence, crustal deformation and origin of 3-D conductivity bodies may exist parallel to the regional strike direction. In that case, the electric field normal to the regional strike direction is affected mainly by the accumulation of charge on the surfaces of the 3-D body; hence, the TM mode is more robust to resolve the 3-D structure.

Anisotropy and its implications present in the Dharwar craton: A magnetotelluric study

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The Dharwar craton is present in the southern Indian shield region (SISR). It exposes some of the oldest basement rocks on the Earth making it one of the most significant cratonic regions of the world. Chitradurga Shear zone (CSZ) separates the Dharwar craton into two blocks namely Eastern Dharwar Craton (EDC) and Western Dharwar Craton (WDC). Magnetotelluric data were collected in both parts of the Dharwar craton along three parallel approximate 280 km long profiles. The impedance measurements were done using the robust processing code within the period range of approximately 0.01 to 10,000 s. Nature of the Earth structure is determined by the dimensionality and directionality analysis. 2D modelling is carried out using the Nonlinear Conjugate Gradient (NLCG) scheme. Anisotropy is detected in the study region of the Dharwar craton. Anisotropy modelling was done for the few stations data. Significant variations are observed between the off-diagonal and diagonal components apparent resistivity and phase values. For anisotropy, the phase values always should be considered in their proper quadrant and having different off-diagonal components and equal diagonal components with opposite sign. The other important results of this anisotropy modelling will be discussed.

Growth rate and direction of growth faults

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The creeping of growth fault and slow shrinkage of salt-dome are a growing problem in hydrocarbon exploration (oil leakage) and landslide-prone areas. This problem has been dealt with "fluid migration through the active or reactivated growth fault" by researchers of petroleum industries and academia. Both growth faults and salt-domes are mostly found within the passive sedimentary basins due to gravitational effect only. We can calculate the depth, density, porosity, thickness, deposition time of different beds from high-resolution 3D seismic and well log data using PETREL and OpendTect software. Footwall erosion is insignificant for offshore regions whereas faults from onshore regions have significant footwall erosion. So, those data are collected from offshore basins like Krishna-Godavari basin, Bombay offshore basin, etc. It is seen that the range of the absolute displacement rates is 0.40–2.0mm/yr. for faults belong to offshore region. Displacement rates are remarkably stable over longer time periods within a given fault system and the rates are strongly dependent on the relative size of the fault. Larger faults are those that have grown faster rather than the ones which were stable for a longer period of time. The regions with higher strain rates have proportionally higher fault displacement rates on faults of all sizes, not because of proportionally greater numbers of faults. The past and present growth rates of growth faults measured by the ratio of the difference in thickness of up-thrown and downthrown part of a particular bed and time of growth of the fault through that particular bed. This can also be achieved from GPS tracking data. By organizing the past and present growth rates with respect to the time span, stress level, different lithology, porosity for a unit zone of rock body surrounding the growth fault, the future growth rate of the growth fault can be calculated. The future direction of growth of the growth fault and shrinking of salt-dome can be determined from seismic by 'point movement analyses' and '3D finite element analysis of deformation' using ANSYS and NORSAR software.

1 second data characteristics of IMO-Choutuppal Geomagnetic Observatory (CPL), INDIA

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The Choutuppal Geomagnetic Observatory (CPL) was initiated in 2012 in the campus of the Choutuppal Geoelectric Observatory (1967-1991), 65 km east of IMO-HYB, India operating by CSIR-NGRI. CPL 1-minute absolute data is awarded with INTERMAGNET observatory status in August, 2019. Instruments are deployed at CPL in noise-free environment situated for geomagnetic observations at low latitude. The acceptance of 1 minute records of CPL is encouraging to initiate the high frequency data characterization (1 s) as the high frequency data from low latitude region is essential in contributing towards ionospheric and magnetosheric process. Producing high frequency data involves increased noise levels and holds regional effects. So, in our study, we concentrated on addressing the regional effects and their impact on the high resolution data to characterize the data for improving the data quality to produce 1 s precision data in near future from CPL Observatory.

Implementation of an automatic earthquake data processing tool for the Koyna region

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Enormous number of micro-earthquakes are identified on the borehole records, which are absent or not able to trace due to ambient noise or background noise that present in the seismograms of the surface network at Koyna, India, a best known site for the artificial water reservoir triggered seismicity. These micro-earthquakes are also difficult to detect on daily seismograms using manual analysis. In the present study, we have analysed the time series and spatial distribution of micro-earthquakes for the two moderate earthquake sequences that occurred on 3rd June 2017 and 20th June 2019, both being of M ~ 4. For the first time, an automated algorithm is implemented for the Koyna earthquake data. Further, automatic 'P' and 'S' phase picking recipes to process the bulk data has been designed. A grid search algorithm is also applied in two stages on the arrival times to estimate the locations of earthquakes. A total of ~ 1500 earthquakes are identified based on the auto detection process, out of which ~ 1000 earthquakes are locatable. A quality check has been carried by reading all the seismograms for 'P' and 'S' phases by visual inspection. Previously, only ~ 435 events are well located based on the physical inspection of events on the borehole records for the same time period.

Estimation of Site Amplification for Preparation of Contour Maps and Accessing the Seismic Vulnerability of Existing Buildings using HVSR Technique in Kurukshetra Region

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The fundamental step in the estimation of seismic damage and losses in urban areas is the identification of regional potential seismic hazard. The study area of the Kurukshetra region lies in the Indo Gangetic Plain represents almost flat alluvial plain which can amplify seismic ground motion. This study presents the assessment of seismic site amplification for accessing the seismic vulnerability of a few existing buildings in this region by the microtremor

horizontal-to-vertical-spectral-ratio method. This methodology provides an alternative, promising tool towards a quick and reliable estimate of seismic, as the microtremor observations are much easier and economical than conventional geophysical methods in the field and the laboratory as well as earthquake observations, and also suitable for spatial variability of seismic site characterization. The site amplification factor obtained at these sites is found to be in the range of 2.3-2.9 which is due to the loose sediment cover over the region. The predominant frequency varies from 0.75-0.81 Hz. The contour maps for predominant frequency and amplification factor has been prepared. Along with that assessment of the seismic vulnerability of a few existing buildings is also done. Based on microtremor measurement and HVSR analysis, site amplification factor and contour map indicates low to moderate seismic danger zone.

Earthquake Precursor Studies Using Magnetotellurics at Koyna Dam, Mh

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Significant changes were observed in both Amplitude and Phase of the Magnetotelluric data before, during and after the earthquake at two recording stations near Koyna Dam, Maharashtra. Data of two different Earthquake Magnitude i.e ., M 3.9 and M 4.9 is analyzed before, during and after the Earthquake shows considerable changes in Amplitude with the change in Magnitude. Power Spectral Density is plotted for both the station, before, during and after the earthquake shows that the frequency range from 0.1 Hz to 0.5 Hz are mostly affected by the Earthquake Energy. The telluric and magnetic signals recorded in the frequency range (0.1–0.5 Hz) of MT spectrum shows considerable variations in their spectral characteristics during the earthquake event compared to the data recorded before and after the earthquake. Further, it is observed that the magnitude with 4.9 shows the highest energy in both electric and Magnetic component than with magnitude 3.9. The wavelet spectra clearly show two distinct spectral regimes for the MT signals. During the Earthquake, there is a sharp rise in spectral amplitudes, across all the frequency range. But amplitudes of frequency range 0-1 Hz and 3-4 Hz is higher compared to the other frequency range. The period range of anomalous change in apparent resistivity corresponds to the depth of about ~10 km. This depth is coincident with earthquake focal depth. The anomalous variation of Apparent resistivity which is near to the epicenter shows the considerable decreases in resistivity before and/or during the earthquake firstly and then increases after the earthquake in the strike direction.

Constraints of crustal anisotropy behaviors from Silghat, Northeast India from the analysis of shear wave splitting effects

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Crustal anisotropy is explored by means of shear-wave splitting of local earthquakes beneath the Silghat region that occupies the north-western part of the Mikir hills near the Assam valley of Northeast India. An active strike-slip fault i.e. Kopili Fault orienting in NW-SE direction separates the Mikir Hills from Shillong Plateau, adding complexity in geodynamics and seismicity in the North-eastern province of India. Thus, we made an effort to understand crustal anisotropy beneath Silghat. Splitting of S-waves can be analyzed by aid of the splitting parameters- the Fast polarization direction (Φ) and Delay Time (δt) between the Fast and Slow axis, deduced by using an automated cross-correlation technique following certain criteria in choosing the good quality S-wave arrival without being contaminated with other refracted phases. Here, we analyzed local shallow focus earthquake events resulting a little variation of delay times, signifying the presence of moderate crack density in the study area. The Φ at most of the cases are aligned nearly parallel to the strike of the Kopili fault and in some cases, Φ is parallel to major lineaments traversing the region in NE-SW and E-W orientations revealing the FPD of this region as parallel to the local tectonic structures and stress field. Hence, the reason behind the seismic anisotropy in crust is predominantly due to the aligned cracks, micro-cracks and pore spaces developed from the local stresses and in some extent the consequences of tectonic forces governed by the strike-slip mechanisms in the study area.

MT Data Processing using Time Varying Filter (TVF) Based Empirical Mode Decomposition (EMD)

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Estimation of impedance tensor from time-varying electromagnetic fields is executed using Short Time Fourier Transform (STFT) in conventional MT data processing as a function of frequency. MT data is processed based on the assumption i.e. the electromagnetic field components are stationary over a period of length. In general MT signals are non-stationary in nature. In this paper, we used Time Varying Filter based empirical mode decomposition to process the MT signals which handles the non-stationarity. Time varying filter based empirical mode decomposition is modified version of empirical mode decomposition which

solves the mode mixing problem and sifting process is completed using a time varying filter technique. And, the impedances are estimated based on the instantaneous spectrum i.e. instantaneous amplitudes and instantaneous frequencies.

Lithospheric thermal structure of central India

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Elucidating the lithospheric thermal structure is vital in the regions having complex geological and geophysical signatures. Satellite magnetic data is frequently used for estimation of Curie depths. We computed the Curie depth from satellite magnetic data for the fractal distribution of sources in thermally less understood central Indian region. The Curie depth is varying from 21 to 48 km in the area. Shallow and deep Curie depths correspond to southern and northern parts of the study region, respectively. The Curie depth values are further used to compute the geothermal gradient and heat flow anomalies. The computed geothermal gradient anomaly, inversely related to the Curie depth values, varies from 0.012-0.028 °C/m. The heat flow anomalies are found to range from 30-89 mW/m^2 and broadly matches the observed heat flow values. The derived surface heat flow values are used to compute the crustal temperatures and thermal lithospheric boundary (TLB) of the region incorporating lateral and vertical variations in thermal conductivity and radiogenic heat production values for a four-layered earth model. We found the Moho temperatures are high (740-960 °C) for Aravalli-Delhi & Satpura Fold Belts and Bastar craton, moderate for the Bundelkhand craton (620-680 °C) and low for the Deccan Volcanic Province (550-610 °C). Shallow TLB is observed in Aravalli-Delhi Fold Belt (65 km), Satpura Fold Belt (78 km), Bastar Craton (80 km) and, Bundelkhand Craton (105 km) and Deccan Volcanic Province (135 km) are found to be relatively deeper. The Curie depths shallower and deeper than the seismic Moho indicates a non-magnetic crust-mantle boundary. Probably, the plume activities in the past have modified the lithospheric thermal structure of various geological units in the central Indian region.

Attenuation characteristics of Lg waves in the Indian Shield and its implications

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The lateral variation of Q (Quality factor) and its η dependency for 1 Hz frequency is estimated for the Indian Shield using Lg waves. Lg waves are the prominent seismogram phase at a regional distance having an average velocity of 3.5 km/s, generated as multiply reflected shear waves or higher mode surface waves. Insensitivity of Lg for source characteristics makes it an ideal tool to study large-scale crustal variation such as attenuation estimation.

For this study around 209 earthquakes recorded at 122 seismometers located in the Indian Shield are used. These stations are deployed and maintained by CSIR-NGRI, NCS and Geoscope. Here, we used 2328 interstation data which is inverted to estimate Qo. A checkerboard test is being performed to ensure the resolution of our image.

The results show that Lg-Q varies from the range ~50-750 with its frequency-dependent parameter η of about 0.7 as average. The values obtained for the cratonic region, sedimentary region and rift valleys where most of the Indian shields are in a broad agreement with the values estimated for other similar tectonic regimes globally by various researchers. Also, we have compared the Lg-Q values with available crustal thickness, heat flow and Vp/Vs ratio for the Indian shield. We suggest that the attenuation scenario in the Indian crust is mainly controlled by both composition and temperature.

Study of radiowave of very low frequency for Sub- ionospheric perturbation during Turkey earthquakes.

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In Turkey region to study seismo -ionospheric phenomena radio waves are used which is associated with two major earthquakes by using very low frequency (VLF) data. Investigation of sudden ionospheric disturbances (SID) is being carried out with sampling rate is 10 sec at 23.4 KHz from SID monitoring station of Bafa (latitude 37.24° N , longitude 27.19° E) at France by using very low frequency data (VLF). During the process of earthquake preparation over the earthquake epicenters in the Turkey Anatolian block night time fluctuations are being observed. We compute effective magnitude of all earthquakes for that day which acts like a single quake and calculate the total energy accumulation by all those earthquakes.. For the whole year we analyse the trend of VLF signal and compute the sunrise and sunset terminator time from it. We found the unusual fluctuations in VLF signal strength are well correlated with earthquake magnitude and on few days prior to earthquake events the fluctuations is maximum by computing a cross correlation between trend from the night time fluctuation value with earthquake of effective magnitude.

Reverse Time Migration Assisted initial model building for Full Waveform Inversion

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Full waveform inversion (FWI) is a state of art technology for velocity model building. The practical application of FWI is often limited due to it's high computational and disk storage requirements. FWI provides excellent velocity models, but the convergence toward the true model is not always granted if the initial model has large variance as compared to the optimum model. We proposed an optimal workflow to build the initial model using structural information estimated from migration images obtained using Reverse Time Migration. The seismic images from RTM is used to create dip information which is further used to interpolate and condition the picked time-migration velocity. Different initial models with the integration of information from well logs, horizon based interpolation and the proposed approach are studied on the three-layered and Marmousi velocity model.

The convergence of the FWI using different initial models to create an optimum velocity model is studied to select the best method for initial model building. The run-time for FWI implemented on GPU with the different initial model are also compared. The RTM assisted initial model provides better convergence as compared to other initial models for FWI on the selected models. The faster convergence of the FWI provides the optimum quality velocity model in relatively less time. The seismic depth images processed with RTM using the final velocity model obtained using different initial models are also compared. The better seismic images from RTM assisted initial model for FWI confirm the effectiveness of the proposed approach.

Velocity-depth modeling across Himalayan frontal thrust near Pawalgarh using high frequency ambient noise tomography

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Development of ambient noise tomography (ANT) to extract the Green's function from seismic wave-field, recorded for a sufficiently long duration, by cross-correlating a number of receiver pairs, is proven to be a reliable tool and has been effectively applied to study the deeper crust and mantle structures over the globe. Here, we have applied the ANT technique in the frontal part of Himalaya near Pawalgarh in Nainital district of Uttarakhand to obtain the shallow velocity-depth models. The study region lies in the lower Siwalik where the major

rock types are sandstone, conglomerate and alluvial deposits from the river Dabka. Ambient noise is recorded using a state-of-the-art data acquisition technique planting total 23 sets of geophones and remotely acquisition unites (RAUs) for 46 days between 2 and 5 am. The time duration is deliberately chosen to avoid anthropogenic noises. Cross-correlation of the vertical components of the recorded noise datasets are used to estimate the Rayleigh wave dispersion curves for the time period ranging from 0.1 to 1.5 s for each station pairs with a good SNR, providing a map of 2D Rayleigh wave distribution with depth. Our study shows that the average Rayleigh wave group velocity ranges from 700-800 m/s down to the depth of 500 m. We further observe a velocity jump across the speculated position of the main frontal thrust. The Rayleigh wave dispersion curves are inverted to obtain shear wave velocity-depth distribution in the region. Some patches of low-velocity zones are also observed as shear waves are more sensitive to the presence of liquid; so we infer these low-velocity patches might be due to the presence of water table. As the study region lies in the Himalayan central seismic gap, any great earthquake can be devastating for the society residing in the foothills; and thus the shear wave estimation from this study would be highly beneficial to the hazard assessment in future.

Two-dimensional modelling of topographic corrected Magnetotelluric data from Sikkim Himalayas and its interpretation.

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Magnetotelluric (MT) method is one of the passive electromagnetic method used to investigate the deep crustal information of hilly terrain such as Himalayas. Due to topographic variations, the telluric current lines are focused in the valley and diverge under the hill, this produces galvanic and inductive distortion in the MT data, this distorts the resistivity curves. The two-dimensional (2-D) topographic effects in Transverse Magnetic (TM) mode is only galvanic whereas inductive in Transverse Electric (TE) mode. In three-dimensional (3-D), the topography effect is both galvanic and inductive in each element of impedance tensor and hence the interpretation is complicated. In the present study, 3-D topography effect for a trapezoidal hill model was investigated. The research work presents the impedance tensor correction algorithm to reduce the topographic effects in MT data. The distortion caused by surface topography effectively decreases by using homogeneous background resistivity in impedance correction method. In this study, the response of ramp, distance from topographic edges, conductive and resistive dykes are analyzed. The new correction method is applied to the real data from Sikkim Himalayas, one-dimensional (1D) and 2D inversion results after topography correction show the true nature of the basement in this region.

Geospatial techniques for Landslide Assessment and Susceptibility Mapping over Kodagu Region, Western Ghats, India

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Landslides have become most disastrous in India in the recent past and more so along the Western Ghats. Triggered by severe rainfall events, most of the slope failures along the Western Ghats are debris flow type landslides while the northern parts of Kerala and Karnataka region are characterized by rotational and translational slides as well. Rainfall driven disaster affected Kerala and Kodagu region during August 2018 causing numerous slope failures resulting in huge loss of life and property. The recent incidences have reiterated the need for comprehensive methods of landslide mapping, monitoring and forecast. The present study attempts to assess the spatial extent of the landslides by developing a geospatial landslide inventory using the Sentinel 2A MSI satellite datasets. Landslide susceptibility mapping is carried out using the Geospatial landslide inventory in addition to the various other landslide causative factors like elevation, slope angle, Aspect, drainage density, geology, lineament density, slope curvature, landuse/landcover, Stream power index, Topographic wetness index and distance from roads. The Frequency Ratio (FR) and Weights of Evidence (WoE) methods are used to rank and classify the different thematic layers into a final landslide hazard zonation map. The performance of the two methods were statistically assessed based on the Area under the ROC curves which stood at 0.743 for FR and 0.744 for WoE indicating consistency in the selected landslide causative parameters. The cumulated rainfall event *Vs* rainfall duration thresholds were analyzed using the power law based model adopting frequentist and bootstrapping techniques. The study provide insights into the rainfall conditions that triggered the landslides over the Kodagu region during the Extreme rainfall events of 2018 leading to better understanding of process to enable hazard forecasting, thus reducing the risk to ensure secure life.

Co- Seismic Ionospheric disturbances (CID) due to Major and Great Earthquakes

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The Coseismic Ionospheric Disturbances (CID) due to the 26th December 2004 earthquake of Mw 9.2, which occurred in the Sumatra-Andaman subduction zone, are analyzed using cGPS-aided Total Electron Content (TEC) measurements. The source of generation of disturbance

in the total electron content in ionosphere can be due to many forces which occur in the upper atmosphere like solar and geomagnetic disturbance. Apart from this, there are other phenomenons below the atmosphere which contributes to the variation of Total electron content (TEC). One of the main sources of these disturbances in the electron content, below the atmosphere is due to the occurrence of large earthquakes with Mw>7.0. Variation due to earthquake can be seen in smaller scale prior the earthquake and comparatively larger during and after the occurrence of the earthquake. These variations are known as pre-seismic disturbance, co-seismic disturbance and post-seismic disturbances respectively.

It is well known that during the occurrence of an earthquake, the surface experiences horizontal as well as vertical displacements, depending upon the type of rupture fault.Shallow thrust earthquakes, giving strong vertical ground displacements, produce infrasonic pressure waves in the vicinity of the neutral atmosphere. These neutral atmospheric disturbances, known as acoustic gravity waves, propagate upwards to ionospheric altitudes and create disturbances in the electron density there. These disturbances are well known as seismo-traveling ionospheric disturbances (STID) or co-seismic ionospheric disturbances (CID). It is believed that upward propagation of wave perturbations happens in the vicinity of the earthquake epicenter or within the so-called earthquake preparation zone. Using a case study, Otsuka et al. (2006) suggested that there can be multiple sources for acoustic wave generation along the rupture that propagate away from the epicenter at the rupture velocity. Heki and Ping (2005) have empirically shown that only acoustic waves emanating within the zenith angles of 0° to 20° can reach ionospheric heights and affect the electron density. The remaining waves get reflected, mainly because of atmospheric temperature variations, and return to the ground. Induced ionospheric electron density perturbations related to seismic activity are often observed with various radio techniques, such as HF Doppler sounding, ionosonde, and global positioning system (GPS) Like the Coseismic displacement estimated by GPS, GPS can also be used to estimate the Coseismic Ionospheric Disturbances. Three kinds of atmospheric waves that disturb ionosphere and can be observed with GPS as TEC changes, i.e., (1) direct acoustic wave from the focal area, (2) gravity wave propagating obliquely upward from the focal area or from propagating tsunami, and (3) secondary acoustic wave excited in far fields by the Rayleigh surface wave. Part of the direct acoustic wave comes back to the ground by atmospheric refraction and is observed by infrasound sensors. Vertical movements of ionized particles in the geomagnetic field induce current in ionospheric and cause geomagnetic pulsation.

Applications of Microgravimetry in exploration of subsurface resources

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To know the mass distribution along earth surface, measurement of gravity anomaly is a common process. Since the development of gravimetry it has been very useful in many industries for finding crude oil, hydrocarbons and minerals present in the subsurface. Although it is the first-choice method in finding sedimentary basins containing crude oil.

Microgravimetry is a recently developed branch of gravimetry which gives us more accuracy (up to $1\mu gal = 10^{-9}$ g), are taken with a microgravimeter. These instruments are very sensitive to small voids also. The instrument showing a negative anomaly of 10 μgals corresponds approximately to the effect of a 2m diameter spherical void. Thus, it offers a high resolution to gravity prospecting which will be very useful interpreting any local mass distribution. Apart from finding geological resources it is also effective to detect complex cavity systems like water-filled cavity. The method also offers special advantages over other subsurface exploration methods in a wide variety of applications.

Petrography and Geochemistry of Charnockites along Painavu - Trichur Segment of Karur – Kambam – Painavu – Trichur Shear Zone (KKPTSZ), South India

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Southern Granulite Terrain (SGT) of Peninsular India is dominated by granulite facies rocks located to the south of the orthopyroxene - in isograd, demarcated along a line connecting Mangalore - Mysore - Bangalore - Chennai, bounded to the north by the granite greenstone terrain of the Dharwar Craton. Karur - Kambam - Painavu - Trichur Shear Zone (KKPTSZ) was proposed by Ghosh et al. in 2004 as a V - shaped Neoproterozoic terrain boundary that separates the Precambrian Southern Granulite Terrain an older (Archaean) terrain to the north and younger (Proterozoic) terrain to the south. It is extending from south of Karur in the East to just north of Kambam in Tamil Nadu with a NE-SW trend followed by NW trend to south of Trichur, in Kerala.

Here we focus on the Painavu - Trichur segment of KKPTSZ. Petrography and geochemistry of sixteen charnockite samples from places in Idukki and Ernakulam Districts in Kerala across the Painavu-Trichur segment were analysed to check whether any significant variation in composition exists across the shear zone. Charnockites from the study area exhibits a common mineral assemblage of quartz, plagioclase, K-feldspar, hypersthene and biotite. Accessory minerals such as zircon, ilmenite, apatite and magnetite are present. Both garnetiferous and non-garnetiferous varieties of charnockites are present. Their geochemical characteristics in the northern and southern domain of Painavu - Trichur segment are similar which shows calc - alkaline and highly magnesian nature (Frost et al., 2001). The plot of CaO / Al_2O_3 vs. CaO + Al_2O_3 and the plot of (Na_2O + K_2O) / (FeO + MgO + TiO_2) vs. Na_2O + K_2O + FeO + MgO +

TiO_2 shows protolith of charnockites are amphibolitic in composition with high Ba - Sr granitoid nature and Rb enrichment. Based on the available data on the charnockites, it is observed that there exists no marked compositional variation among charnockites across Painavu - Trichur segment of KKPTSZ.

Analysis of gravity and magnetic anomalies of South Rewa Gondwana rift basin, India

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South Rewa Gondwana basin (SRB) situated on the northern part of Son-Mahanadi rift basin of India, is a typical intracratonic basin containing more than 4 km thick Gondwana sediments. A total of new 2500 gravity data, with a station spacing of about 1 km, and 5000 magnetic data with 0.5 km spacing were collected and prepared the complete Bouguer anomaly, as well as IGRF, corrected Total Intensity Magnetic anomaly map.

The Bouguer gravity anomaly map depicts WNW-ESE and ENE-WSW anomaly trends in the southern and northern part of the basin, respectively. The sharp gravity gradient coincides with the boundary fault between the exposed Archean basement/Mahakoshal rocks towards the north. Gravity low over the exposed Deccan volcanic in the south may reveal the presence of subtrappean sediments. 3D inversion of residual gravity anomalies has brought out undulations in the basement, delineating two major depressions (i) near Tihki in the north and (ii) near Shahdol in the south, which divided into two sub-basins by an ENE-WSW trending basement ridge near Sidi. The maximum depth to the basement is 5.5 km towards the northeast of Tihki Well.

Total intensity magnetic anomaly map of this region has brought out linear bi-polar nature with ENE-WSW to E-W trending short-wavelength anomalies intruded by mafic dykes and sills. It is interesting to note that the amplitudes of magnetic anomalies are positive in the north, whereas these are predominantly negative in the south. Some significant high-low pair of anomalies may be associated with basic intrusive dykes, having remnant magnetization corresponding to upper normal and reverse polarity (29N and 29R) of the Deccan basalt magneto-stratigraphy.

Besides, the joint analysis of gravity and magnetic field, using the constraints from the borehole and seismic studies, has been carried out to delineate the shallow basement structure of the South Rewa basin. This joint modelling reveals large upwarps and downwarps in the basement, which is fault-controlled. It has brought out transverse ridges separating the basin into a number of sub-basins. Dykes intruding the sediments belongs to normal and reverse polarity chron of Deccan volcanism.

On degeneration of the Shafat glacier (1971-2017), western Himalaya and plausible controls

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Possessing a unique geometry, every glacier behaves heterogeneously towards the climatic conditions. Their comprehensive behaviour, is thus, necessary to be evaluated in detail to develop a complete picture of glacier response. Remote location, rugged terrain and inhospitable climatic conditions limit the continuous monitoring of these glaciers. Therefore, remote sensing can be used as a best tool to compliment field studies spatially and temporally. Comprehensive glaciological studies, considering multiple glacier parameters are meager in the Himalayan region, particularly the Ladakh Himalaya. Therefore, this study is an attempt to understand the multidimensional variability of the Shafat glacier parameters (area/length/ debris cover/ surface ice velocity (SIV) / surface elevation change (SEC)), for the period 1971-2017 and correlate them to the climatic (temperature and precipitation) and non-climatic (debris cover, topography, glacial lakes) variables. Shafat is a north-south trending glacier in the Suru sub-basin, J & K, India. It is a partially debris covered glacier, with the total debris coverage of 25% (2017). To accomplish our objectives, we have utilized high-medium resolution satellite imageries of Corona-KH4B, Landsat series sensors: TM, ETM$^+$, OLI and Terra ASTER during the period 1971-2017. State of art methods have been used for estimation of glacier parameters and associated uncertainties.

Results reveal a degenerative pattern of the Shafat glacier during 1971-2017 period. The glacier area has reduced by 8% from 34.6 ±0.13 (1971) to 31.9 ±1.6 (2017) km^2, with an average growth in the supraglacial debris (SGD) by 1.52 times. Meanwhile, the glacier has retreated by an overall 438 ±32 m (retreat rate of 26 ±0.7 ma^{-1}), with an average debris thickness of 10.4 cm in 2017. Besides, the phenomenon of glacier disintegration has also been observed post 2000, in which the main trunk separated into two glacierets, i.e., Shafat-1 and Shafat-2. The differential distribution of SGD might have facilitated the enhanced degeneration, resulting into the glacier disintegration. Moreover, the overall shrinkage and retreat of the Shafat glacier is synchronous with an increase in minimum and maximum temperature by 38% and 6%, respectively during the period 1971-2017. The annual average precipitation has also increased during this period, however, insignificantly (1%). The glacier has also slowed down by an average 5% from 10.33 ±3.68 (1993/94) to 9.83 ±1.83 ma^{-1} (2016/17). However, an increase in glacier velocity has been observed during 1993-2000 (18%), with a pronounced decrease (19%) thereafter from 2000-2017. The decline in glacier velocity during 2000-2017 is accompanied by surface lowering of nearly 0.82 ±0.15 m.w.e.a^{-1} during the period 2000-2017. The debris accumulation was more (65%) during 2000-2017 as compared to that during 1971-2000 (54%). Also, glacial lakes of variable sizes (0.003 to 0.03 km^2) have formed after 2000. These results indicate towards the negative health of the Shafat glacier, with an enhanced degeneration post 2000. The prime driver for overall glacier response can, thus, be ascribed to the climatic conditions prevailing in the glaciated valley. However, the pronounced glacier changes in the last two decades (2000-2017) may be attributed to the differential distribution of debris coverage and associated glacial lakes.

Shear wave velocity distribution along coastal corridor of Andhra Pradesh and Odisha states

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The paper presents the shear wave velocity profile along the east coast of India covering coastal Andhra Pradesh and Odisha states. The estimation of shear wave velocity plays a significant role in earthquake hazard studies. Generally, the coastal region consists of thick alluvium cover which tends to amplify at certain frequencies during earthquakes. Keeping this in view, the shear wave data was acquired at selected locations using Multichannel Analysis of Surface Waves (MASW). Seismic refraction studies were used to estimate the (V_P) at the same locations of MASW. Using the obtained velocities the average shear wave velocities (V_S^5, V_S^{10}, V_S^{15}, V_S^{20}, V_S^{25}, V_S^{30}) were computed. The study was substantiated by estimating the N values, fundamental frequencies and the corresponding amplifications. The acquired V_S using MASW is found to be in the range of 150m/s to 1800m/s and the sites with low Vs in the range 150-200m/s. Low shear wave velocity sites showing the maximum amplification of 5.2 at fundamental frequency <1Hz. Further, N values vary in the range of 0 to 50. The results revealed that the deeper bedrock (<30m) from Srikalahasti to Vishakhapatnam whereas at sites from Vishakhapatnam to Berhampur bedrock depth noticed below 30m. From Berhampur onwards the deeper bedrock is observed i.e (>30m).

Characterization of Porosity, Pore-size Distribution and Permeability estimation in Tight Formations of North East India regions

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In today's scenario of hydrocarbon production, extraction of oil and gas from unconventional reservoirs becomes more important. However, production from these reservoirs is still challenging. Tight formation refers to low permeability reservoirs characterized with low porosity, small drainage radius and low productivity. Tight reservoirs are generally defined as having less than 0.1 milli Darcy (mD) matrix permeability and less than ten percent matrix porosity. But these reservoirs account for a large percentage of the long-term supply of oil and gas. The prospecting potential of oil and gas production largely depends on the quality of the reservoir. Unlike conventional reservoirs, the quality of tight formation cannot be measured from their porosity and permeability alone, because their physical properties can be poor and their pore-throat geometry very complex. Therefore, a better understanding of the pore microstructure would be of great significance for knowing the migration mechanisms of

hydrocarbons; which would advance our ability to precisely assess potential of hydrocarbon reserves in tight formations.

This work focus on rock properties estimation of sediments of Upper Assam and Mizoram areas. The study area covering parts of Mizoram and Upper Assam of northeastern India belongs to Assam and Assam-Arakan basin. The study area from Mizoram is a major part of Surma basin. The study area belonging to Upper Assam basin is located in the south of the Brahmaputra River. The south east dipping area is bounded by the Himalaya mountain ranges to the north, the Naga Hills on the southeast and the Mikir Hills to the west. In order to understand the rock physical properties an integrated approach using well log data and rock physics is employed here. In tight formations, porosity, pore throat size distribution (PSD) and permeability are the key petrophysical properties which describe reservoir potentiality of production. The pore structures of reservoirs are investigated by various laboratory techniques, including thin section analysis, scanning electron microscopy (SEM), X-ray diffraction (XRD), 3D micro CT scan and N_2 gas adsorption on core samples collected from the wells of the study area. However, each technique has its own advantages and disadvantages. Finally, the results of the different techniques are compared and calibrated with the conventional as well as NMR log derived properties. The results of this study would assist in comprehensive evaluations of the reservoir by achieving the main objectives (a) to analyze pore types of the tight formation using laboratory measurements, (b) to characterize the pore structure from different direct and indirect techniques and to discuss the complexity of pore network of tight formations, (3) to compare the different techniques of porosity, pore structure and permeability estimation.

AMT studies across Tural and Rajawadi geothermal zones

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Tural and Rajawadi Geothermal springs form the southern segment of springs that spread over a linear stretch of about 300 km along the west coast fault trending in NNW-SSE direction. During March-April 2019, detailed audio magnetotelluric (AMT) survey was carried out across Tural and Rajawadi springs to understand geoelectrical structure and possible source zone for the above-mentioned springs.

AMT data has been collected along 17 stations along E-W profile with station spacing of 1 km. Regional strike have been estimated through Phase Tensor (PT) and Groom-Bailey (GB) techniques suggests N 45^0 E & N 54^0 E regional strike direction for Tural & Rajawadi profiles that correlates well with the low gravity anomaly trending in NE-SW direction. 1D Occam inversion brings out the source region at a depth of about 2-4 km for Tural region and is located towards east of the profile. In case of Rajawadi profile, the source region is deep seated beneath the spring at a depth of about 4 -5 km. These anomalous conductivity zone could be associated with the formation of hot water aquifers related to fractured controlled meteoric fluid circulation.

Unstructured grid based forward and inverse modeling for different geophysical data to improve subsurface structures

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Regular grid based discretization of subsurface has been widely used as conventional discretization approach. However, it provides lower precision when it comes to model the topography and complex shaped anomalous bodies within the subsurface. In present work, we have used triangles for discretizing the subsurface because it does overcomes the problems encountered by the regular gridding method. From already presented work of various researchers and authors, Forward formulation for Gravity, Magnetic and VLF Electromagnetic data has been taken in such a way that supports the resulted anomaly due to a three sided polygon which in our case is a delunay triangular cell and assuming physical properties within that particular triangular cell as constant, Net response of the subsurface anomalous body is modeled by summing the effect due to all triangular cells. For inversion, we have used the optimization scheme of Conjugate Gradient method which guarantees the convergence within n-steps for n-dimensional model space, Kernel matrix has been converted to square symmetric and positive definite by preconditioning the kernel matrix because this is the prerequisite condition for using conjugate gradient algorithm. The obtained results of forward and inverse modeling for different geophysical data has been compared with various real and field data set and results are matching exactly as expected.

Calibration of a Local Magnitude Scale M_L and Empirical M_L – M_W relation for the Kachchh region, Western India

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Kachchh region in the western continental margin of India is one of the most active intraplate regions of the world. In view of this, comprehensive seismic hazard assessment is necessary to mitigate losses. An earthquake catalog with calibrated local magnitude scale (M_L) is essential for such an endeavor. We have developed a local magnitude scale (M_L) for the Kachchh region for the same. A total of 9167 amplitude measurements on the horizontal component recordings of 1456 earthquakes with hypocentral distances ranging from 6 km to 100 km were used to derive this scale. All the amplitude measurements were inverted simultaneously to determine constants that define the local magnitude scale and station corrections for the Kachchh region. The final distance correction term for the Kachchh region is given by *-log (A0) = 1.86 log(r/17) – 0.00195 (r-17) + 2* and *-log (A0) = 1.83 log(r/100) – 0.00236 (r-100) + 3* for 17 km and 100 km normalization, respectively. The distance correction term at 17 km normalization suggests that attenuation in the Kachchh region is higher as compared to other regions of the world, for hypocentral distances above 45 km. We have also computed the standard deviation of the magnitude residuals to check the effect of the newly derived attenuation terms on the magnitude estimates. While the standard deviation without station correction is 0.26, the value is 0.22 with station correction. This indicates that the use of station correction reduces the variance by 30% and brings the average residual closer to zero. The station corrections obtained in the present study varied from -0.20 to +0.27. The relationship between the local magnitude M_L (this study) and the moment magnitude (M_W) reveals that the derived M_W is larger for earthquakes with magnitudes smaller than 3 and smaller for earthquakes of larger magnitudes.

Relationship between electrical resistivity and seismic v_p/v_s ratio: A case study from Koyna –Warna Seismic Zone, India

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We establish a relation between electrical resistivity (ρ) and seismic Vp/Vs ratio by analysing two dimensional (2D) resistivity and seismic Vp/Vs sections of two coincident profiles from Koyna-Warna Seismic Zone (KWSZ), India. First we analyse the 2D sections at each grid points of the resistivity model and found that the electrical resistivity and the seismic Vp/Vs ratio for this zone can be related as $Vp/Vs = (-0.0907 \times \log \rho) + 2.0137$. Later we use this relation to construct the initial resistivity model from known Vp/Vs values and use the constructed models as a priori information during inversion to compensate the data gap region of KWSZ. To test the effectiveness and reliability of the suggested relation, we compare the earthquake hypocentre distribution in KWSZ with the inversion results and came up with satisfactory outcome.

Quark Gluon Plasma: A State of Matter of Earth (A Fraction of second just after the Big Bang)

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The order of Quark-Gluon Plasma (QGP) phase transition under a model density of states for quarks and gluons in analyzed. In the course of analyzing order of phase transition of QGP, we compute the thermodynamic quantities of the quasi static state of QGP Droplet. The concept of Big Bang is known, we look to find what existed a fraction of second after the Big Bang and study the state of earth after a millionth second after the Big Bang. The states of matter and the Geophysical properties of Earth that we see around in nature were completely different millions of years back. Earth and the Universe have evolved a lot over the time. The quark-gluon plasma is a state of the extremely dense matter with the quarks and gluons being its constituents. Soon after the Big Bang the Earth matter was just in such a special phase, called the Quark Gluon Soup/Plasma. When the Universe was expanding and cooling down the quark-gluon plasma turned into hadrons-neutrons and protons, in particular-which further formed the atomic nuclei.

There are currently impressive evidences that the universe started as a fireball, the alleged "The Big-Bang", with to a great degree of high temperature and high energy density. For a few micro of seconds, Shortly after the Big Bang, the early universe was at a high temperature ($T > 100GeV$) and high density environment that all the known particles (including quarks, leptons, gluons, photons, Higgs bosons, $W\pm$ and Z) were extremely relativistic. Even the strongly interacting particles, quarks and gluons, would interact fairly weakly due to asymptotic freedom and perturbation theory should be sufficient to describe them. Thus this was a system of hot, weakly interacting color-charged particles, a quark-gluon plasma (QGP), in equilibrium with the other species.

To reproduce conditions like those of the early Universe and understand the characteristics of initial stages of earth, researchers have directed numerous experiments since the mid-1980s. Calculating the Free Energy and observing its decreasing trend is a hint that QGP could have existed in nature at some point of time. In the era 1995-2003, CERN and BNL made another several attempts to detect the existence of QGP with the highest beam energy reached up to 11 GeV (per nucleon). These collisions generated thousands of particles per event with energy densities exceeding $1 GeV/fm3$, emphasizing that the community had produced small samples of a new form of condensed matter. The data could be successfully interpreted according to hypothesis of QGP formation as a nearly perfect liquid, not a weakly-interacting gas thus birth of new state of matter of Earth.

It is expected that Large Hadron Collider (LHC) at CERN (European Organization for Nuclear Research) may facilitate that QGP state through ALICE in the Laboratory. The LHC is the world's largest and biggest energy particle accelerator.

Connectivity of the hydro-morphology with subsurface structures and seismicity in the Koyna-Warna region

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Earthquakes in the Koyna-Warna region are controlled by interaction of hydrology with subsurface structures. Several investigations have been done on the correlation of earthquakes with water level changes in boreholes.

In our present study we investigate the connectivity of the surface hydro-morphology with subsurface structures and connection to continued seismicity in the Koyna-Warna region. Drainage network system and watershed map have been generated from airborne LiDAR DEM. We used tilt angle derivative techniques to aeromagnetic data for subsurface structural mapping. Euler depth solution technique has been used to aeromagnetic data for fault location and their extent in the subsurface. Most of the Euler depth solution from aeromagnetic data showed upto the Deccan basaltic depth (~1km). Our results from integrated drainage network system with subsurface structures showed the direction of drainage system is largely controlled by subsurface tectonic process. The analysis of recent earthquake catalog data show, three clustering of epicenters along i) NNE-SSW south of Koyna reservoir ii) NW-SE north of Warna reservoir and iii) N-S south of Warna reservoir. Most of the earthquakes occurred in the region of four large watersheds with medium to high slope area. The combination of all these studies reveal connectivity of surface water flow into existing fault system in the basement which increases pore pressures leading to triggered seismic activity in this region.

HIMALAYAN CRYOSPHERE CLIMATE INTERACTIONS, CONSEQUENCES AND FUTURE TRENDS (HCCF)

Glacial varve and moraine sediments as Palaeoclimatic Archives in Lahaul & Spiti Valley, NW Himalaya: present understanding

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The Himalaya orogeny is a classic example of an orogenic system of immense significance, it also bears thousands of glaciers, thus, source of fresh water supply to the Indian subcontinent. Secondly, its position at the semi-arid to the arid desert (westerlies influenced) makes it unique to understand the different phenomenon associated with lower and upper atmospheric circulation. However, the region has also received more snow/rain earlier, during Abnormal Monsoon Years due to the northward shift of Intertropical Convergence Zone (Bookhagen et al., 2005). The glacial lakes in this region are the best example of valley glaciations and count as the best archive to record continuous palaeoclimatic data from terrestrial region. The study was carried out in two Palaeolake, section with special emphasis on palaeoclimatic reconstruction and tectonic activity during the late Quaternary. At Hansa, major phase of the inverted sequence of aggradation is observed at ~12.3 ka BP. Similarly, one more varved palaeolake profile (~ 8 m thick), in upper Lahaul was analyzed using geomorphic, sedimentological, geochemical, magnetic and carbon isotope proxies. AMS radiocarbon chronology covers the lake bracketed between 25-3 ka BP, which bears the signature of the warm and humid climatic condition during past. The formation of lake initiated ~25 ka BP and continued till 3 ka BP and also bears soft-sediment deformational structures. The seismic activity in this 8~m section recorded at ~25 ka BP, ~20.1 ka BP and 12.1 ka BP and characterized by the presence of cycloids or pseudo nodules, ball and pillow structures, flame-like and pocket structures, sand dyke injections, bed dislocation/faulting and flow folds. From earlier published data and the seismic events recorded in this palaeolake section suggests that these are regional in nature and thus tectonic process plays an important role in the evolution of landform in the Spiti region.

ADVANCES IN HYDROCARBON AND ALTERNATE ENERGY RESOURCES

Complex structure interpretation for detection of thin sand reservoir body in deep shale formation: a case study from Stratton field, South Texas

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The Stratton field is a famous natural gas producing province in the South Texas region of Kleberg and Nueces counties in the USA. The primary reservoir of this province is the Oligocene Frio formation, and it is a thick, fluvially deposited sand-shale sequence type reservoir. Growth fault and rollover anticlines are the part of Frio formation, and this is extended up to deeper layer in the area. The reservoir architecture in Frio formation primarily is observed as channel fill reservoir as thin and narrow shape. Our study did focus on deeper part of the sub-surface geology, especially in shale formation. This shale formation is deposited at the bottom of Frio formation. The top of the shale formation reported as approximately 2000m. The fluvial system domination in depositional history made highly heterogeneous reservoir character in the study area. The object was to find out reservoir facies in the deep deposited shale formation. The study is conducted over post-stack zero-offset seismic data with the close association of conventional well log data. Spectral decomposition analysis in different frequency level with the help of MPD algorithm is used for this study. The well log analysis is supported as a crucial step for spectral decomposition study. The thin-bed reservoir body is identified at well level with the help of log responses in shale section, and in the later stage, it is characterized in spectrally decomposed seismic volume. The study has also represented the complex structural framework with higher detectability of spectrally decomposed data. The geobody interpretation of scaled spectrally decomposed seismic supported by well log data detected the thin-bed reservoir extension in the significant shale formation at deeper level of the Stratton field, South Texas.

3D post-stack seismic inversion for identifying reservoirs in the formations and the basement of upper Assam Basin

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Seismic inversion is the process to transform the wavelet of original reflection data into a quantitative rock-property (i.e., impedance). In the paper, the seismic inversion is used only model-based inversion to extract the absolute value of impedance from 3D seismic data in the upper Assam basin which is located in the northeastern India. The valley is a northeast to southwest trending intermountain basin between the eastern Himalayan Mountains and the Assam-Arakan fold and thrust belt, where oil occurs in fractured granitic basement rock (Precambrian). The basement is deepens toward the northeast direction. The block using in

the paper is of Dhansiri valley of upper Assam valley, which covers 81sq km of the area. The well log (KA) imported in the seismic section is Kasomarigoan for correlating its events with the seismic events. The reservoir estimates in KA well is at depth ~1900 m to ~2200m and the basement is at ~2200m depth. The well log imports in 3D seismic data are at inline-325 and crossline-300. The horizons are picked at time 1409.1ms and 1629.79ms for Barail and basement formations respectively. First, statistical wavelet has been extracted and synthetic seismic events have been generated. The synthetic and seismic events are being tried to match at the maximum correlation value. Then, the same process again has been repeated for another wavelet extracted from seismic and log data both. Finally, The correlation of well to tie seismic is 0.626. The initial background model of impedance has been produced for low frequency below 10/15 Hz. The error between initial log impedance and inverted impedance is ~3368.65 ft/sec*gm/cc and residual error between seismic trace and synthetic trace is ~0.12 after model-based inversion. Finally, impedance volume has been produced for Barail and basement showing higher values of impedance. The basement is dipping in NE direction containing thicker sediments with lower impedance values. The fracture in the basement is also noticed filled by lower impedance sediments indicating the presence of oil-bearing sand.

Reservoir facies Prediction from Well Log Data Using Statistical Tool

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Lithology identification from well log data is essential, and consistent work in reservoir characterization. Multiple methods have been developed for lithology identification from well log data. There are few intrinsic properties of rock which use to identify the lithology of formation. Conventional well log data such as Gamma Ray (GR), Self-Potential (SP), Density (Rhob), Neutron-Porosity (NPHI) and Resistivity (shallow and deep) are important log for lithology identification. Based on high and low values of conventional well log responses the lithologies of the formation are determined. These cut-off values are treated as foundation for dominant lithologies of the reservoir formation such as shale, sand, siltysand, and shaly-sand. The significant challenges for identification of reservoir facies observe during clastic-carbonate involvement scenario in the reservoir. Our work is based on sand, shale, limestone, and dolomite lithology scenario from which reservoir facies has identified. The study is conducted based on statistical analysis of well log data which was justified with sidewall core (SWC) data. The lithoporosity function (M) and lithoporosity variable (N) are the fundamental functions for the statistical analysis of well log data. Both these factors can be related to bulk density (for M and N), sonic transit time (for M) and neutron log (for N). The low and high-value cut-off in M and N plot is used for identification of possible reservoir lithology in clastic-carbonate sequence. In the next phase of the study the M-N plot is used to identify the reservoir facies under contributory reservoir lithology of clastic-carbonate reservoir formation sequence with distinct separation from non-reservoir facies.

Attribute Analysis for Fault and Fracture Delineation -A Case study from Combat Basin.

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The role of faults and fractures in oil and gas exploration is invaluable. Identifying structural information of subsurface area is the most important objective in hydrocarbon exploration. Faults and fractures are the major components of structural information and mapping these faults and fractures gives valuable information about fluid and their flow inside the reservoir. Seismic attributes often provide a quick way to visualize the trends of faults and fractures which are not visible in seismic amplitude. The objective of this study is to delineate faults and fractures in the study area though different attribute analysis. Application of these attributes with proper conditioning of seismic data can provide crucial and valuable information about faults and fractures of the study area.

The data used in the present study is conditioned by applying different filters. This forms the key step in improving the seismic data quality is reducing uncertain noise. Dip Steered Median Filter (DSMF) and Fault Enhancement Filter (FEF) techniques are applied on the given seismic data to remove the noise and to delineate the faults and fractures with more confidence. As a result, the continuity of events are enhanced considerably. Geometric attributes from the seismic data are derived to delineate the fault and fracture geometry. It was observed that the faults and fractures in the central part of the study area are associated with main fault and are delineated clearly by geometric attributes. The polar dip and the most negative curvature attributes have clearly indicated the geometry of the faults and the fractures. An integrated analysis of all the attributes has clearly depicted the existence of faults and fractures in the central part of the area and their association with main fault.

Geological interpretation of well log data from D-6 Block, KG Basin, India

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Geological interpretation can be carried out in several phases, such as during drilling, after logging as a thorough log interpretation, and in the laboratory key evaluation, etc. As logging tools and techniques of interpretation develop in precision and sophistication, they play an extended part in the process of geological decision making process. Petrophysical log interpretation is one of petroleum geologist's most helpful and crucial tool today. Logs help to identify physical rock features such as lithology, porosity, pore geometry, and permeability in addition to their traditional use in exploration to correlate areas and assist with composition and isopach mapping. In this study, geological interpretation is performed from the wireline logs from the D-6 block, KG Basin, India. Lithology was recognized from Spectral and Natural Gamma Ray records where resistivity and lithology logs, including cross-checking of porosity logs, detect hydrocarbon bearing areas. The quantity of the shale is estimated from the techniques of Gamma Ray and true Resistivity respectively. Porosity was estimated from both single log techniques and the combined formula of Neutron-Density. Six sand zones are present in this well, where tiny mud cake is present within the depth interval of gas bearing sand areas, according to log data analysis. The dominant lithology is laminated shale. Different crossplots such as neutron density, neutron sonic and sonic density is also produced to identify rock type in the reservoir.

Evaluating in-situ stress and safe mud window for the influence of CO_2 injection: A case study in Cambay Basin, India

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As one of the possible ways to alleviate climate change, large volumes of CO_2 ought to be injected in hydrocarbon reservoirs, implying geomechanical challenges to be understood properly. In general, the reservoir experiences pressure build-up due to CO_2 injection that may affect the fault stability. In this study, we investigate the geomechanical effects due to feasible CO_2injection in the reservoir from Cambay Basin, India to improve understanding of the in-situ stress behavior and wellbore stability. This analysis involves estimation of pore pressure and fracture pressure using high resolution wireline log data. To ensure fault/well stability, we show examples for pre and post CO_2 influence on the stress regime of the reservoir under study. Wellbore stability is realized considering three well-known borehole failure models e.g., Mohr-Coulomb, Mogi-Coulomb and Modified Lade.

Prior to CO_2 injection, the estimated pore pressure in Ankleshwar formation ranges between 9-13.5 MPa, which increases to about 15% due to the influence of CO_2. Nevertheless, the stress state in this field is anticipated not to be disturbed much to reactivate the fault system or causing wellbore failure. Further, in comparison with two other well-known models, Mogi-Coulomb failure model is found to be most suitable to decipher the required minimum mud pressure for this reservoir, which is recommended further for future sustainable well planning in this field. This study has major implications to understand the geomechanical response in this mature field and ensure safe drilling during long-term field development through pressure and wellbore stability studies, especially when a reservoir undergoing CO_2 injection.

2D hydrocarbon acoustic modeling to generate synthetic seismogram.

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Full waveform inversion (FWI) is a promising technique to accurately model the finer details of buried complex structures and therefore, it has been widely used in hydrocarbon industries to decipher reservoir properties. Forward wavefield modelling is an essential and necessary step in FWI to generate synthetic seismogram. Solving acoustic wave equation numerically using the finite-difference (FD) method has been proven to be an efficient technique, which generates reflected phases along with other phases including refracted arrivals, multiples from different reflectors in a synthetic seismogram. we have generated several synthetic seismograms tests on 2D models that we have developed in house by implementation 2D forward modelling acoustic wave equation algorithm that we have developed inhouse. The synthetic seismogram are developed for simple 3 layers case, keeping a spherical inclusion in the centre of the middle layer and then for the complicated geologic setting introducing faults in it. Finally, we have generated shot gathers using the Marmousi model. The effect of reflections from the model boundary is reduced, initially, using perfectly matching layer (PML) artificial absorbing layer and then using convolutional perfectly matching layer (CPML) technique. The accuracy of the modelling is tested comparing the numerical solutions with the analytical ones.

COUPLING BETWEEN EARTH SYSTEM PROCESSES AND ITS MANIFESTATION IN THE HUMANOSPHERE

Investigating the Horizontal Accuracy of Standalone-Galileo System Over a Low Latitude region

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European Galileo is a Civilian controlled Space-based Satellite navigation system. Galileo employs 30 equally spaced satellites (currently 22 satellites are in operational) within three orbital planes at an altitude of 23,616 km with a 56-degree inclination. The higher altitude and inclination offer the Galileo better coverage including some polar regions especially benefiting civilian users in Scandinavian countries, than military-controlled united states GPS. Galileo provides services across the globe with a combination of the E1(1575.42 MHz), E5A (1176.45MHz), E5B (1207.14 MHz) and E6 (1278.75 MHz) signals. The initial services of Galileo offered from December 2016. To evaluate the performance of Galileo-only, 24-hours raw data is collected on 27th July 2018 at Advanced GNSS Research Laboratory (AGRL), Osmania University, Hyderabad (17°24'28.07"N, 78°31'4.26"E) using Novatel triple-frequency GPStaion-6 receiver. The Standalone-Galileo accuracy is much affected by the number of active satellites and their geometry over the horizon indicated by GDOP parameter (Geometric-Dilution of Precision). The number of visible satellites throughout the observation period is about a minimum of 4 and maximum of 10 satellites. According to satellite visibility and corresponding geometry, the GDOP parameter is of about maximum 4.03 and minimum 1.49. Similarly, HDOP is maximum of 2.31 and minimum of 0.74 are observed. GDOP and HDOP parameters have values within the acceptable good range for better position accuracy. However, the accuracy is worse when the visible satellites are around 4 to 5. Accuracy index is often represented by DRMS parameter (Distance-Root-Mean-Square), 2DRMS and CEP (Circular-Error-Probability). The CEP (2.38m), DRMS (3.12m), 2DRMS (6.24m) describes Standalone-Galileo accuracy. Here, CEP indicates that 50 percent of the position fix errors don't exceed 2.38 meters. The obtained results will be helpful for the development of future single- frequency Galileo receivers as done for GPS and how it will increase the position accuracy when used with other GNSS or regional systems for Hybrid-positioning.

Coupling of Lithosphere-Atmosphere- Ionosphere during Japan Earthquakes

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A necessary channel of Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) is acoustic and gravity waves and the most important role is played by ionization process. Before any seismic process, atmospheric waves are excited this influenced due to seismic gravitational variations. These effects are seen in the atmospheric or even in the ionospheric region. Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model define the events as a synergy between different ground surface, atmosphere & ionosphere processes & anomalous variation which are usually known as earthquake precursors. Present work provides information about

ionosphere & their physical process involved in generation of anomalous seismic atmospheric phenomenon. In Japan region various earthquakes are examined and Lithosphere-Atmosphere-Ionosphere coupling (LAIC) is verified by using satellite & ground based data sets. During tectonic activity greenhouse gases such as methane (CH_4) , nitrous oxide (N_2O) ,water vapour (H_2O) & carbon-dioxide (CO_2) are released, and they absorbed certain wavelength of Outgoing Long wave Radiation (OLR) which contributes in adding more heat to the atmosphere. Meanwhile in the ionosphere, F region is perturbed due to ionization of green house gases and it will take place generate modulated anomalous waves.

The local anomalies are also observed along with larger linear fault system by NOAA gridded satellite data. The short term earthquake precursors based study to clarify the Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) approach to solve the earthquake problem.

Estimation of GLONASS Receiver Bias Using Fitted Receiver Bias Method

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Global Navigation Satellite System (GNSS) includes Global Positioning System (GPS) of USA, Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) of Russia, GALILEO of the European union and Beidou of China. GLONASS constellation is operated by the Ministry of Defense of the Russian Federation. GLONASS consists of 24 satellites, using frequency division multiple access technique (FDMA). The frequencies for the L1 and L2 signals are given by 1602 MHz and 1246 MHz. The position accuracy of GLONASS system is limited by several errors such as ionospheric error, tropospheric error, clock error, multipath and ephemeris error. Among all the errors, ionospheric time delay error is the predominant error, which depends up on the Total Electron Content (TEC). As TEC measurements are corrupted by receiver instrumental bias, estimation of receiver bias is an essential step in TEC data processing. The instrumental biases exist as the signals at the two GLONASS frequencies experience different delays within the GLONASS satellite and receiver hardware. In this paper, the receiver instrumental bias is estimated using Fitted Receiver Bias (FRB) method. To carryout this work, GLONASS data is collected from triple frequency GPStation6 (NovAtel) receiver (Lat: 17.400N Lon: 78.510E) is located at Advanced GNSS Research Laboratory (AGRL), Osmania University Hyderabad. The considered days are 18th April 2017 and 21st May 2017. Also, the results of TEC estimation before and after the receiver bias removal are presented. It is observed that estimated receiver bias values for GPStation6 (NovAtel) receiver is -10ns and -9ns. It is, observed that before removal of satellite and receiver bias values the STEC (Slant TEC) values are varying from -18.7738 to -13.8368 TECU for PRN18 and -20.37356 to -15.390282 TECU for PRN21. After removing the receiver bias, the STEC is found to be vary between 11.45614 to 16.39316 TECU for PRN18 and 0.88459 to 5.867868 TECU for PRN21. It is, observed that before removal of satellite and receiver bias, the STEC values are varying from -10.7406 to -11.3061 TECU for PRN6 and -10.7406 to -8.354 TECU for PRN7. After removing the receiver bias the STEC is found to vary between 0.0125 to 2.345TECU for PRN6 and 7.7359 to 10.122 TECU for PRN37. These results will be helpful in development of hybrid solution for the dual frequency receivers.

Rock magnetic investigations on road dust and fly ash near Mejia Thermal Power Station of West Bengal, India: emphasis for industrial pollution

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Investigations are carried out to delineate the relative degree of fly-ash and industrial pollution using rock magnetic methods. Due to strong correlation between heavy metals and magnetic minerals present in soils, we use rock magnetic study as a proxyto characterize the anthropogenic magnetic particles in road dust from typical industrial cities of West Bengal by tracing the distribution and concentration of magnetic contaminants along the thermal power stations in the present study. 45 Dust samples and 44 soil samples were collected during pre and post monsoon time from the crossings and the middle of the street junctions around Mejia Thermal Power Stations (MTPS). The rock magnetic measurements such as magnetic susceptibility (k), Isothermal Remanent Magnetization (IRM), hysteresis loop, backfield (coercivity remanence) and k-T (Susceptibility vs. Temperature) analyses were performed using Advanced Variable Field Translation Balance (AVFTB) at CSIR-NGRI, Hyderabad to identify the magnetic properties of dust and fly ash samples. 13 representative samples from pre monsoon period were analysed and the results suggest that the magnetic mineralogy is predominantly carried by Magnetite (Fe_3O_4) and also indicate the presence of other magnetic minerals such as Titanomagnetite solid solution series which varies between Fe_3O_4 and $TiFe_3O_4$. Due to the presence of magnetite in representative samples heavy metals concentration also increased which can create many health issues for humans, animals, and plants as well. The Hysteresis loop ratios; the Remanence ratio (Mrs/Ms) and the Coercivity ratio (Bcr/Bc) were calculated and plotted in the Day plot suggests a Pseudo Single domain state. Collectively, the magnetic properties of these dust samples are dominated by Pseudo Single domain state of Magnetite. k-T study also confirms that the remanence carrier is Magnetite (Tc = 578°C). We emphasise that the main source of pollution around MTPS could be from road traffic and fly ash which emitted from the thermal power stations. In this adverse situation we need strong remediation in order to reduce the pollution effects around these Thermal Power Stations.

The Preliminary Performance Evaluation of BeiDou Navigation Satellite System over a Low Latitude Region

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China has started developing its own global navigation satellite system is known as BeiDou Navigation Satellite System (BDS). It provides Position, Velocity and Timing (PVT) services to the global users. The development of the Chinese global navigation system will be carried out in three phases. In the first phase PVT services was provided for regional region, then it was enhanced to Asia-Pacific region in the second phase (BDS-2). The final phase (BDS-3) was started functioning over the global region by providing primary services since December 2018. The deployment of full constellation is expected to be completed by the end 2020. The current constellation status of BDS-2 is 15 satellites which include 5 GEO, 7 IGSO and 3 MEO satellites and BDS-3 is 18 MEO satellites. Presently, B1I and B2I two public signals are broadcasted by the BDS-2 and BDS-3 satellites in the frequency bands of B1 and B2. The center frequency of B1 band is 1561.098MHz and B2 is 1207.140MHz. The navigation messages in BDS-2 and BDS-3 are broadcast in two formats D1 and D2 based on their rate and structure. This paper presents the preliminary performance evaluation of BDS over a low latitude region. We assessed the performance of BDS-2 and BDS-3 in terms of Satellite visibility, Signal strength and Dilution of Precision (DOP) value at Hyderabad station. The results show that compared with BDS-2, the BDS-3 improves significantly in terms of Satellite visibility, Signal strength and DOP over Indian Low Latitude Region.

Multipath Environment Analysis using GNSS Interferometric Reflectometry (GNSS-IR) Technique

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The usefulness of Global Navigation Satellite Systems (GNSS) technology is not limited only to positioning, Navigation and Timing (PNT) applications but also revolutionizing in monitoring the environment. Multipath effect is considered as one of the major debilitating factor on GNSS systems. In the open literature, several approaches based on hardware, software and hybrid methods to mitigate the multipath are proposed. Since the multipath scenario depends on individual antenna environment, new techniques and methods like GNSS-IR are also now in use to sense the near-field environment. The signal reflections in near-field environment are due to terrain, buildings, etc. The focus of work in this context is mainly applied to understand the Fresnel zone for GNSS antenna site and estimation of changes in the height of a reflecting surface from GNSS SNR data. A multi-frequency GNSS receiver of Make: Septentrio, NV (Model: PolaRxs pro) capable of tracking GPS, GlONASS, Galileo and SBAS (WAAS, GAGAN, EGNOS) satellite signals was setup at Geethanjali College of Engineering and Technology (GCET), Hyderabad. The antenna was mounted on the terrace for better view of SVs. The data with sampling interval of 15 s is used for the

analysis. The first Fresnel map view shows a 360-degree azimuthal coverage at the site at an elevation of 15□ and below.

MARINE GEO-SCIENCES AND OCEAN SYSTEM

S-wave estimation and elastic parameters computation in anisotropic medium: A case study from Mahanadi offshore, India

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We have estimation of shear (S) wave and elastic parameters for understanding the anisotropy behaviour of gas hydrate sediments in offshore basin. Mahanadi basin offshore is located in the Eastern Passive Continental Margin (EPCM) of Indian sub continent. Gas hydrate in the basin is mainly connected with clay/silt sediments and fractures zones of Pleistocene age in the deep water. We have considered three wells (namely A-01, A-02 and A-03 with seafloor depth (1433m to 1935m) for estimation of the S - wave and elastic parameters in the study area. The S - wave estimations were first done by using Castagna's empirical relation between P- wave and S - wave velocity in the well A-01 which contains shear and compressional wave data. The estimated relation was used to calculate velocity of shear wave in other two wells. Therefore we can easily compute the elastic parameters (Young's modulus, Shear modulus, and bulk modulus) for A-02 and A-03 respectively. The value of elastic parameters such as young's modulus, bulk modulus and shear modulus increases from 268.33 to 565.38MPa, 3634.57 to 3780.55MPa, 291.60 to 580.38MPa in depth interval of 1493.11 m to 1690.32 m for well A-01, 354.36 to 423.97 MPa, 3392.88 to 3680.26 MPa, 119.53 to 143.97 MPa in the depth interval of 1935.02 to 2258.87 m for well A-02 and 372.82 to 485.43MPa, 3760.69 to 4021.62MPa, 125.69 to 164.05 MPa in depth interval of 1700.089 to 2031.86 m for well A-03 respectively. We have examined presence of anisotropy based on shear wave split data in well A-01 after computation of epsilon, gamma, and delta and fracture density with assumption that the fractured medium is transversely isotropic with a horizontal axis of symmetry (HTI). The anisotropy has been observed in depth interval from 1433 to 1935m and is further validated by natural fracture from micro image log data in the same well.

MINERAL EXPLORATION - CHALLENGES FOR NEW DISCOVERIES

Geothermal potential of Bakreswar-Tantloi geothermal area, Birbhum district, West Bengal: A promising green energy resource

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Geothermal energy resource of the country has the capacity to replace a substantial portion of its energy needs in the 21stcentury. However, at present, this virgin source of energy remains much unexploited in India. The present paper focuses on geothermal exploration of Bakreswar-Tantloi geothermal province. The said geothermal area is situated in a geologically mixed fractured and faulted area and consists of a cluster of several thermal springs with differing water temperatures (40^0C – 70^0C). The Bakreswar-Tantloi hydrothermal systems lie close to the extinct (117 Ma) Rajmahal volcanism of the Chotanagpur gneissic complex in West Bengal-Jharkhand area. The spring gas along with the soil air in the region is characterized by the presence of high helium as well as high radon flux. The paper describes some preliminary but important results on resistivity and magneto-telluric survey of Bakreswar-Tantloi geothermal area.

In resistivity traverse along Bakreswar-Asanshuli, one conductive anomaly zone localized in nature is mapped at n (separation parameter) =10 in between 1200-1500 m station. Bakreswar hot spring lies adjacent to it and geologically the source of hot spring may be controlled by hidden fault. In resistivity traverse along Chandrapur-Tantipara, the presence of subsurface conductive bodies (50-400 Ohm m) mapped between stations 1000-1200 m at a pseudo depth of 400-700 m, which is localized in nature. This may be the structural breaks like shear zones/geothermal region.

1D inversion of MT data indicates the presence of a nearly N-S striking buried fault which is not localized in nature providing passage for hot water to emerge in the form of springs. The fault is deep seated starting from shallow surface at Tantloito deeper depth around Bakreswar.2D inversion shows that the entire lower crust consists of an anomalous structure of conductive layers with a relatively low-resistivity (approximately in the range 40-90 Ohm-m) embedded in the high resistivity background. This feature is interpreted as a potential reflection of the partially melted magma in the upper crust, which might correlate to mantle upwelling along the fault. It is likely that the magma is the heat source of the Bakreswar geothermal system. Thus, this inference potentially provides new geophysical evidence to understand the occurrence of the partially melted magmas in the upper crust. These models suggests for a possible recovery of heat from heterogeneous, fractured geothermal reservoirs. The MT exploration of the geothermal reservoir can provide valuable constraints on the physical conditions within the delineated fault zone. It has guiding significance for the exploration of other geothermal resources along fault zones especially in granite areas.

Green Function Seismic Imaging

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An Upgoing Wave can be continued using information only from the upper surface. For a downgoing wave, the lower surface contributes to the result. For an upgoing wave, the anticausal Green's function removes the contribution of the lower surface from the Green's theorem expression. This makes sense, in that the anticausal Green's function extrapolates backward in time, which, for an upgoing wave, means downward in depth. Similarly, a downgoing wave can be extrapolated from the upper surface only, provided the causal Green's function is used. These observations extend to the case of a variable velocity, to the extent that up- and downgoing waves remain well defined. Kirchhoff migration is based on Green's function theory and on an integral solution of the wave equation. When the velocity function is really complex, and the wavefronts triplicate, the Green functions become multivalued, and consequently the summation surfaces become multi-branched. In theory, the computation of the migration integral (summation) is possible for arbitrary complexity of the summation surfaces. In practice, when the multipathing is severe, both the computation of the Green functions and the numerical evaluation of the migration integral become expensive and inaccurate. This is a practical limitation of Kirchhoff migration. the wavefield recorded at the surface, as a function of recording location and recording time. It represents the full-wavefield Green function in time-space domain corresponding to a reflector point located above the salt. A hyperbolic trajectory, which represents the approximate time-delay function employed by time migration, is superimposed onto the wavefield. In this case, the hyperbolic trajectory overlaps the "true" Green function almost perfectly. complex multipathing of the wavefield and the multi-branching of the Green function. The line superimposed on the wavefield represents the time-delay function computed using a finite-difference solution of the Eikonal equation. In this case, the Eikonal solution is a poor approximation of the "true" Green function.

Interpretation of Electromagnetic(EM) data using the concept of Analytical Signal

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The electromagnetic (EM) prospecting technique is most commonly used in mineral exploration. EM data can be acquired by different combinations of transmitter (T_x) and receiver (R_x). Unfortunately, for the same type of geological structure different combinations of T_x and R_x results in different response. EM data obeys Laplace's equation. In the present work one intends to interpret the EM data using the concept of analytical signal. Amplitude of analytical signal (AAS) is approximated by a bell shaped function which is dependent on the constant, the horizontal and vertical locations of the source and the nature of the causative source. The constant depends on the physical property. The peaks of AAS coincides with the edges or the peaks of the source. The methodology is a unified approach which does not require any *a priori* assumptions about the nature of the source geometry. Rather the nature of the source geometry will be deciphered/visualized by computing the structural index. It is a parameter related to source geometry. We have analysed field examples with different coil configurations over the same geological structure from the published literature. The field examples are over the vertical and inclined sheets. The optimizations of bell shaped function has been made through Grey Wolves Optimization (GWO). The optimization of profiles over the same target but with different coil configurations resulted in same horizontal location, depth of source body and structural index. The analysis over both vertical and inclined sheets resulted in structural index of 1.0.

Gold Mineral Exploration with Geophysical Data

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Geophysical survey in main challenges is to estimate the physical parameter using limited geophysical field data with noise. Geophysical datasets are measured with sparse sampling in a survey. However, the limited data constrain the geophysical interpretation. Generally, the Geophysical field data has been intercalates using mathematical algorithm. In some cases, the approximated field data inconclusiveness are prerequisite to determine which earth models are consistent with the observations. A miniature based data estimation method can provide precise information for imaging and interpretation. The approach used in this paper is based on a stochastic partial differential equation, and it is employed to predict the geophysical data. With this demographic model based approach, the inadequate sample from a survey is used to estimate the underlying spatial surface, and it is assumed that the predicted geophysical data have the same anticipation density function as the observed data. Furthermore, this method can return the uncertainties of the prediction. Both the fabricated data and the gold mineral exploration field data cases illustrate that this approach leads to better results than traditional methods.

Extension of Usgaon Ultramafics below the Sanvardem Formation in Goa by Gravity and Magnetic (Total Field) Interpretation

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A Geophysical Survey employing Gravity and Magnetic Methods has been carried out in Survey of India Toposheet No. 48I/3 & 4, comprising geologically of Barcem, Sanvordem and Bicholim Formations of Goa Group. These in turn are intruded by Usgaon ultramafic complex and younger granite. Gabbro/dolerite dykes intrude all the rock formations. Geologically reported two major folds which were oriented towards NW-SE may be one of the controlling factors for intrusion of ultramafic. The Gravity and Magnetic (Total Field) Geophysical mapping has been done with station density of one station per 2.5 sq.km.

The Bouguer anomaly value varies from -53 mGal to -94 mGal with relief of about 40 mGal. Magnetic anomaly value varies from -150 nT to 550 nT with relief of 700 nT. On the basis of the Bouguer anomalies characteristic features, the map is divided into three major zones viz. A, B and C. The area having Bouguer anomaly high, moderate and low is named as A, B and C respectively. Bouguer anomaly linears like nosing are correlating with axes of two major folds. Horizontal gradient of Bouguer anomalies has brought out the contacts between (a). Barcem and Bicholim Formations (b). Bicholim Formation and PGC-I. High values of horizontal derivative have been observed over the exposed Usgaon ultramafics and Sanvordem Formation. From the Bouguer anomaly and its derivative maps, it may be inferred that the exposed Usgaon ultramafics (bearing Chromite) has been extending towards SW direction below the argillite of Sanvordem Formation. Magnetic bipolar features and high analytical signal have been observed over exposed Usgaon ultramafics and inferred ultramafic below argillite of Sanvordem Formation. The euler deconvolution applied on gravity data gives depth of this ultramafic more than 2 kilometre. Thus, it may be emphasised that the geophysically inferred Usgaon ultramafic body extension should be explored for chromite.

Estimation of Lateral and Vertical Extensions of the Mangeniferous Phylite Band in Parts of North Kanara District, Karnataka by Gravity and Magnetic (Total Field) Methods

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A Geophysical Survey employing Gravity and Magnetic Methods has been carried out in Survey of India Toposheet No. 48I/9, 10 &11 having exposure of Pennisular Gneiss Complex-

I & argillite, sericite schist and meta-sediments of Chitradurga Group of Dharwar Supergroup of Archean time. The regional trend of the rock formations is N-S to NNW-SSE with moderate to steep easterly dips The work is aimed at estimating lateral and depth-wise extensions of manganiferous phyllites band falling in survey of India Toposheet nos. 48I/10 and 48I/11. Initially, for getting an idea about the manganiferous phyllites band, gravity and magnetic (total field) surveys have been carried out on a regional scale with a station density of nearly one statin in 2.5 sq.km area. After interpreting the results from these surveys, detailed gravity and magnetic measurements at 100m station interval were done along two profiles- first across the limb and the second across the hinge portions of megascopic fold, near Nagargadi and Ganeshgudi villages respectively.

The Bouguer anomaly value varies from -106 mGal to -79mGal with relief of 27 mGal. Magnetic anomaly value varies from -200 nT to 350 nT with relief of 550 nT. Based on the regional scale surveys, the Bouguer gravity anomaly map has been divided in to three major zones designated as “A”, “B” and “C”. Horizontal gradient of Bouguer anomalies has delineated the about 10 km laterally spread contact between the PGC-I and argillite of Dharwar Supergroup. Mineralisation of maganiferous phyllite band as evidenced from prospective mineral map prepared by Boolean method in ArcGIS, has occurred along this contact. Magnetic moderately low E-W oriented anomaly patch has been brought out and it is nearly following megascopic fold of manganiferous phyllites band. Detailed gravity and magnetic (total field) surveys near Nagargadi and Ganeshgudi brought out one kilometre extent of the band. The depths estimated by the Werner method and GM-SYS 2D modelling using density and susceptibility of the rock samples are170-250 metres and 250-300 metres for Nagargadi Ganeshgudi profiles respectively. This outcome will be a guide for further detailed exploration of magniferous phyllite.

Germanium in Coal and Ash from Kamptee Coalfield, Central India: Evidence for Zilbermints Phenomena

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Goldschmidt, way back in 1930, proposed coal fly ash as an alternate source for germanium with levels up to 1.1% in coal ash compared to crustal values (~ 1.6 μg/g). Germanium (Ge) is an unusual element exhibiting siderophile, lithophile, chalcophile, and organophile (bio lithophile) behavior and appears to concentrate at the top and bottom of coal seams, a phenomenon known as Zilbermints law. India has a large coal reserve of ~276 billion tonnes spread in more than 60 coalfields of Gondwana and Tertiary basins. An attempt is made here to investigate Ge in the lower Gondwana (Permian) Kamptee coal field in Maharashtra, for their distribution in coal and fly ash. There are 17 to 20 m thick workable coal seams (I to V, bottom to top) in Kamptee coalfield with some seams interbanded with sandstone and shale partings. They lie towards the west of Sakoli fold belt in the Bastar craton and encompasses lower Gondwana formations (Bararkar) overlain by Deccan traps and underlain by Archaean gneisses. Trace elements in sub-bituminous coal samples collected from these five working seams were determined by ICP-MS analysis after digestion through wet processes in both coal and ash. Germanium in coal varied from 4 to 6 μg/g while in the ash it is 16 to 38 μg/g (averaging 23 μg/g). Marginal enrichment of Ge in coal and corresponding flyash was detected in the roof (coal seam V) and floor (coal seam I) in Kamtee coal field, and also in the coal seam number 3 where the seam is interbedded with carbonaceous shale varying in thickness from 0.7 to 17m. An asymmetrical model invoking Zilbermints law is proposed in Kamtee coal field wherein prominent intra-bed Ge enrichment is observed while the floor and the roof lithologies are similar. Enrichment of Ge in coal is inferred to have happened under favorable paleoclimatic conditions through the release of Ge from a felsic source into migrating fluids and its fixation by chemisorptive processes before precipitating as humate complexes during coal formation.

Characterisation and Beneficiation Studies on a Pyroboles Bearing Beach Placer Sample from Andhra Pradesh Coast

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The Andhra Pradesh coast extending approximately over 900 km length, out of the total Indian coast over 6000 kms, which exposes varied compositional suite of beach placer heavy minerals like ilmenite, rutile, sillimanite, garnet, zircon and monazite. However, separation as well as purification of these heavy minerals from the associated gangues like quartz and feldspar does not pose significant problems normally but the presence of pyroboles {pyroxene (Pyro-) and amphibole (Bole-) could not be readily differentiated, so they are collectively termed pyroboles (Pyro+bole)} along with these economic heavy mineral pose significant problems during their processing as these pyroboles are heavy as well as magnetic in nature. One such beach placer deposit is the Kakinada-Uppada beach placer deposit of Andhra Pradesh, which contains significant amounts of pyroboles. For ease of downstream beneficiation operation for such a pyroboles bearing beach placer sample, Ministry of Mines (GoI) sponsored project has been undertaken at CSIR-IMMT, Bhubaneswar. In lieu of this, three beach placer samples were collected, each weighing around one tonne; starting from Kakinada beach to Uppada beach (with in a distance of around 9 kilometres) coast keeping approximately 3 kilometres distance from one sample to the other sample. The 1st sample (S1) was from Kakinada beach while the last sample (S3) was from Uppada beach. The second sample (S2) was in between Kakinada and Uppada beach. In each place around five tonnes of the beach placer samples were collected from twenty different locations along as well as across the beach. Then each five tonne sample was sampled by conning and quartering method to collect only one tonne of the homogeneous representative sample from three different locations as mentioned.

All these individually homogeneous representative samples were mixed, washed thoroughly and subjected to integrated instrumental characterisation as well as processing studies. The samples were initially subjected to size analyses. The individual size classified fractions were subjected to dry magnetic separation (Permroll) and heavy media separation using bromoform followed by methylene iodide. All the processed samples were subjected to optical microscopic studies and chemical analyses for their major, minor and trace elements. Mineralogical studies indicated that the samples contain ilmenite, rutile, garnet, zircon as major heavy minerals and while sillimanite and monazite are in traces in the processed products. The results further indicated that majority of the economic minerals are mostly occurring below 150 µm and pyroboles, which are mostly coarse grained, can be eliminated if the feed sample screened to 180 µm size. The plus 180 µm size sample thus will contain majority of pyroboles and insignificant values of economic heavy minerals. The other sample that is minus 180 µm size contain majority of the economic heavy minerals leading to least problems in the downstream beneficiation as well as purification of individual economic heavy minerals. Based on these preliminary results, wet as well as dry mode of separation processes are adopted for complete elimination of pyroboles from the economic heavy minerals, which are discussed in the present paper.

Determination of Lattice-constant and Defect-density of Alkali Halide without X-ray Diffraction

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X-Ray Diffraction (XRD) method is widely been used for identification of fine grained minerals, characterization of crystalline materials, determination of unit-cell dimensions, measurement of sample purity etc.. But, this method is time-consuming, quite expensive and troublesome too. More importantly, if the sample seems to be inappropriate after the XRD analysis, all the efforts in terms of wealth and time are going to be nothing but wasted. So, before the detailed analysis through XRD method, here, a simple experimental setup has been arranged based on basic theoretical ideas of Quantum and Classical Mechanics to find out the *lattice-constant* and *defect-density* of mainly *alkali halide* crystals. Pure alkali halide crystal is transparent through out the visible regional spectrum but due to *F-centre* defect it shows a characteristic colour. In nature F-centre defect is very common among alkali halides as they are found in marine evaporite deposits (geology of evaporites favourable for oil, gas exploration), salt domes, diapirs etc. By replacing the situation of an electron trapped inside a negative ion vacancy for F-centred lattice defect of alkali halide with the *particle in a box problem* of Quantum Mechanics, *Mollow's relation* is followed to obtain the *lattice-constant* and to find the defect-density oscillator-strength is defined by assuming F-centre as a *damped* *harmonic oscillator* and *Smakula's formula* is applied. For both the cases, we require the plot of the product of absorption coefficient and thickness vs wavelength. Through this *cost-effective* process we can obtain our target easily in a very short time. But from this method we can't obtain the accurate value because visible light only interacts with the outermost orbit-electron of an atom, whereas X-ray interacts with the inner-cell electron. Though XRD is the most accurate method that can be applied, the process that we have used in our experiment gives very close result. Here, for KCl crystal we get 6.082Å as lattice-constant while XRD result for the same sample is 6.12Å. In geophysical cases when we require a quick rough idea about the crystal we can apply that process.

Magnetic investigation to delineate the Causative Sources of Subsurface Interfaces in Anjukunnu, Panamaram area, Wayanad Gold Belt of North Kerala

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Magnetic investigation to delineates the causative sources for in subsurface interfaces and there extension has been carried out in the area falling in the Bavali shear zone of the Wayanad Gold Belt of North Kerala. The investigated area exposes sheared and unsheared hornblende biotite gneiss of Peninsular Gneissic Complex, meta-pyroxenite and amphibolite of Wayanad Group, Late Archaean metagabbro and Proterozoic intrusives like syenite and quartz veins. The lamprophyre dykes are seen intruded in to the syenite. All these rocks are capped by laterite at many places. The rocks exposed in and around Mananthavady area are highly sheared and is resultant of Bavali Shear Zone which passes through the area. The general trend of the gneissic foliation is NW-SE with moderate to steep dip towards southwest. The shear foliation trends in NW-SE with 35^o-70^o dip towards NE. Surface indications of sulphide mineralizations i.e. Pyrite, pyrrhotite and chalcopyrite are mainly noted in quartz veins, banded metagabbro and meta-pyroxenite bodies exposed in and around Anjukunnu, Panamaram area.

Semi-regional magnetic survey with total no. of 503 magnetic stations was established in 120 sq.km area. Magnetically this area can be divided into parts/zones. First zone which lies in the North Western part of the area is dominated by high magnetic anomaly localized features and with some moderate magnetic anomaly features. Magnetic (Total Field) anomaly contours in this zone does not show any specific trend and magnitude indicating depletion of magnetic mineral content due to development of some structural features. Second zone lies in the South Eastern part of this area and dominated by moderate to low dominant magnetic anomalies which has some high dominant anomalies in between. A contact has been marked separating these two magnetically different zones depending upon the contours pattern and behavior of the magnetic field.

The Radially Averaged Power Spectrum analyze the depths associated with magnetic sources contributing to magnetic anomalies has identified three different depth zones, (0 - 250) m, (250 -750) m, and last having depth greater than 750 m. This analysis shows the dominance of shallow to moderate depth features. Based on this Euler 3D depth solutions to the causative features associated with shallow to moderate depths is attempted. Euler3D depth solutions map has been prepared for structural index of value zero. The Euler depth solution has accurately demarcated the contacts associated with localized highs and lows in magnetic map. Most of the identified features have depth range (55 - 250) m with few having depth range (250 - 750) m and very few having depth greater than 750 m. This indicates that the identified structural features for contacts (SI = 0) have depth values in the range (55 – 250) m.

Magnetic and Electrical Exploration of the shearing contact in the mineral systems of Shimoga Schist Belt, Western Dharwar Craton

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The high-resolution geophysical 2D profiling techniques are useful in mineral exploration to identify geological structures and demarcation of the target areas where major parts of the study area covered with vegetation and reserve forest, which limits to understand geological structure and their strike extension. A semi-regional magnetic surveys were conducted over a block having area 150 Sq. km for gold and associated mineralization in the Shimoga Schist Belt (SSB), a part of Western Dharwar Craton (WDC) to assist in basic mapping and identification of target areas for follow up studies. Then IP and Resistivity profiling employed over target areas to corroborate the magnetic signatures and geological information of the mineralization. This schist belt is notable for intensive mining activity for over several decades, due to its large reserves of manganese ore, and also the small-scale deposits of limestone, gold and iron ores. Gold mineralization is confining to the quartz-carbonate veins within the sheared/altered meta-basalt and banded ferruginous quartzite of Jhandamati Formation, Chitradurga Group.

The magnetic surveys brought out significant regional and residual magnetic anomalies over various lithological units, in the north, south and southeast directions. These anomalies reflect the disposition of basement rocks and metasedimentary units of SSB. The major long linear anomalies observed in the central part of the study area reveals the nature of meta-basalt / carbonated meta-basalt bands within the quartz-chlorite-schist. Magnetic highs are falling at the contact of these linear anomalies are marked as major magnetic lineaments trending from northwest-southeast. Rock samples collected from the field show that these sheared contacts intruded by quartz-carbonated-veins, which are favorable for sulfide-bearing gold mineralization. The low resistivity with high chargeability anomalies is falling at the contact of marked magnetic linear anomalies confirm the shearing of the contact with possible mineralization.

Reconstruct the paleoenvironment by proximate and ultimate anaysis using remote sensing

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Coal is one of the main sources of energy in India. Coal resources are very rich, but the exploration level is relatively low. This is mainly caused by the complicated geological structure, the low efficiency, the related damage, and other bad situations. To end, we need to make use of some advanced technologies to guarantee the resource exploration is implemented smoothly and orderly. Numerous studies show that remote sensing technology is an effective way to study the distributed coal. As we know Gondwana coals are present in over 14 separate basins centred in the north-eastern and central-eastern parts of peninsular India, In this research, I am going to take one of main south basin of India which is Godavari (part) analyse the quality variation follow from north to south by using of remote sensing and GIS technology for further the comparative data of variation in coal quality with basin structure and its depositional environment. This research going to help in selecting future sites for coal exploration with more economically profitable.

Sulphide and Tungsten Mineralization from Sarni, Betul Fold Belt, Central India: Evidence for VHMS type mineralization?

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The Proterozoic Betul Fold Belt (BFB) located in the CITZ has prominent lithotectonic unit trending ENE-WSW with three distinct rock associations' broadly classified as: (i) Supracrustal rocks of BIF and carbonate metasediments, bimodal mafic and felsic volcanics, metaexhalites, clastic metasediments, (ii) Mafic-Ultramafic rocks comprising large plutons of pyroxenites, gabbro, diorite and foliated ultramafics, and (iii) Syn to post kinematic granitic rocks which intrude the basement gneissic complex. The complexity in the geology of different rocks formed and their tectonic conditions, in addition to the occurrence of the base metal sulphide mineralization (VHMS type) and the presence of magmatic Ni-Cu-PGE ores in the BFB have immense potential for metallogeny. An integrated geological and geophysical study carried out for sulphide mineralization resulted in rock-core drilling for about 100 meters at Sarni, where acid volcanic rocks (rhyolite) and amphibolites were encountered representing bimodal volcanic rocks. Relict sulphide pits, leached zones with occasional bluish tinges, limonitic patches are common in both felsic and mafic volcanic rocks indicate hydrothermal activity, while brecciation is observed intermittently. Pyrite, chalcopyrite, pyrrhotite along with minor sphalerite occur as disseminations or as discrete clusters mimicking stockwork. Earlier reports have suggested the occurrence of volcanic-hosted massive sulphide (VHMS) deposits in the eastern part of the study area and an attempt was made to correlate similar occurrences in the subsurface. The copper ratio [100Cu/(Cu+Zn)] vary from 13 to 41 while the zinc ratio [100Zn/(Zn+Pb)] is from 34 to 98 indicating VHMS type of mineralization. Further, the wall rock alteration is moderate to intense with the degree of alteration more or less increasing with depth. The presence of quartz veins along the mineralized zones in concomitant with sericitization and chloritization characterizes the stringer zone. At deeper depths, carbonate alteration with solution cavity structures is observed in felsic volcanic rocks indicating VHMS mineralization. We also report tungsten mineralization which is presumed to be formed during later stage of sulphide mineralization in the quartz vein. The formation of VHMS type mineralization is attributed to the subsurface hydrothermal circulation along with adequate heat flow in the continental arc environment.

Implications for the formation of the ultramafic-hosted magnesite mineral deposits in the Archean Sargur greenstone belt

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The ultramafic-mafic rocks of the Archean Sargur greenstone belt are the remnants of the Paleo-Mesoarchean oceanic crust of the western Dharwar craton. The Sargur greenstone belt is dominated by ultramafic-mafic layered intrusive and volcano-sedimentary rocks distributed as linear belts or as dismembered units and enclaves within the TTG gneisses of the western Dharwar craton. The narrow ultramafic-mafic bodies are confined mainly to a >250 km long belt extending from Nanjangud, Mysore district, in the south to Hanumalpura, Devanagere district, in the north. The ultramafic rocks spanning from Precambrian to Phanerozoic have acted as storehouses for CO_2. The common minerals that are formed during the interaction of CO_2 with ultramafic rocks (Mg-rich mineral phases such as olivine and pyroxene) are generally magnesite [$MgCO_3$], dolomite [$CaMg(CO_3)_2$] and ankerite [$Ca(Fe,Mg,Mn)(CO_3)_2$]. The genesis of ultramafic-hosted magnesite deposits in Sargur area is ambiguous as the sources for CO_2 could have come from multiple reservoirs. As the host rocks for the stockwork and vein-type magnesite deposits are invariably ultramafic in composition, the one end member of the reaction is apparently the Mg-rich minerals of the ultramafic rocks. Questions arise when the source of the other end member component, CO_2, is considered. Our geochemical and stable isotope study indicates that the possible sources of CO_2 are hydrothermal fluids with or without interaction with phreatic waters that could have carried CO_2 due to interaction with the metamorphosed carbonate bodies in the vicinity. The range of $\delta^{13}C_{PDB}$ and $\delta^{18}O_{SMOW}$ values for the magnesite samples are from -6.72 ‰ to -1.21 ‰ and

30.26 ‰ to 31.68 ‰, respectively. They do not fall within the field of Phanerozoic magnesites reported from other parts of the world. The possible timing of formation of the magnesite deposits could be during the end Archean granulitization event that had metamorphosed the rocks south of the orthopyroxene isograd.

Edge detection and depth estimation of Potential Field Data

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The present study aims to produce an excellent picture for the basement depth, contact locations deduced from the collected Gravity and Magnetic data. The study area are occupied by rocks of Chhotanagpur Gneissic Complex (CGC), Gangpur Group and Upper and Lower Bonai Group. Singhbhum Craton exists on the south in contact with CGC. Bouguer gravity and magnetic anomaly values varies from -51 mGal to -21 mGal and -96 nT to +699 nT respectively. Radial averaged power spectrum (RAPS) of gravity and magnetic data (according to the slope) represents, the maximum depth is ~5.0 Km that probably reflect the crustal thickness at this place, depths of deep sources which reflect the maximum depth to the basement complex is found to be ~4.0 Km and the shallow sources and noise (near-surface geological structures), its depth will be ~1.8 K m. This slope probably represents the minimum depth to the basement, at the eastern part of the study area. In western part, the basement will be deeper than the eastern part. This shallow part corresponds to Bonai Group of rock and the deeper part corresponds to average basement of CGGC. Different edge detection technique such as, tilt angle derivative (TDR), total horizontal derivative (HD_TDR) and 3D-Euler deconvolution were applied to determine the edges of sources. The estimated Euler depth solutions were plotted on the tilt angle derivative map and and excellent correlation was noticed between these techniques indicating that both of them can be attributed in delineating the general structural of the area. Moreover analytic signal (AS), Source Parameter Imaging (SPI) as well as 3D-Euler deconvolution were applied for estimating the basement depths and observed similar results ranges from 1.8 km to 4.0 Km . On the other hand, all the methods used in this study gave a similar results to the depth of the basement rocks, ranging in depth between 1.8 km to 4.0 Km.

Delineation of subsurface structures along the western extension of Gogi-Kurlagere fault, Malla-Buzurg area, Bhima basin using magnetic methods

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Extensive exploration in southern margin of Bhima basin has established the uranium mineralization, localised within structures which are sympathetic to E-W trending Gogi-Kurlagere fault (GKF).

Magnetic survey is conducted in Malla-Buzurg area which is 20km west of Gogi Uranium Deposit, for delineating basement configuration as well as sub-surface structures along the western extension of GKF. The total magnetic intensity anomaly map shows few prominent linear magnetic anomalies in central part indicating a contact between the basement and sediments**.** The first vertical derivative (FVD) of RTP map enhanced the shallow magnetic sources and also resolved the closely spaced bodies. This map further shows linear trending high magnetic anomalies due to basic dykes. Basic dykes trending E-W and ENE-WSW directions are cross cutting each other in the eastern part of the area. These dykes are dislocated in western part due to NW-SE trending faults indicating later deformation. Another NE-SW trending magnetic anomaly observed in northern part of the area indicates an intrusive body concealed by sediments. Euler depth solutions of shallow depths (<100m) were correlating with the high magnetic anomalies of dyke intrusion in the southern part of the map. 2D modeling of magnetic profiles across the dykes in the eastern part of the area shows the basic intrusives dipping towards north within the basement; whereas in the western part of the area shows effectively vertical dip. The basic dykes are important as they might have created necessary geothermal gradient for remobilization and precipitation of uranium mineralization along the fracture zones. This study has helped in constraining location of dykes and understanding the basement configuration for locating structural controls for Uranium mineralization in parts of Bhima basin.

Geophysical Investigations for Iron Ore Bodies in Rebanpalli Block Adilabad District Telangana

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Geophysical surveys employing detailed IP/Resistivity/Magnetic and Regional Magnetic surveys were carried out in Rebbanapalli Blockwith the objective to establish iron ore bodies and their lateral and depth extension to estimate the resource.This block is represented by Archean-supracrustal and granitoid association of Karimnagar Granulite Belt (KGB). In this block relatively low grade rocks such as BMQ, actinolite schist, metapyroxenite and younger intrusive of syenogranite are noticed.

The Regional magnetic surveys were carried out in the area maintaining the station interval about 200m. During detailed studies traverses were laid perpendicular to the general strike of iron ore bands of Rebbanpalli block and stations were stacked 10 m apart. The IP/Resistivity (dipole-dipole array) surveys were carried out along these traverses keeping current and potential dipole lengths i.e. 'a' of 20m and current and potential dipole separations ranging from 'n'=1 to 10.

Regional magnetic (TF) map shows bipolar magnetic anomalies ranging from -4643nT to 16852 nT in Rebbanapalli block. The analytical signal map of magnetic data shows linear highs which coincide with the alignment of iron ore bands of the block.The detailed magnetic surveys have shown high gradients over the known/suspected iron ore bands. The magnetite bearing iron formation is reflected in the form of high chargeability and low to moderate resistivity in the block. The pseudo depth section along line 10 of Rebanpalli block shows high chargeability (~ 27mV/V to 31 mV/V) corroborated with low to moderate resistivity (~ 53-90Ohm-m). The Depths of the anomaly zones seem to extend up to and beyond 60m from dipole-dipole surveys which corroborated well with Euler depth solution. All the three boreholes were drilled over high chargeability-low resistivity zones within magnetic AS high zones and have intersected iron ore bodies the depth extension coincide with dipole-dipole pseudo depth sections. Thickness of BMQ in Rebbanapalli North block is ~ 20 m but in Rebbanapalli South block and Central block average thickness varies from 60-100 m. The average Fe content is 31.75%. The concentration of magnetite increases at the hinge portion of microfolds.

2-D geophysical model of structurally controlled subsurface high-density horizon beneath the meta-volcanics in parts of Shimoga

Schist Belt, Karnataka

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The Archean Dharwar Craton, covering an area of about 4.5 lakh sq. km, is bounded to the south of the Pan-African Pandyan mobile belt (PMB). The craton is divided into two tectonic blocks, viz, the western block and the eastern block, renamed respectively as Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC) by Rogers (1986). The WDC and EDC are separated by the Chitradurga Shear zone that is situated at the eastern margin of Chitradurga Schist belt. The Western province (Dharwar Foreland) in the west of the craton comprises four major schist belts (Western Ghats-Babudhan-Shimaga-chitradurga) and numerous minor schist belts (Sargur – Nuggihalli-Holenarsipur-ICpura-Kalyadi-Nagamangala-Ghattihosahalli Kunigal-Sigegudda). An integrated gravity and magnetic survey were carried out under the project NGPM over parts of Shimoga Schist Belt, Karnataka. In the study area, the Bouguer gravity anomaly field shows overall variation of 26 mGal. The low gravity zones at the southern portions (near Belanduru and Harnahalli) are mainly due to PGC gneisses. The magnetic (TF) anomaly field is showing a variation of 160 nT. The low magnetic anomaly zones are in well correlation with the low Bouguer gravity anomaly zones.

High circular Bouguer gravity anomaly is observed at the southern portion (near Hitala) of the survey area, corroborated with high magnetic anomaly. Euler depth solution (SI=0) depicts the depth of this anomalous source zone to be around 1 km and deepening towards SE direction up to 2 km. 2D GMSYS modelling across the study area has been done along profile A-!'. The density and susceptibility values were assigned from the measured density and susceptibility values of the rock samples collected during field survey. The major rock unit i.e. argillite has density around 2.68 gm/cc and susceptibility 0.0007 SI units. The rock sample of manganese ore collected from south of survey area (near high Bouguer gravity anomaly zone) has density 2.8 gm/cc and susceptibility 0.0006 SI units. Model basically decipher the relation of schist rocks and the basement. However, the high gravity anomaly (mentioned above) has been modelled as structurally controlled causative horizon which may be inferred as manganese bearing horizon which have come to optimum depth, because of folding and faulting in the region, thus providing a favourable zone for manganese deposition.

A geophysical approach to delineate the subsurface extension of schist rocks, in parts of Davangere district, Karnataka.

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Gravity, Magnetic (Total Field) & DGPS surveys have been carried out in the south and south-eastern part of Gadag Schist belt, covering a total 2160 sq. km of area with minimum station density of 1 per every 2.5 sq. Km as part of National Geophysical Mapping. The study area is part of the Western dharwar craton and major litho-units of the area are migmatite gneisses of PGC supergroup, schistose rocks of Dharwar supergroup and younger acid and basic intrusives. Physical property measurement of major rock units reveals that the migmatite gneisses having density 2.7 gm/cc and susceptibility of 966 x 10^{-6} in CGS unit and are denser and more susceptible than argillites, having density around 2.56 gm/cc and susceptibility of 11 x 10^{-6} CGS unit.

Overall 44 mGal Bouguer gravity anomaly variation has been observed in the study area. The litho-contact between migmatite gneiss and argillite of greywacke suite are revealed by high Bouguer gravity gradient zone. The Bouguer gravity anomaly field successfully brought out the extension of concealed schistose rocks. Further residual gravity anomaly, tilt derivative of Bouguer gravity anomaly and analytical signal map affirms the presence of high-density schist in the subsurface and also gives the spatial extension of the inferred concealed schist rocks. Radial power spectrum of Bouguer gravity anomaly field brought out three linear slope segments and has been used to estimate depth of the density interfaces at 1.33 km, 1.86 km and 4.66 km. The magnetic (TF) anomaly shows a total variation of about 300 nT and its RTE field shows total variation of about 380 nT. Argillite suits of rock shows magnetic low dominant anomaly whereas response of migmatite gneisses are moderate magnetic anomaly, reflecting high susceptibility of gneiss as compared to the argillite. At the contact of gneisses and argillite, BIF are present over which high magnetic anomaly is observed.

Delimitation of Manganiferous Zones in Kondamasuru area based on Gravity and Magnetic (T.F.) Data

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An attempt has been made for delineating the presence of favourable zones for Manganese ore body and to study the control of mineralisation in Kondamasuru block, Vizianagaram District, Andhra Pradesh by analyzing Gravity and Magnetic (T.F.) data.

The manganese deposits in Peninsular India occur in Precambrian rocks and are confined to discrete belts. In the Eastern Ghats, manganese deposits are either associated as syngenetic reef deposit or lateroid deposit and supergene enrichment associated with it. Special Thematic Mapping (STM) in TS.No.65N/3 has resulted into identification of manganiferous bands trending in NE-SW direction near Kondamasuru area. The ore body is intimately associated with the calc-silicate Granulite and pelitic variants of Khondalite. The Magnetic (TF) surveys have brought out a NNE-SSW to NE-SW trending anomalous features of significant bipolar magnetic anomaly which may be a shear zone. The Bouguer gravity anomaly is showing gradual increase in value towards south with some pinching character in between. Euler depth solution and Radial Average power spectrum have indicated that the major responses are originating from depth range of 50m to 150m. By corroborating, the results obtained from Bouguer Gravity and Magnetic (T.F) anomaly with corresponding processed and derivative maps, four distinct anomalous zones have been identified in the area with intermittent discontinuities. The probable manganese ore bodies in this area are in NNE-SSW to NE-SW direction separated from each other by orthogonal structural contact. Based on the prevalent geological setup of manganese existence in the area, it may be assumed that the possible zones for manganese occurrences are structurally controlled and occur in the form of pockets or intercalations within the host rock rather than continuous bands. In addition, the pockets of Manganese ore body occurrences appear to continue further in the south-western end and shows a varying dimension from north-eastern to south-western part of the study area.

UNDERSTANDING AND COMBATING NATURAL HAZARDS

Dynamic triggering in Southern Asia during the Indian Ocean Earthquake, 2012

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Large shallow earthquakes are capable of triggering of shallow earthquakes or deep tectonic tremors at faraway places. The Indian Ocean earthquake, April 11, 2012, Mw 8.6 was the largest strike-slip event ever recorded and triggered the seismicity in many parts of the world, including an increase in the earthquakes of ≥M5.5. The study of the dynamic triggering in southern Asia was limited. Therefore, we searched remotely triggering in Southern Asia following the Indian Ocean earthquake. The dynamic triggering found in terms of tectonic tremors and earthquakes in the region during the event. The tremor triggering found beneath the Java Island, and the Sulabes Island in Eastern Indonesia whereas triggered earthquakes in Vietnam, Koyna-Warna, Western India and Iran. The dynamic triggering found in the isolated region without any clear relation of triggering with the amplitude of stress, duration, and frequency. The triggering started to occur in the first few cycles of the Love waves, and continue during the Rayleigh waves.

Source characteristics study of North East India with its special reference to natural hazard

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A "Natural hazard" refers to all atmospheric, hydrologic, geologic (especially seismic and volcanic), and wildfire phenomena. Natural hazards are those natural activities which affect or causes damage to humans or their residentials. So, if we are known with the risk prone areas then we can easily convert a Natural hazard into a Natural activity and this could be our important step in making a sustainable development. In these Natural hazards, 'Seismic hazard' is most vulnerable as it can cause most lives damage. In present study, we analyzed the seismic activities of Eastern thrust of North-Eastern Himalaya region to understand the source characteristics of this region. The study area comprises a longitude 92.5°E – 96°E and latitude 22°N – 27°N. The region is one of the most seismically active regions in the world. It is being under the influence of three major plates Indian, Eurasian and Burma. Due the compression of Indian and Burmese plate this region experiences a lot of earthquake. For analyzing the seismic activity we have to study the source characteristic of the region like b-value, p-value and most important is stress drop. We analyzed the precise catalogue developed by National Centre for Seismology, New Delhi as well as we analyzed the waveform data for a period of 2011-2018. The stress drops computed are more than 200 bars with minimum as 53.57 bars and maximum as 230.54 bars. The stress drops values show increasing trend with the magnitudes of the earthquakes but are independent of the size of the source. The empirical relationships between the source parameters and the magnitude are computed for this region which would need upgradation when more data becomes available.

To understand the relationship between geomagnetic disturbance and seismicity through surface latent heat flux

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This study presents an analysis of surface latent heat flux, disturbance storm time index and auroral electrojet index variations before the magnitude of 6.3 Java (Indonesia) and magnitude of 6.4 Yujing (Taiwan) earthquakes. Surface latent heat flux results were obtained victimization through satellite remote sensing techniques and reanalysis datasets. Multi-year background knowledge was utilized to figure anomalies. The results exhibit spatial and temporal abnormal variations of surface latent heat flux before most of the event. Surface latent heat flux anomalies typically occurred 1–3 weeks before the earthquake. These variations were caused because of temperature increase and also the unharnessed of gases before the earthquake. The discharge of energy was focused on the geographic point and regional fault lines. Disturbance storm time index and auroral electrojet index analysis show the presence of geomagnetic storm before the prevalence of earthquakes and also the synchronization of geomagnetic surges and seismicity. The study conjointly expresses that the geomagnetic storm conjointly synchronizes with earthquake prevalence. The study can facilitate to spot precursor anomalies in regions vulnerable to earthquakes.

Kerala Flood, 2018 – Hydro-climatological Changes and Modelling

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The extreme rainfall and associated flooding of August, 2018 in Kerala had a remarkable impact on the socio-economic and environmental fabric of the state. The state experienced an abnormally heavy rainfall from 1st June 2018 to 19th August 2018 with peak downpour during 15 - 17th August, 2018. As per India Meteorological Department (IMD), Kerala received 2346.6 mm of rainfall during this period as against the expected rainfall of 1649.5 mm. This 42 % rise in the downpour caused many rivers to overflow and made the people in the riparian areas, valleys and coastal lowlands homeless. The climatological changes in the state is evident from the detailed analysis of the rainfall and its characteristics. Southwest monsoon showed a decreasing trend while the northeast monsoon months showed an increasing trend. The state showed an increasing trend in the evapotranspiration. Earlier studies showed an increasing trend in the high intensity rainfall events across the western Ghats and it is projected to increase during the next three decades. The loss of flood plains and lakes which acts as a buffer to hold flood waters and unplanned developmental activities in the riparian region poses a major challenge in the flood water management in the state. Modelling the inundation scenario for different combination of headwater, tide conditions and rainfall conditions is a way forward to minimize the ill effects of the flooding events. The present study presents a comprehensive analysis of the Kerala flood – 2018 together with the hydro-climatological changes in the state and flood modelling.

Study of soil ^{222}Rn anomalies as earthquake precursor at a network of monitoring stations in Eastern India

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Anomalous variation of concentration of radon (^{222}Rn) gas in soil is a promising precursor of earthquake. A network for continuous monitoring of soil radon concentration for the study of its earthquake precursory nature is being set up in eastern India – covering the eastern Himalayan region and Bakreswar-Tantloi geothermal region. Three monitoring stations – at Ravangla, Sikkim, Diphu, Assam and Tantloi, Jharkhand – have already started working. At Ravangla, soil radon concentrations have been recorded continuously since 2016, whereas the centres of Diphu and Tantloi have been functional from mid-2018. The data recorded at all three sites reveal that meteorological parameters influence soil radon emission, leading to a very complex non-linear time series. Therefore, a two-step non-linear technique consisting of empirical mode decomposition and Hilbert-Huang transform has been used for analysis of the data. A number of precursory anomalies caused due to earthquakes of magnitude ≥ 5.0 within 500 km epicentral distance from the monitoring station have been found in the soil radon time series recorded at all three centres. In particular, a radon anomaly was observed simultaneously from all three monitoring centres preceeding the 5.3 M earthquake that occurred on September 12, 2018 in Kokrajhar, Assam. This demonstrates that a network of monitoring stations can provide an efficient method for earthquake precursor study which may also give an idea about the probable region of occurrence of an earthquake.

Investigation of site chracteristics in and around Kurukshetra city using ambient noise

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The seismic site response characteristics inferred from 'single site' ambient noise H/V spectral ratio has been investigated in the present study. Measurements have been taken at different sites in and around Kurukshetra city. The site characteristics, in terms of fundamental frequencies and site amplifications, have been investigated using ambient seismic noise. For

this purpose, we used horizontal to vertical spectral ration (HVSR) method. The fundamental frequency is obtained low at most of the sites and falls in the range of 0.60-0.90 Hz i.e. less than 1 Hz. The amplification level range lies in between 2 and 3 due to the loose sediment cover over the region. The spatial distributions of fundamental frequency and amplification in Kurukshetra city demonstrate the level of seismic hazard and vulnerability. The results demonstrate the usefulness of the H/Vspectral ratio method using ambient noise in order to provide reliable information on the dynamic behaviour of surficial layers. Based on these results, we can suggest that the ambient noise H/V spectral ratio technique can satisfactorily indicate areas of higher or lower damage potential in the city of Kurukshetra. The results can be employed to for microzonation studies in urban environments because of the fast data acquisition, low cost, limited requirements in personnel and equipment and reliable results.

Study of radiowave of very low frequency for Sub- ionospheric perturbation during Turkey earthquakes.

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In Turkey region to study seismo -ionospheric phenomena radio waves are used which is associated with two major earthquakes by using very low frequency (VLF) data. Investigation of sudden ionospheric disturbances (SID) is being carried out with sampling rate is 10 sec at 23.4 KHz from SID monitoring station of Bafa (latitude 37.24° N , longitude 27.19° E) at France by using very low frequency data (VLF). During the process of earthquake preparation over the earthquake epicenters in the Turkey Anatolian block night time fluctuations are being observed. We compute effective magnitude of all earthquakes for that day which acts like a single quake and calculate the total energy accumulation by all those earthquakes.. For the whole year we analyse the trend of VLF signal and compute the sunrise and sunset terminator time from it. We found the unusual fluctuations in VLF signal strength are well correlated with earthquake magnitude and on few days prior to earthquake events the fluctuations is maximum by computing a cross correlation between trend from the night time fluctuation value with earthquake of effective magnitude.

Influence of meteorological parameters on the soil-radon (Rn^{222}) emanation in Kutch, Gujarat, India

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The soil radon (Rn^{222}) and thoron ($Rn^{22°}$) concentrations recorded at Badargadh and Desalpar observatories in the Kutch region of Gujarat, India, have been analyzed to study the sources of the radon emissions and the influence of meteorological parameters on radon emission. Radon and meteorologicalparameters were recorded using Radon Monitor RMT 1688-2 at these two stations. The times series of radon and other meteorological parameters for two different time duration(From 21stFebruary, 2011 to 8th June, 2011(series A) and from 1st January, 2017 to 31st December, 2017 (series B)) have been chosen for Badargarh, whereas the time series from 2nd March, 2011 to 19th May, 2011 has been chosen for Desalpar station with a sampling interval of 10 minutes.It is observed that the radon concentrations at Desalpar varies between 781 Bq/m3 and 4320 Bq/m3with an average value of 2499 Bq/m3, whereas thoron varies between 191Bq/m3 and 2017 Bq/m3 with an average value of 1433.69 Bq/m3. For series A, radon concentration at Badargadh varies between 264Bq/m3 and 2221 Bq/m3 with an average value of 1135.4 Bq/m3, whereas thoron varies between 97Bq/m3and 556 Bq/m3.For series B, radon concentration at Badargadh varies between 5.9Bq/m3 and 1134Bq/m3 with an average value of 343.7Bq/m3, whereas thoron varies between 14.3Bq/m3 and 2993Bq/m3. To understand how the meteorological parameters influence radon emanation, the radon and other meteorological parameters were correlated with linear regression analysis. For Desalpar and series A at Badargarh, radon is negatively correlated with temperature, whereas, it varies positively with pressure and humidity. Again, for series B at Badargarh, radon varies negatively with both pressure and temperature, whereas it shows positive correlation with other parameters (humidity, rainfall and wind speed). For both time series A and B, radon shows negative correlation with temperature and this concluded that the reduced temperature has allowed the convective transport of radon. The trend of similarity between radon and other parameters is examined by conducting cross correlation at both the stations. Further, the ratio between radon and thoron has been analyzed to determine the deep or shallow source of the radon emanation in the study area. These results revealed that the ratio radon/thoron enhanced during this period which indicates the deeper source contribution is prominent. Incidentally, all the local earthquakes occurred with a focal depth of 18-25 km at lower crust in this region.

Geospatial techniques for Landslide Assessment and Susceptibility Mapping over Kodagu Region, Western Ghats, India

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Landslides have become most disastrous in India in the recent past and more so along the Western Ghats. Triggered by severe rainfall events, most of the slope failures along the Western Ghats are debris flow type landslides while the northern parts of Kerala and Karnataka region are characterized by rotational and translational slides as well. Rainfall driven disaster affected Kerala and Kodagu region during August 2018 causing numerous slope failures resulting in huge loss of life and property. The recent incidences have reiterated the need for comprehensive methods of landslide mapping, monitoring and forecast. The present study attempts to assess the spatial extent of the landslides by developing a geospatial landslide inventory using the Sentinel 2A MSI satellite datasets. Landslide susceptibility mapping is carried out using the Geospatial landslide inventory in addition to the various other landslide causative factors like elevation, slope angle, Aspect, drainage density, geology, lineament density, slope curvature, landuse/landcover, Stream power index, Topographic wetness index and distance from roads. The Frequency Ratio (FR) and Weights of Evidence (WoE) methods are used to rank and classify the different thematic layers into a final landslide hazard zonation map. The performance of the two methods were statistically assessed based on the Area under the ROC curves which stood at 0.743 for FR and 0.744 for WoE indicating consistency in the selected landslide causative parameters. The cumulated rainfall event *Vs* rainfall duration thresholds were analyzed using the power law based model adopting frequentist and bootstrapping techniques. The study provide insights into the rainfall conditions that triggered the landslides over the Kodagu region during the Extreme rainfall events of 2018 leading to better understanding of process to enable hazard forecasting, thus reducing the risk to ensure secure life.

Co- Seismic Ionospheric disturbances (CID) due to Major and Great Earthquakes

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The Coseismic Ionospheric Disturbances (CID) due to the 26th December 2004 earthquake of Mw 9.2, which occurred in the Sumatra-Andaman subduction zone, are analyzed using cGPS-aided Total Electron Content (TEC) measurements. The source of generation of disturbance in the total electron content in ionosphere can be due to many forces which occur in the upper atmosphere like solar and geomagnetic disturbance. Apart from this, there are other

phenomenons below the atmosphere which contributes to the variation of Total electron content (TEC). One of the main sources of these disturbances in the electron content, below the atmosphere is due to the occurrence of large earthquakes with Mw>7.0. Variation due to earthquake can be seen in smaller scale prior the earthquake and comparatively larger during and after the occurrence of the earthquake. These variations are known as pre-seismic disturbance, co-seismic disturbance and post-seismic disturbances respectively.

It is well known that during the occurrence of an earthquake, the surface experiences horizontal as well as vertical displacements, depending upon the type of rupture fault.Shallow thrust earthquakes, giving strong vertical ground displacements, produce infrasonic pressure waves in the vicinity of the neutral atmosphere. These neutral atmospheric disturbances, known as acoustic gravity waves, propagate upwards to ionospheric altitudes and create disturbances in the electron density there. These disturbances are well known as seismo-traveling ionospheric disturbances (STID) or co-seismic ionospheric disturbances (CID). It is believed that upward propagation of wave perturbations happens in the vicinity of the earthquake epicenter or within the so-called earthquake preparation zone. Using a case study, Otsuka et al. (2006) suggested that there can be multiple sources for acoustic wave generation along the rupture that propagate away from the epicenter at the rupture velocity. Heki and Ping (2005) have empirically shown that only acoustic waves emanating within the zenith angles of 0° to 20° can reach ionospheric heights and affect the electron density. The remaining waves get reflected, mainly because of atmospheric temperature variations, and return to the ground. Induced ionospheric electron density perturbations related to seismic activity are often observed with various radio techniques, such as HF Doppler sounding, ionosonde, and global positioning system (GPS)

Like the Coseismic displacement estimated by GPS, GPS can also be used to estimate the Coseismic Ionospheric Disturbances. Three kinds of atmospheric waves that disturb ionosphere and can be observed with GPS as TEC changes, i.e., (1) direct acoustic wave from the focal area, (2) gravity wave propagating obliquely upward from the focal area or from propagating tsunami, and (3) secondary acoustic wave excited in far fields by the Rayleigh surface wave. Part of the direct acoustic wave comes back to the ground by atmospheric refraction and is observed by infrasound sensors. Vertical movements of ionized particles in the geomagnetic field induce current in ionospheric and cause geomagnetic pulsation.

Observation of Pc3-4 geomagnetic pulsations from Swarm satellite and ground: Solar-terrestrial source

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Geomagnetic storms influence the Ultra-low-frequency (ULF) wave structures by introducing unstable pitch angles and energization of particles. We investigate ULF waves (> 15 mHz) from Vector Field magnetometer (VFM) from Swarm-A and Swarm-C during disturbed geomagnetic conditions in 2015 to account for ULF waves in the top side ionosphere. The magnetospheric and ionospheric magnetic field is retrieved using CHAOS model and investigation is restricted to low latitude regions. We extract transverse (poloidal and toroidal) and compressional oscillations and a total of 49, 40 and 100 events in poloidal, toroidal and compresssional, respectively, are identified over 220 passes over low latitude regions. Moreover, we compute the local time dependence of amplitude ratio between transverse and compressional components which clearly shows a diurnal variation. Further, observed Pc3-4s (15-100 mHz) are investigated in the light of background IMF parameters and activity indices depicting a low dependence on IMF cone angle. Corresponding comparison with ground magnetometer data in the low latitude stations are also used for investigating the effect of ionosphere on these ULF waves.

Evaluation of probabilistic earthquake hazard in Andaman- Sumatra region

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Sumatra – Andaman arc region is one of the destruction of lives and properties in the Indian Ocean rim countries. In this study, earthquake hazard parameters (maximum regional magnitude, mean seismic activity rate (λ), the parameter b (or $\boldsymbol{\beta}$) of Gutenberg-Richter (G-R) frequency magnitude relation) have been calculated using a homogenous and complete earthquake catalogue during 1900-2018. The return periods of earthquakes with a certain threshold magnitude along with their probabilities of occurrences have been also calculated. For this purpose, the study region has been divided into 11 shallow and 04 intermediate depth seismogenic source zones. The obtained earthquake hazard parameters, return periods and probabilities of earthquake occurrences have been geographically mapped in 11 shallow and 04 intermediate-depth seismogenic source zones to analyse the spatial variation of localized seismicity parameters. It is observed that seismic hazard level (low return periods and high probabilities) is high in source zones 4, 7, 9 & 11 for shallow focal depth (≤ 70 km) earthquakes and zones 1 and 4 for intermediate depth zones. The study suggest that seismic hazard level varies spatially from one zone to another in Andaman- Sumatra region, which suggests that the examined region have high crustal heterogeneity and seismotectonic complexity.

Pre-seismic ULF electromagnetic emissions before a moderate earthquake on 20 June 2012 (M 5.1) in Bhuj epicentral region, Gujarat, India.

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In this study, pre-seismic ULF emissions recorded by Digital Fluxgate Magnetometer at Multi Parametric Geophysical Observatory (MPGO) of Desalpar, Gujarat, India, are studied in the frequency band 0.001–0.5 Hz. In order to reduce the man-made and atmospheric perturbations, we considered the magnetic data of midnights (i.e., 18-21 UT) from 1st January to 31st July 2012. During this period, five earthquakes of Magnitudes in the range of 3.5 to 5.1 occurred within a range of 50 km from Desalpar. We observed a decrease (downward effect) in the diurnal variation of the vertical component before 10 days for the 20th June 2012 earthquake (M 5.1) and a similar decrease has been observed after this earthquake which we speculate as pre and post-seismic anomaly respectively. In order to discriminate seismo-magnetic signatures from global geomagnetic effects, polarization analysis is applied to the magnetic data. The data is analyzed at five frequency bands in the light of local seismicity, geomagnetic storms, and lightning events. The results showed that the maximum variability in polarization ratio appeared during local earthquakes and particularly prior to the moderate earthquake on 20th June 2012. As there is a negligible influence of geomagnetic storms and lightning during this period, the observed anomalous variations in ULF emissions can be correlated with the local earthquakes. In order to understand the dynamics of earthquake processes, fractal dimension analysis is also applied to magnetic data in the ULF range. It is observed that there is a marginal increase in the observed fractal dimensions a few days before the earthquake of 20th June 2012. We also observed a small increase in fractal dimensions and polarization ratios after the occurrence of this earthquake which may indicate the effect of post-seismic readjustment of seismogenic processes

Analysis of seismicity of western India in relation to the 2001 Bhuj earthquake

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The nature of intraplate seismicity of western India is studied in relation to the large 2001 Bhuj earthquake (Mw 7.6). The long-duration earthquake sequence since the occurrence of the 2001 event in the region is analyzed to investigate whether the observed seismicity is resolvable from low intraplate background. Our analysis is based on the estimation of fractal dimension of epicenters, seismic *b*-value, and modelling of co-seismic Coulomb stress for explaining the triggering mechanism of the aftershocks. The catalog used for describing the

seismicity of the region includes 5338 events in the magnitude range Mw=0.6-7.7. A spatial fractal dimension, *D* of 2.01±0.02 obtained indicates epicenter distribution in a two-dimensional plane that is being filled-up by fractures. A low seismic *b*-value of 0.72±0.03 for the sequence indicates that the region is highly stressed. We could not reach at the conclusion whether the sequence belongs to ibe background or truly represents the 2001 aftershocks based on the statistical analyses of the catalog analyzed, the reason is not yet well understood, but is probably rooted at the nature of the catalog used that seems not complete at the threshold magnitude we fixed to describe the background. The spatial mapping of estimated *b*-values suggests that the Bhuj earthquake originated in a highly heterogeneous fluid-filled fractured rock matrix beneath the mainshock hypocenter. The Coulomb stress obtained using the variable slip model in the depth range 0-30 km exhibits a 'butterfly' pattern, where most of the aftershocks fall in the region of positive stress, which suggests that the aftershocks, preferably of larger magnitude in the sequence, have been triggered by transfer of positive Coulomb stress due to the coseismic slip of the mainshock. The results of this study would be useful for future seismic hazard assessment and risk mitigation related to the intraplate seismicity away from the plate boundary regions.

WATER RESOURCES MANAGEMENT UNDER CHANGING ENVIRONMENT AND CLIMATE

Role of Geospatial Technology for the Exploration of Groundwater Prospect Zones-A Case Study from Kotturu Mandal of Srikakulam District, A. P., India

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The aim of this research is to address how to explore the groundwater prospect zones for agriculture in the Western part of Kotturu Mandal headquarters, Srikakulam district, Andhra Pradesh. Investigation of the study area has been done by using the remote sensing data along with background data like geology, soil thematic maps etc. for extracting various thematic layers (i.e., base, geology, geomorphology, lineaments, soil, drainage density, land use/land cover and groundwater prospect zones) in ERDAS Imagine 2014 and ArcGIS 9.3.1 environment. The groundwater availability of the study area is quantitatively classified into three categories which include good, moderate and poor prospect zones based on the final integrated map. The detailed results were presented and discussed in the research paper.

Geoderma: Interrelations between Soil Ecosystem Quality and Groundwater.

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The interface of relation between the diversity of the soil, is given by the fact that organisms are soil-forming, and at the same time, the soil has formed the ecosystems it supports. Therefore, when studying the soil in its genesis and evolution, it is evident that the soil has marked in its profiles, the history of land uses and its implications on the quality of land cover. The taxonomic classification of the soil, in relation to the ecosystems it supports, offers ecosystem services, such as the production of food and raw materials, air and clean water, flood regulation, recreation and ecotourism. Such services, among others, in turn, affect the dynamics of groundwater. In addition, global ecological changes are changing some behavior patterns in the relationship of the geosystem, hydrosystem and biosystem. This interrelation is what allows the soil to be called the GEODERMA, which fulfills a protective and regenerating function in the terrestrial system. When inquiring into these natural and human dynamics, sustainable management of the functional and ecological benefits of the soil is oriented. Natural phenomena generate taxonomic changes in soils and their ecosystem services, more quickly than is perceived, if urbanization, conurbation and rapid

transformations of land cover are added, the surface quality that varies the capacity is impacted infiltration in the edaphic section, which in turn alters the quality of groundwater. For example, the Inceptisols and Entisols, which are soils that encounter an incipient pedogenetic development, regulate the surface and underground water resources; Oxisols and Ultisols, which are very old soils, support the planet's jungle ecosystems, recharge aquifers, are a genetic and medical source. Due to the aforementioned, the knowledge of the interrelations of the Geoderma, serves as a planning tool and helps to contribute to the knowledge of the following Sustainable Development Goals such as: Objective 11, Make cities and human settlements inclusive, safe, resilient and sustainable, Objective 13, Take urgent measures to combat climate change and its impacts, Objective 14, Conserve and sustainably use the oceans, seas and marine resources for sustainable development and Objective 15 Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and stop and reverse land degradation and stop biodiversity loss.

Aquifer Characterization of Hard Rock Area and Spatial Variability Analysis via GWO-NN, PSO-NN, and Memristor LSTM Models using Geoelectrical Data

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A traditional hydrogeological technique like pumping test studies is sometimes invasive and costly in the calculation of hydrogeological parameters like transmissivity (T) and hydraulic conductivity (K). Moreover, these traditional estimation methods are of linear; do not take care of the underlying non-linearity between "data" and "model parameter". The weathered/ fissured hard rock basement complex, saturated with water shows the dominancy in all porosity and affecting the electrical conductivity (σ) and hydraulic conductivity. A mathematically formulated framework ($K = A\sigma$) was used to estimate the transmissivity (T) and hydraulic conductivity (K) of hard rock complex that uses the analogy between Darcy's law in fluid dynamics and Ohm's law in electricity. Previously calculated hydraulic conductivity and true resistivity of the aquifer at 37-locations were used in place of pumping test data to estimate the coefficient '$\boldsymbol{A}$' based on a strong positive correlation (Pearson's correlation coefficient ~0.80) between hydraulic conductivity and electrical conductivity of the aquifers. A positive correlation (Pearson's correlation coefficient ~0.51%) between transmissivity and longitudinal conductance at assumed well sites was obtained. The average value of the coefficient '$\boldsymbol{A}$' is further used in the calculation of hydraulic conductivity and transmissivity at the assumed pumping sites using layer resistivity parameters. A good agreement between aquifer hydraulic conductivity and transmissivity obtained from the resistivity parameters and those obtained from assumed pumping test data was obtained.

Further, this method is used in the calculation of K and T at the vicinity of 85 VES points using electrical resistivity parameters. A variogram fitting was obtained by Memristor Long Short Term Memory (LSTM) Deep Neural Network, Gray Wolf Optimization-Neural Networks (GWO-NN) and Particle Swarm Optimization-Neural Network (PSO-NN) for further interpolation of hydraulic conductivity and transmissivity parameters in that area and comparison are demonstrated to establish the proposed approach.

Geophysical approach for sustainable management of groundwater by identifying shallow aquifer networks and artificial recharge zones

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Scarcity for groundwater is aggravated across the globe due to industrial revolution, civilization and ever-growing population. Anthropogenic activities along with dry spells monsoon have severely affected the natural recharge and discharge system and widened the imbalance between them. Country like India, where groundwater is the primary source of irrigation, industrial demands, institutional setups, and daily household needs, is thereby hugely impacted due to this scarcity. Now, we have to look out for the measures which can fasten the recharge of groundwater and save the surface runoffs. Indian Institute of Technology (IIT) Kanpur, one of the premier institutes of the country, is situated in Kanpur and its population solely dependent on groundwater extracted from the deep tube wells (>200m). However, gradual population increase and unpredicted rainfalls have led to problems like water shortage and drying out of a few deep wells in the campus during summer. A pilot study using Electrical Resistivity Tomography (ERT) method has been planned to delineate shallow subsurface groundwater networks and to identify probable sites for artificial recharge. ERT is acquired along six profiles using Wenner-Schlumberger electrode array configuration inside the campus at various locations depending upon the availability of space. RES2DINV inverse modeling software based on smoothness-constrained least-square inversion is used to model the measured ERT datasets. 2-D resistivity models were then correlated with the available log data and following major lithologies were identified throughout the campus: dry alluvium, clay, fine sand and sandy clay. The study delineated shallow aquifer (at ~16m depth) zones of saturated (highly to partially) fine sand layer with resistivity ranging from 10 – 20 Ohm.m and thickness varying from 30-65 m. ERT results along some part of few profiles revealed a low resistive (0–10 Ohm. m) saturated zone which might act as a potential recharge zone for shallow aquifer in the campus. Thus, the findings of the study (i.e., identified shallow aquifer and recharge zone) may provide significant inputs for sustainable groundwater management in the campus.

Impact assessment of bioclogging on the flow of water in porous media

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Microorganisms are capable of causing physicochemical transformation in geological media. Fast urbanization and improper disposal of domestic and industrial wastes are responsible for the induction of organic substrate, biological contamination and other chemical species in soil and the shallow subsurface, which facilitate the microbial growth in porous media/sandy aquifer systems. Adequate infiltration of organic-rich water into the porous media may cause intensive microbial activity and clog the pores by microbes. The process of clogging of the pores by microbes and their byproducts is known as bioclogging. A sandbox laboratory experiment has been conducted for understanding impact assessment of bioclogging on the hydraulic properties of the porous media. A tank packed with coarse-grained sand was saturated with deionized water with sugar (10 gm/L) as organic matter and 10 ml bacterial seed for promoting the growth of microorganisms. It is found that hydraulic conductivity remained unchanged until the bacterial seed is injected in the middle of the tank. In the uppermost part of the tank, initially, hydraulic conductivity increases due to dominated aerobic microbial processes. However, in the lowermost part dominated by anaerobes, hydraulic conductivity decrease with time. After depletion of oxygen by the activity of aerobic bacteria, biofilms spread in the entire tank, and the reduced hydraulic conductivity is observed both in upper and lower parts of the tank.This study shows that bioclogging may cause a significant reduction in the pore space, pore throats, and hydraulic conductivity of the porous media.

Fluvial carbon transport by mountainous tropical rivers of the Western Ghats, India

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The previous global scale investigations have estimated fluvial carbon flux transport by rivers to coastal seas to be 0.80-1.33×10^{15} gm (or Pg) C y-1, and up to 60% of it comes from the tropical regions. However, most of the previous estimations are based on carbon discharge by a few major rivers. Despite being large in numbers and having high yields, the coastal/mountainous rivers have received less attention. To fill the gap, we investigated 70 west-flowing coastal Indian rivers, draining the Western Ghats (WG) for their carbon transport characteristics. These rivers deliver approximately 0.005 Pg carbon to the Arabian Sea annually. It means that despite occupying only 1% of Asia's area, this region exports 3%

of fluvial carbon load. Of this, 42.9% is dissolved inorganic carbon (DIC), 12.9% is dissolved organic carbon (DOC), 10.1% is particulate inorganic carbon (PIC), and 34.2 % is particulate organic carbon (POC). Inorganic carbon concentrations comparably higher in non-monsoon seasons throughout the region. The inorganic carbon yields from the rivers draining from Deccan Traps region are higher than the all global inactive basaltic provinces and comparable with the active basaltic fields draining catchments. Strong region variability observed in terms of carbon yields and type of major carbon species across the region. The WG region with a load of 44.38 gC m-2 y-1 is one of the highest carbon yielding region across the world. Intense precipitation, high topographic relief, catchment lithological, and presence of thick vegetation cover with varying soils from south to north of the Western Ghats are the major factors make this region unique for fluvial carbon transport.

Distribution of dissolved organic matter (DOM) in urban lakes of Hyderabad, a metropolitan city from Southern India

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Lakes are an important part of urban ecological commons performing and maintaining a myriad of environmental functions to protect the local climate, the exchange between surface and groundwater for heat, water and materials, and habitat for the floral and faunal aquatic community. However, unprecedented growth in population and demands of infrastructure development for modern-day needs have adversely impacted these very important water bodies around the world. These lakes have turned into dump yards of untreated sewerages, industrial wastes, and other kinds of organic materials originating from natural and anthropogenic sources in the cities. In this study, we investigated the character of dissolved organic matter (DOM) in surface waters of multiple lakes (21) of Hyderabad, a metropolitan city has a rapidly growing population in southern India, using absorption and fluorescence techniques in conjunction with multivariate analyses. The results of fluorescence excitation and emission matrices (EEMs) spectroscopy and parallel factor analysis (PARAFAC) revealed four components (C1, C2, C3, and C4) of FDOM, which were related not only to surface and sewage sources but also chemical industrial wastewater sources. Strong correlations between optical indices and DOM components (or composition) were found for these lakes indicating the dominance of anthropogenic sources for DOM. The lakes were separated into three major groups – lakes with high untreated domestic wastes, chemical, and industrial wastes, and relatively unaffected lakes from these pollutions, using cluster analysis with distinct water quality obtained from optically measured parameters. This study also highlights the potential of using absorption and fluorescence spectroscopy in addition to multivariate statistical methods as a status fingerprint for DOM characterization in urbanized lakes. Additionally, these techniques may serve for regular monitoring of such critical aquatic ecosystems as

urbanized lakes for water quality purposes. Further, the study highlights the importance of applying these modern spectroscopic tools in collaboration with multivariate techniques in distinguished water bodies based on their chemical and optical characteristics.

Soil and Land Irritability Classification of Mahi Sub-Basin, North Bihar

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Earlier there was no specific method for soil/land irrigability classification system. The parameter/ criterion used for land capability classification were subjective and based on the researchers experience, judgment and ability. Now there are various methods available for classification of soil/land irrigability and land capability class. Water and Land Management Institute (WALMI), Aurangabad has developed a method giving credits to the soil characteristics and has classified the soil into five irrigability classes.

The main purpose of the study was soil and land irrigability classification of Mahi sub basin. Recently various studies have been done for the accurate and scientific classification of land and soil assigning weights to different physical characteristics of land and soil. Soil samples were collected from crop land of Mahi sub-basin and analyzed. A criterion developed by WALMI, Aurangabad has been used and characterized the basin as Class 'A' for soil irrigability classification. Then considering soil irrigability class, land slope and depth of ground water table from ground surface, land irrigability classification has been made. It was found most that most of the area fall under Class 'II' and a patch in the eastern part of the Mahi sub basin were found under Class 'I'.

Geoderma: Interrelations between Soil Ecosystem Quality and Groundwater

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The interface of relation between the diversity of the soil, is given by the fact that organisms are soil-forming, and at the same time, the soil has formed the ecosystems it supports. Therefore, when studying the soil in its genesis and evolution, it is evident that the soil has marked in its profiles, the history of land uses and its implications on the quality of land cover. The taxonomic classification of the soil, in relation to the ecosystems it supports, offers ecosystem services, such as the production of food and raw materials, air and clean water, flood regulation, recreation and ecotourism. Such services, among others, in turn, affect the dynamics of groundwater. In addition, global ecological changes are changing some behavior patterns in the relationship of the geosystem, hydrosystem and biosystem. This interrelation is what allows the soil to be called the GEODERMA, which fulfills a protective and regenerating function in the terrestrial system. When inquiring into these natural and human dynamics, sustainable management of the functional and ecological benefits of the soil is oriented. Natural phenomena generate taxonomic changes in soils and their ecosystem services, more quickly than is perceived, if urbanization, conurbation and rapid transformations of land cover are added, the surface quality that varies the capacity is impacted infiltration in the edaphic section, which in turn alters the quality of groundwater. For example, the Inceptisols and Entisols, which are soils that encounter an incipient pedogenetic development, regulate the surface and underground water resources; Oxisols and Ultisols, which are very old soils, support the planet's jungle ecosystems, recharge aquifers, are a genetic and medical source. Due to the aforementioned, the knowledge of the interrelations of the Geoderma, serves as a planning tool and helps to contribute to the knowledge of the following Sustainable Development Goals such as: Objective 11, Make cities and human settlements inclusive, safe, resilient and sustainable, Objective 13, Take urgent measures to combat climate change and its impacts, Objective 14, Conserve and sustainably use the oceans, seas and marine resources for sustainable development and Objective 15 Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and stop and reverse land degradation and stop biodiversity loss.

Seasonality and Trend Analysis of Rainfall & Temperature by Mann-Kendall Test for Vadodara Region

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Change in rainfall pattern is one of the most critical factors in determining the impact of climate change. Rainfall is one of the climatic variables that affect both spatial and temporal patterns on water availability. The present study aims to examine spatial and temporal rainfall variability and trend during 20th century in Vadodara district. Also, Seasonality Index is carried out to measure distribution of rainfall throughout the season. For the present study monthly rainfall data of 100 years from 1901 to 2000 has been collected for Vadodara district. In the present study monthly rainfall variability and percentage contribution of rainfall is studied and Non parametric trend test i.e., Mann-Kendall (MK) Test have been used together with the Sen's Slope Estimator for the determination of determine whether there is any positive or negative trend in the rainfall data with their statistical significance. From the results and analysis it was observed that rainfall during July is the highest 369.32 mm which contributes to 37.76% of annual rainfall (978.07 mm), followed by August 230.63 mm contributes (23.58%). Rainfall in June and September contributes to 16.07% and 17.87% of the annual rainfall respectively. For temperature January, February, March, April, May, June, September, October, November, December there is an evidence of rising trend while Zc value is showing negative trend in July, August. This study provides the information on rainfall trend on long-term basis and the impact of climate change on different parts of the basin which will be very useful for water resource management, agriculture and economic development of the region. This changing rainfall and temperature trend during monsoon months is major concern for the rain-fed agriculture. Moreover, this will affect hydro power generation and reservoir operation in the region.

Impact of land use and climate change on hydrological services of forested and agricultural headwater catchments in the Central Himalaya

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Forests are considered making vital contributions both to people and the planet, conserving biodiversity, soil and water, and responding to climate change. Land use and climate change have severe effects on water availability in Central Himalaya (Uttarakhand) particularly in the Kosi catchment with overall change in precipitation pattern including high intensity rains occurring over a short period regulating in a higher incidence and intensity of floods and reduction in groundwater recharge, reducing water storage. In order to explore the influence of land use and climate change on hydrological services, a long-term hydro-meteorological monitoring programme was launched in pine forested and agricultural catchments. The pair instrumented catchments are the headwaters of the Kosi river - the life-line of Kumaun region. We have monitored various hydrometeorological parameters in the instrumented forested catchment (1987- 2019) and agricultural catchment (1993-2010) and conducted detailed studies on individual storm events in both the headwaters. The long-term data suggest that on an average, there is a decrease of about 290 mm in the annual rainfall with a decreasing trend and a significant increase in the rainfall intensity. The lean flow capacity of Kosi river during summer has witnessed a massive about 700% drop. Rainfall-runoff and sediment discharge from the pair catchments suggest that high intensity monsoon rainfall on a 1.83 km^2 forest catchment produced a peak discharge of 91.945 l sec^{-1} including 983 mgl^{-1} suspended, 310 mgl^{-1} dissolved and 716051 cm^3 bed load sediments. This increase several fold runoff 661.733 $lsec^{-1}$ km^2 and sediment discharge including 2190 mgl^{-1} suspended, 295 mgl^{-1} dissolved and 865606 cm^3 bed loads in the 0.21 km^2 agricultural catchment. Analysis of long-term data reveals that land use and climate change induced hydrometeorological phenomena in the instrumented experimental catchments are active. This paper highlights the role of protective forests in the hydrological services and also highlight on the changes of these services due to land use and climate change in the mountain headwater catchments.

Estimation and comparison of discharge using SWAT and HEC-HMS tools for a flood event – A case study for Thamirabarani river basin, India

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Unpredicted major flood exposed in the year 1992 in Thamirabarani river basin, India, led to loss of human life, damage to property, crops, and livestock. Lack of discharge data during floods restricted investigators in identifying the vulnerable zones in Thamirabarani river basin. With the availability of IMD rainfall and weather parameters during the disaster event, an attempt has been carried out in the present study to estimate the discharge at different locations using SWAT and HEC-HMS tools. Discharge estimated by considering hydraulic structures, soil type, land use and weather parameters from SWAT and HEC-HMS are utilized as input in HEC-RAS to simulate and obtain flood inundated extent during the disaster event. Results estimated can aid in updating the zones that are vulnerable to flood and help the local authorities in mitigation purposes during major rainfall event.

Rise of groundwater table in Jodhpur city and its proposed remedies.

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Jodhpur city is situated in Western Rajasthan. The city has historically been known for scarcity of water. It experiences arid to semi-arid type of climate. Ground water occurs under unconfined to semi-confined conditions in rocks of Malani rhyolite, Jodhpur sandstone and shale. The main inner city is divided by ridges in between which the main city is settled on Jodhpur sandstone and shale. Earlier, most of the demand of water for the daily uses of general public of the city was fulfilled by pumping of groundwater aquifers, wells and water impounding structures throughout the city. This scenario was changed after the Indira Gandhi Canal Project (aka IGNP) which started supplying water to Kailana reservoir situated outside the city which has basement of Malani rhyolite; and from late 1990's most of the water supplied by public health engineering department (PHED) was of canal water. Slowly overtime due to impervious layer of shale beneath the main city the water table in the aquifers started rising which earlier where balanced by natural monsoonal recharge and year-round discharge. This lead to rise of water table from 200-300 meters to 2-5 meters in a very short time span. Thus problem of water logging started arising in basements of houses and other civil engineering structures in the city such as parking spaces. As a precautionary measure the

Jodhpur development authority has banned formation of new buildings in sensitive zones. As a remedy to the problem the public health engineering department (PHED) pumps water from water logged basements of civil structure to nearby open spaces and gardens which is not at all beneficial since the water slowly percolates down to recharge the same aquifer from which it was drawn by pumping. For combating the situation a holistic approach to the problem should be undertaken by the public administration and hydrologists which should promote awareness of cause of the problem to the general public by outreach and promoting good habits of water conservation along with limited supply of water to highly sensitive zones. Also conjuncitive use of water should be promoted with the water being supplied from public health engineering department (PHED) in the main city should be more from the aquifers and also canal water should only be supplies outskirts of city and nearby rural areas.

Influence of LULC on Groundwater Recharge and Spring Sustainability in Western Ghats in Sindhudurg district of Maharashtra

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The Western Ghats of the Indian Peninsula is dotted with innumerable springs, many of which are utilized for local water supply and many flow unnoticed unrecognized of the vast potential they possess for the service of the humankind. As a part of the study, inventory of the springs have been carried out in parts of Sindhudurg district of Maharashtra. More than twenty springs have been identified under different LULC, lithology and also on geomorphological characteristics such as aspect and elevation. Discharge measurements were taken at selected locations and it is observed that the discharge vary between 4-250 mld in the post-monsoon season and 2-110 mld in the summer. Although rainfall its seasonality, and areas of recharge play vital roles in the springshed revival and water management. Therefore, in the present study, a simulation model HYDRUS-1D was used which deals with the numerical solution of one-dimensional Richard's equation based on the assumption that the soil column may be vertically homogeneous and horizontally uniform. The results indicate that around 25% of the total rainfall received in the springshed flows as runoff. Out of 75% infiltration, around 28% of the water is removed as evapotranspiration thus resulting in 11% as soil water storage and the remaining 24% as ground water recharge. However, it is found that there is a significant variation in the recharge characteristics based on LULC and hydrogeology. It is found that the recharge was maximum in protected forested watershed (35%) followed by agriculture (18%) and degraded forests (16%). Based on the study it is suggested that one of the important process to enhance the groundwater recharge is by increasing the native species either as plantation or as a part of complete afforestation.

Seasonal variation and implications on groundwater recharge and management in northern part of Deccan Volcanic Province, Maharashtra

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India is experiencing the heat of climate change. Studies have shown that the surface air temperatures over India are going up at the rate of about 0.4 degree Celsius per hundred years, particularly during the post monsoon and winter seasons. Extreme weather conditions from heat waves to cyclones and droughts to floods are affecting crop production and gross domestic products besides creating scarcity of water. Climate induced natural disasters such as droughts have become a regular feature of the life of people, particularly in the hard rock terrain of the Deccan Volcanic Province (DVP) in Maharashtra. With persistent dearth of water in the semi-arid areas of DVP, the need for identifying secondary sources of groundwater is felt nearly all over the region. In view of this, the present work is committed to the comprehensive study of dykes and their function in the hydrogeology of basaltic aquifers from Dhule and Nandurbar regions of northern Maharashtra. The critical analysis of electrical resistivity data using two seasons' data (pre- and post-monsoon) from this area suggests a major role being played due to the seasonal variation. Results of the VES data are discussed which revealed heterogeneity in hydrogeological characteristics of subsurface dyke litho environment with discontinuous carrier and barrier stretches.

Water Sustainability through Coastal Reservoirs

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India is blessed with many rivers and monsoon system. It is a fact that every civilization in the past lived along the banks of the river for their water needs. In India, water is treated as holy means divine from the past and water was being used properly. Now, situation is entirely different. Urbanization comes into play. Utilization as well as wastage of water is being hiked everywhere. To conserve it, many methods were employed. But nothing sustains well mainly due to ill behavior of every citizen. Mainly 1/3rd of India's population living along the coastal regions. So, it's better to put a full stop to the crisis of water scarcity by a method which is inspired from the nature i.e., lagoonsCoastal resources contains all natural resources obtaining at coastal waters and their adjacent shore lands. There are mostly five types of water resources available in the world. They are Groundwater, on-land reservoir, desalination of sea water, reuse of wastewater, Diversion of water from a remote source. Each has its own characteristics. A Coastal reservoir is a freshwater reservoir located in the sea at the mouth of a river with a appreciable annual river flow. All we need is to construct a barrier between fresh water and sea water to conserve fresh water for our purposes. In India, the Kalpsar Project in Gujarat has emerged as a well planned coastal reservoir with a length of 30 km, live storage of 10000mcm, spread over an area of 2000 sq.km. It has a life span of 300 years.

Role of Integrated Mega Watershed Management Programme in Water Resources Management in Drought prone areas – A case study

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Earlier watershed programmes used to cover about 500Ha. And used to be considered as the geographical unit for implementation of Micro-watershed project and the duration was 5 years. Under IWMP, geographical area allows taking ranging between 1000 to 5000Ha of land as a single unit that drains to a single point (month) to be treated in saturated manner integrating all element of watershed area and get holistic impact. These guidelines forces on the need for convergence of all existing natural resource conservation, development and potential increment in productivity, associated enterprise and market, trade improvement, management of all resources under IWMP for improved and sustainable livelihoods, Rajupalem watershed in Kadapa District was selected as IWMP block based on the selection criteria. The major problem is one of the acute poverty of small and land less families in Rajupalem watershed and also land degradation is a serious problem in this watershed area, uneven rains, soil erosion, backward savior drought conditions, scarcity of drinking water. Based on all these challenges in rainfed areas therefore is to improve rural livelihoods. While optimizing the natural resources through participators watershed development with focus on integrated production systems for enhancing income and secure livelihoods in a sustainable manners. The main objectives of the paper is to compile all hydrological data, to observe and analyze water harvesting structures and soil conservation structures. To study the cropping pattern and agricultural practices, to evaluate the participatory rural appraisal in the watershed and also to evaluate approaches for conservation and preservation of natural resources like water and soil and to identify methods of improving wastelands, and to evaluate performance of Rajupalem watershed and suggested the methods to improve the gaps observed between on ideal watershed an actual achievement.

Applications of Pollution Index to Assess the Water Quality along the stretch of Cauvery River in Namakkal District, South India

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Water quality problem at different levels has increased considerably during the last century and is being polluted due to rapid industrialization and urbanization activities. Assessment of water quality in a regional scale requires not only an investigation of water pollution and the recognition of main pollution factors, but also the identification of polluted risk zones resulted due to polluted river sections. The present research aims to assess the water quality along the stretch of Cauvery River flow in Namakkal Disctirct, Tamil Nadu, India using the different pollution indices such as single factor pollution index (SFPI), comprehensive pollution index (CPI), Carlson's trophic state index (C-TSI), eutrophication index (EI) and organic pollution index (OPI). There are 15 surface water samples along the river stretch and 19 groundwater samples in and around the study area was collected and analyzed during pre and post monsoon period (2018). The results revealed that the Cauvery river comes under the category of clear (CPI<0.8), oligotrophic (C-TSI<30-40), no eutrophication (EI<1) and excellent water quality (OPI<0). The overall results also show that the river water is suitable for irrigation and life supporting for flora and fauna. With slight treatment, the water can be made available for drinking as well. The present study shows that EI and OPI index are the best parameters to assess water quality since it gives precise results based on four water quality parameters.

Ground Water quality studies in Visakhapatnam Industrial Area

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The city of destiny Visakhapatnam in Andhra Pradesh has been undergoing tremendous development in the form of industrialisation and consequent urbanisation. An amount of ground water has been contaminated due to industrial effluents making it miserable for the habitants. In most of the industrial regions, the ground water has been polluted due to the industrial effluents. These effluents in the course of reaching their sites of destination become hazardous not only to the surface soil but also to the surface and ground water régimes. As a result, the quality conditions of water resources in the region are subjected to rapid deterioration and have become a threat for the health of the human beings. Hence, in this context, a detailed survey has taken up on ground water contamination in and around industrial area of Visakhapatnam.

Development and Evaluation of Groundwater Vulnerability Assessment Methodology

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Coastal aquifers all over the world are threatened by saltwater occurrence, as a result of small head gradients, excessive groundwater abstraction rates, and drain management of the landscape, which is likely to intensify with climate change. Though there are numerous numerical models available for the simulation of sea water intrusion to understand the impact of seawater intrusion on coastal aquifers, the reliability is still a matter of concern due to limitations in data availability. In this regard, it is necessary to have a simple, more realistic and reasonably accurate empirical models so that predictions can be made based on regular monitoring parameters. Accordingly, an attempt was made to develop a tool to identify the sources of the salt and thus to increase understanding of the driving mechanisms and important parameters controlling the extent of saltwater intrusions. This way, areas vulnerable to sea level rise can be identified and managed. Challenges include unknown initial salt concentrations, heterogeneous geology, and anthropogenic alterations. In this study, hydrogeological, geophysical, and geochemical data are used to develop a methodology based on hydrological, hydrogeological and geochemical parameters. The developed model was applied to North Goa coast, south west coast of India. An empirical model known as GRADES was formulated by combining the parameters of GALDIT Model and Ghyben-Herzberg Principle. In the present model, Hydraulic Gradient (G), Recharge Factor (R), Pumping Rate (A), Distance from the Coast (D), Static Water table elevation (E) and Chemical Concentration (S) are the primary components for vulnerability assessment. Weights and Ratings were provided based on background values developed based on detailed hydrogeological and hydrogeochemical analysis. Model results were compared with the GALDIT model and found a reasonably good match. Site specific observations were also showed a similarity with the field data. Therefore, GRADES model may be an useful tool to estimate the vulnerability index of the coastal aquifers in India.

Appraisal of Groundwater Quality for Drinking and Irrigation Purposes in the coastal aquifers from Visakhapatnam to Kochcherla coast, Andhra Pradesh, India

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Groundwater quality monitoring is especially important in the coastal areas for irrigation and domestic purposes in the coastal aquifers. In the present study, 136 groundwater samples along the Visakhapatnam to Kochcherla coast were collected from open/bore wells. The groundwater samples collected during pre and post monsoon seasons were subjected to physico-chemical analysis for major ions. The important parameters with their range of variation viz., electrical conductivity (242 - 9010μS/cm), hardness (50 - 1282mg/l), SAR (0.54 - 10.89meq/l), Percent Sodium (11 - 77meq/l), Residual Sodium Carbonate(-22.26 - 5.51meq/l), Magnesium Hazard (11 - 95meq/l), Kelly's Ratio (0.12 - 3.28meq/l) and

Permeability Index (17 - 105meq/l) are obtained for all the water samples to judge the suitability of water for drinking and irrigation purposes. It is observed that these parameters in majority of the area are within permissible limit except villages near Pyadibhimavaram, Konada and Bheemili areas along the coast. Thus, this study helped to recommend rain water harvesting structures in the coastal area between Visakhapatnam and Kochcherla where the quality of ground water is not suitable for drinking and irrigation.

Evaluating the suitability of domestic wastewater for Irrigation in a peri-urban cluster- A case study from Vizianagaram, Andhra Pradesh, India.

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With ever-increasing demand for water for multiple uses, domestic wastewater has been used for irrigation in many semi-urban and urban clusters of India. Even though, application of wastewater for irrigation has been principally approved practice all over the world, the quality of the water must be tested to check its fitness prior to use. In this study, we study the water quality parameters of the wastewater generating from Vizianagaram town, AP which is being used for irrigation of downstream villages without any treatment. For this purpose, we collected samples at different locations beginning from the point of generation to the point to application and investigated suitability of water for irrigation. We have reported the irrigation water quality in terms of Total Dissolved Solids (TDS), Total Hardness, Sodium Absorptions Ratio (SAR), Electrical Conductivity (EC) and Residual Sodium Carbonate (RSC), sodium soluble percentage (SSP), Magnesium Hazard (MH), Permeability Index (PI), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Kelly's ratio (KR). From the results, it was observed that in general, the water quality indicated through the different parameters is generally poor and is exceeding the standard limits for the irrigation water.

Physico-Chemical Parameters and GWQI Analysis of Dhanbad District, India

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Groundwater is necessary for the survival of human life. The present study area of the hard rock terrain of Dhanbad district of Jharkhand, India and its adjoining areas are suffering from an acute water crisis which hinders the development of agricultural, domestic and industrial

growth. Further, the quality of groundwater is also at risk owing to pollutions made by various sources including industry and agriculture. Therefore it is essential to carry out the systematic groundwater/surface water quality assessment study and its monitoring for better management of water resources in the study area. To calculate the groundwater quality index (GWQI) and to analyze the recently acquired water samples, in total 30-groundwater samples are collected and all these samples are analyzed subjected to comprehensive Physico-chemical analysis. Each of the groundwater samples was analyzed for 13 Physico-chemical parameters including, pH, electrical conductivity (EC), Chloride(Cl^-), Sulfate, Nitrate, Calcium, Magnesium, Sodium, Potassium, Phosphate, Fluoride, total dissolved solids (TDS), and Arsenic. In some places, the higher concentration of fluoride is found which could be due to the weathering of fluoride bearing minerals like muscovite, biotite, fluorite. Also, the high concentration of nitrate is found in drinking water which could be due to excessive use of agriculture fertilizers, decayed vegetable water, domestic effluent, sewage disposal industrial discharges. Using ordinary kriging (OK) contouring methods with Surfer 16, spatial distribution maps of 13 mentioned parameters in the study area have been analyzed and groundwater quality index (GWQI) has been estimated for 30-locations which ranges from 13.882 to 237.857 with the mean value of 71. 40.

Isolating Submarine Groundwater Discharge aided by Radon (^{222}Rn) Isotopes along the coastal Tamilnadu and Pondicherry regions

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Submarine groundwater discharge (SGD) is a fresh groundwater and recirculated water mix into the sea through the subsurface flow. Measurement of SGD is more significant due to input of nutrient from SGD is comparably higher than the atmospheric and riverine that might influence the marine ecology and environment. Attempt has been made to quantify the SGD and related flow to the coast along the coastal regions of Tamilnadu and Pondicherry using radon isotopes. Radon being an effective tracer to quantify SGD fluxes has been attempted in the present study. Water samples representing groundwater, pore water, surface and sea water samples were collected along the coastal regions and analysed for radon and other physic-chemical constituents. Concentration of radon in groundwater ranges between 95.54±0 Bq m^{-3} to 2643.41±0.09 Bq m^{-3}, in pore water between 0.0 Bq m^{-3} to 748.44±0.09 Bq m^{-3}, in Sea water between 0.0 Bq m^{-3} to 461.8 ± 0.16 Bq m^{-3} and in Surface water between 31.85 ± 0.02 Bq m^{-3} to 414.30 ± 0.05 Bq m^{-3} respectively. The radon derived SGD fluxes ranges between 0.0 to 42.0 m day^{-1} irrespective of water type indicating the dominance of recirculated sea water that accounts for major SGD fluxes to the coast.

Inversion of self-potential anomaly sources using Artificial Neural Networks

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Self-Potential (SP) fields are natural occurring electrical fields that originate from various forcing mechanisms related to electrical, hydraulic, chemical and thermal gradients. Therefore, the inversion of SP data is a complicated task due to the presence of these different mechanism in the source region. This requires appropriate techniques for SP data inversion depending on the application field, which ranges from engineering and geotechnical investigations to geothermal and mineral explorations.

In this work, we explore the possibility to apply the techniques based on the Artificial Neural Networks (ANN) to interpret the self-potential (SP) anomalies. First we test the approach on simple polarized structures, such as, sphere, horizontal cylinder, vertical cylinder and inclined sheet. The ANN is trained by generating the data on the values of source parameters from a given range (bounds). ANN is successfully extracts the source parameters including depth to the center of the source (z_0), horizontal location (x_0), polarization angle between horizontal axis and the polarization axis (θ), half width (a) and electric dipole moment (k). After successfully application on synthetic examples, we then apply it on the real field examples. The results of the application on the real data also show good agreement with the parameters provided by previously applied inversion methods.

Delineation of groundwater potential zones using geo-electrical method in parts of Hadoti region of Rajasthan state, India

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A geophysical survey using geo-electrical method is carried out in parts of Hadoti region of Rajasthan. The study area lies in south-eastern part of Rajasthan state of India. In present study eleven vertical electrical soundings (VES) using Schlumberger configuration were conducted at suitable locations in the area. The present study aimed at determining the geo-electric parameters i.e., resistivities and thicknesses of different layers and delineating the possible zones of groundwater potential in the area. The interpretation of the vertical electrical sounding data has been carried out using software IP2Win which gives layer parameters of the sub-surface in terms of resistivities and thicknesses. The sounding results reveal four to five geo-electric layers and a huge range of resistivities and their corresponding thicknesses of the sub-surface were obtained in the area. The obtained layer parameters are used to generate the geo-electrical cross-sections of the sub-surface. The obtained results of the VES have been corroborated with the existing litholog data in study area. The analysis of interpreted sounding results reveals the nature and composition of subsurface litho-logical units. It is inferred from sounding results that the weathered/fractured or semi-fractured zones of low resistivity could be the potential zones of groundwater in parts of Hadoti region of Rajasthan state, India.

YOUNG GEOSCIENTISTS CONCLAVE

Gravity signature and crustal structure variations over the Mare Tranquillitatis

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Mare Tranquillitatis is an non-circular Mare region located on the nearside of the Moon. This region is also lack of having well defined muti-ringed structure. Irregular topography in this region might be resulted from intersection and overlap of the features from adjoining Mare basins such as Mare Crisium, Marre Nectaris, Mare Fecunditatis, and Mare Serentitais regions. Mare Tranquillitatis is also prime region of interest for earlier landing missions to the Moon such as Ranger-8, Surveyor-5 and Apollo-11 etc. High resolution gravity field derived from dedicated Lunar gravity mission: Gravity Recovery and Interior Laborary (GRAIL) and remote sensing data sets recent remotesensing missions like Lunar Reconnaissance Orbiter (LRO) provides opportunity to understand the evolution of different terranes. Bouguer corrected density of 2760 kg/m^3 is estimated using the fractal method and prepared Bouguer anomaly map This region is characterised by three distinict gravity highs at the junction of wrinkle ridges. Interpretation of nature of gravity anomalies associated with these regions using various interpretation techniques, crustal thickness map and thier vis-à-vis spatial correlation of morphological features (surface expression of sub-surface process) will provide insight in to better understanding of the evolution of Mare tranquilitatis region. Crustal thickness is estimated by inversion of the gravity anomalies, which is varying 5-45 km.

Integrated analysis of core and log data for comparative study in coalfields of Damodar valley and Sohagpur

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Sohagpur Coalfield is located in Shahdol district of Madhya Pradesh in basin of the Son River is a part of Central India Coalfields. Sohagpur Coalfield has ample scope of Coalbed methane exploration. We have collected 11 sample from this field at different depths. Most of the samples collected are sandstone and coal. Sample are tested and analyzed for comparative study between Sohagpur and Jharia coalfield. I have tested porosity, density and permeability with different confining pressure and constant inlet pressure of zero gas (50psi) by using automated core porosity and permeability tester. By changing confining pressure from 100 psi to 700 psi, decreasing exponential curve are plotted. Data cores consisting of data core porosity and core permeability data are points scattered along the depth of the well. According to analysis porosity ranges from 4% to 24% and permeability ranges from 1.5 to 5 md in case of sandstone and for coal porosity ranges from 4.5% to 17.5% and permeability

ranges from 1.7 to 4.7md. For low confining pressure the permeability value is very high and it ranges from 10 md to 20 md for sandstone. This analysis is compared with the 10 samples collected from Jharia coalfield and their permeability ranges from 0.11 to 27.14 md. Comparative study will be shown between Sohagpur and Jharia coalfield. Coal analysis of Jharia coalfield is validated with the well log data available in this field. Log data consisting of log gamma ray (GR), log resistivity (ILD), neutron log (NPHI) and density log (RHOB) measured at well at different depth. Petrophysical analysis will performed by evaluating log data that has been validated with core data. Detailed core analysis data including core porosity, core permeability and core description were supplemented by well logs. Rock Types have been categorized based on flow properties using porosity, permeability. The process of carrying out Petro physical analysis produces data that are very necessary for estimation of CBM reservoir. Analysis from the log data that has been made into a well composite log, is interpreted based on the direction and shape of the log curve deflection to determine the lithology of the formation whether it is shale or non-shale, permeable or non-permeable, porous or non-porous, filled with fluid or empty. Quantitative analysis of log data carried out simultaneously by the response equation determined from interpretation models using software.

Seismic hazard assessment of Intraplate Kachchh Region, Western India by using River Gradient Length Anomaly technique

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In the present study, a new technique called River Gradient Length Anomaly (GLA) is tried and tested in the Kachchh region to understand the seismic hazard scenario. The GLA technique is very effective in precisely detecting the recent tectonic deformation along river courses passing through faults on both local and regional scales. From the analyses, we have detected 16,007 locations of uplift and subsidence associated with tectonic movements that are distributed along 120 river profiles covering an area of ~26,696 sq.km. About 13,963 locations show negative GLA (uplift) and 2044 locations have positive GLA values (subsidence). The maximum observed GLA values of uplift and subsidence are -4 and 6.19, respectively. The estimates of GLA are classified into three categories (highest to lowest activity), where 22.89% of the area comes under highly active regions, while 59.51% of the area falls under moderately active regions and 17.6% of the area shows very low or negligible activity. The results show that the higher magnitude anomalies are identified at the intersection of the faults and river courses. Further, we have compared our results with the existing seismic tomography results and with the Peak Ground Acceleration (PGA) at surface for subsurface correlation with estimated GLA values. The combined analysis of GLA and PGA gives precise information regarding surface deformation and site-specific ground acceleration enabling the accurate assessment of seismic hazard. The results of the GLA estimates corroborates well with the geomorphology of the study area.

Keynote, Invited and Planery Talks

Keynote : At the Crossroads in a Far from Equilibrium Universe

Vinod K Gaur

We live and work in an envelope of flows – of materials and Energy. These are in turn driven by gradients of thermal, gravitational, mechanical or chemical potentials, powered from the daily stock of free energy extracted from solar radiation. But each flow must create its own configuration to minimize energy and any perturbation of an ambient state forces the system to create new configurations. Over the past ten millennia, human engineering has been adding new flows into the earth system with exhumed gological potential energy created by earth system processes over millennia and consequent construction of new configurations. Over the past century and a half, in particular, these flows have slowly approached the nonhuman flows, forcing the earth system to create drastically different configurations and at rates that even humans are finding it difficult to negotiate.

This new configuration earth system has already deviated significantly from the basin of the last Pleistocene stability and there are apprehensions that it may cross over from its recent metastable state that allowed the flourishing of human civilization to a new emergent state of uncertain description. The lecture will discuss the concepts of systems that are far from equilibrium and their tendency to form organized structures that have the seeds of their own transience, flipping over to new states, as exhibited by the long history of our planet, and the earth's recent trajectory in the context of its Pleistocene age.

IUGG in its first century and looking forward to the future

Kathy Whaler, President, IGUU

Robin Bell, President, AGU on VC

Harsh Gupta

Recent Advances in the Ocean Information Services provided by INCOIS

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Indian National Centre for Ocean Information Services (INCOIS) an autonomous body of Ministry of Earth Sciences (MoES) is providing several services on ocean information, forecasts, warnings and data to a vast number of users starting from fishermen to oil and natural gas companies, Indian Navy, Coast Guard, etc. Among them, the Potential Fishing Zone (PFZ) advisories provided to the fishermen since 2002 and tsunami early warnings provided to everyone, specially to disaster management agencies, since 2007 and ocean state forecasts provided to various users including fishermen since 2006 have major impact on the society. Since, their inception, all of them underwent significant improvements in their accuracy, reliability, frequency, readability, adaptability and so on.

The PFZ advisory generated using the satellite data is absent during overcast skies. Also, they can be provided for that day and not for the next 2-3 days to help in multi-day fishing. Similarly, the advisories, warnings and forecasts are inaccessible for low-tech dependent fishermen when they go away from the coast for more than 10 km due to the loss of mobile, VHF, etc. ranges. For example, the fishermen who went out at sea before the development of Ochi cyclone could not be informed about it's fast development and direct them to get back to the nearest coast. As a result, several hundred's got perished at sea. Recently, INCOIS attained success in developing high resolution ocean models that can be used to forecast the PFZ for next 3 days irrespective of cloud cover and developed satellite based, low cost communication systems, to deliver the information to the fishermen irrespective of their location in the sea.

On tsunami early warning front, at present INCOIS is providing the timely location specific early warnings to disaster managers and coastal population. Basically, these warnings contain the information on expected time of arrival of the tsunami wave at that location and its expected wave height. But these warnings lack the details on the level and extent of inundation that could occur, at that location, due to the tsunami wave. Recently, INCOIS has developed models that can predict the likely inundation in the localized area and overlaid that on accurate topography of the coast to produce inundation map of the region on GIS platform and share the same with the disaster managers in real time. This talk will present the details of these major developments in ocean information services and discuss about their advantages to the end users.

Indian Planetary Missions: *Anil Bharadwaj, Director, PRL*

Impact of IAGA on Aeronomy: Archana Bhattacharya, Former Director, IIGM

Climate-Glacier Inter-linkages: An Insight from Himalayan Cryosphere: *B.R Arora, Former Director, WIHG*

V.M. Tiwari, Director, CSIR-NGRI

Prof. R.C.Misra Lifetime Achievement Award Lecture: ***V.P.Dimri***

IGU-Anni Talwani Memorial Prize: Pradeep Srivastava :Geology of floods in Himalaya

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The rivers draining the Himalaya support ~15% of the global population whoes agriculture based economy largely depends on the hydrological consistency of these rivers systems. The normal monsoon floods in the Himalayan rivers act as conduit between mountain and the foreland bringing fine grained nutrient rich sediments to arable floodplains. However, the extreme floods resulting due to the excessive rainfall events, glacial and landslide dammed lake outbursts such the floods of June 2013 in Garhwal Himalaya and of August 2010 in Ladakh Himalaya destroy the economy and life built over the years. The landscape mapping, subsequent to 2013 Kedarnath event indicated that the pattern of damage is predictable and is controlled by the geometry of mid crustal ramp. What is not known, is, whether such flood events are the result of natural climatic ramp or anthropogenic interferences. This would only be understood if we have the longer records of past floods. Available historical and instrumental records are not sufficient to understand the trends and possible future intensity of such events, hence paleoflood archives to understand the variability is explored.

The paleoflood deposits were studied in Indus and the Brahmaputra rivers that suggested that the intensity of floods in these two basins is controlled by the geometry of the Tibetan Plateau and the rainfall distribution over it. The presentation will detail the inferences drawn on the work done in the Upper Indus Catchment. Geologically, the Indus valley is bounded by Ladakh batholith in the northeast and highly folded and thrusted Indus Molasse in the southwest. Zanskar River, one of the major tributary of the Indus, increases the discharge and sediment flux of the Indus in multiple scale. Climatically, the Ladakh Himalaya is classified as cold desert, where the average annual precipitation is ~ 100 mm (at Leh) which at present is shared equally by westerlies (~ 50%). However, excess of contribution from the Indian Summer Monsoon (ISM) in the past often leads to extreme rainfall event and floods in the region e.g. August 2010, 2015 floods in Leh valley.

The Late Pleistocene-Holocene history of extreme flood events in Ladakh using slack water deposits sequences comprised of sand-silt-clay couplet in the Indus river system is reconstructed. Chronology based on twelve ^{14}C AMS and thirty optically stimulated luminescence dating of charcoal and sand samples, respectively, suggest four major clusters of flood events occurring between ~16-4 ka that override the phases of strengthened monsoon. U-Pb chronology of Zircons used for provenance fingerprinting indicated that the flood of Indus and Zanskar rivers originated in the deglaciated regions of the catchment. This suggested the potential role of glacial lake outbursts and/or landslide lake outbursts in compounding flood magnitudes. Further, the flood sequences were noticed comprising burnt layers (hearth) and dung cake at places indicating the flood occurrences vis-à-vis human migration into the Ladakh region.

IGU-Krishnan Medal Award Lecture

Theoretical Modeling of Potential Field data and Integrated application for Mineral Exploration

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The most imperative purpose in the interpretation of the potential field data is to determine the different types of subsurface geological structures in various exploration studies. Numerous interpretative or inversion approaches/techniques have been developed to interpret various geophysical data for subsurface structure associated with mineralization. However, in interpretation of geophysical data, ambiguity is intrinsic in all geophysical data modelling and interpretation. To reduce the ambiguity in geophysical data interpretation, integrated geophysical methods has been applied to solve the problem of complex subsurface structure associated with mineralization. The present talk will be focused on the development of appropriate modelling, interpretation and ambiguity analysis of Potential Field methods viz. Gravity, Magnetic, and Self-Potential (SP) data which yield a robust and reliable results. The theoretical development for SP, Gravity and Magnetic methods can be applied to any field data for mineral exploration purpose with negligible uncertainty in the final interpretation. The interpretation techniques developed specifically for SP data has been applied for interpretation of various field data for mineral exploration purposes around the world. An integrated application of different geophysical data (Resistivity, Gravity, SP, VLF-EM and Radiometric) to delineate the possible structures associated with uranium mineralization in South Purulia Shear Zone (SPSZ). The significance of this type of study is its multi-purpose application in investigating various subsurface structures associated with mineral exploration.

IGU- JG Negi Young Scientist Award Lecture: P Chinmoy Kumar

Earth Systems and Their Interactions: A Geochemist's Perspective

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"What we observe is not nature by itself but nature exposed to our method of questioning". Heisenberg

"Primordial elemental abundances, their distribution in different spheres of the Earth and their migration from one sphere to the other are what make the Planet Earth Dynamic and Livable". Goldschmidt

Every natural process is either a *differentiation*, which takes a homogeneous matter and makes two or more discrete products Or a *Mixing*, which combines two or more diverse sources to make a range of products with intermediate compositions or, in the extreme, a homogeneous mixture. The fundamental physical law that governs the flow of matter from sources to products is *conservation of mass*.

Higher "Fe" in the planet Earth resulting in a kink in otherwise smooth decreasing trend for density among the terrestrial planets is the first gigantic step in making our planet dynamic. This "extra" Fe seems to be an input from the large asteroid impact, which also related to the Moon forming event.

The Primordial differentiation of the planet Earth is essentially density driven. The two most abundant dense elements in the planet (Fe and Ni) sunk to the centre of the Earth to form the core and the remaining elements segregated to form the mantle. However, the planet has to wait for another ~ 1.3 Ga to form the dynamo and formation of weak magnetosphere. Due to low magnetic intensity so generated, life could sustain only in the deep marine conditions. The solid inner core and molted outer were separated possibly circa 1Ga ago, which paved the way for higher forms of life on planet Earth.

Low degree melting of the mantle generated the primordial Continental crust and produced depleted upper mantle residue (present asthenosphere). Thickening of the oceanic crust through vertical accretions resulted in gravitational instabilities and paved the way for horizontal tectonics at around 2.5 Ga. Mantle degassing during the crust formation processes produced gaseous cloud and its eventual un-mixing resulted in Earth's liquid and gaseous spheres. All along this vibrant journey of the planet Fe, O and H_2O played key roles in keeping life alive

Role of GNSS in Geosciences and Emerging Demands

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History changed on October 4, 1957, when the Soviet Union successfully launched the world's first artificial satellite Sputnik I. Since then satellite based Communication and Navigation fields have advanced leaps and bounds. Navigation has become part and parcel of everyday life. An advanced and powerful Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) became operational in 1990s. With the upcoming several satellite constellations from different countries a new term 'Global Navigation Satellite System' (GNSS) is proposed. GNSS refers to the world wide positioning, navigation and time determination capability available from one or more satellite constellations. GNSS has innumerable applications and it is not an exaggeration to say that it is nearly impossible to find an area where GNSS has no application and Geosciences area is no exception. Some of the prominent areas where GNSS has made a mark include surveying, earthquake prediction, estimation of minute movement of earth, high precision measurements of crustal strain, marine navigation for geosciences, weather prediction in terms of atmospheric conditions such as air density, temperature, moisture and electron density.

GNSS will be immensely useful for accurate marine navigation and high performance ship to shore and ship to ship communication and will also help in our national project called "SAGARMALA Project", initiated by Indian Govt. for modernizing ports and another incredible initiative called "Mausam" which aims to explore maritime routes that link India to different parts of Indian Ocean littoral. However, standalone GNSS systems suffer from various errors and to overcome these adverse effects several techniques have been proposed and implemented such as space based augmentation systems (Ex. WAAS and GAGAN) and ground based augmentation systems(Ex. LAAS). This is expected to satisfy necessary precision-based applications. Due to tremendous advancements in the GNSS technology, several demands some critical and some not so critical are emerging. Selected few of these along with the above-mentioned application will be briefly dealt in the presentation.

Resilience of Earth System:

RN Singh

Potential River Bank Filtration (RBF) well Identification using ERT and VES

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River Bank Filtration (RBF) is an efficient natural river water filtration method in which surface water contaminants are removed or degraded as the infiltrating water moves from the river to the aquifer. This paper presents RBF investigations along the downstream of the Varaha river near the Vommavaram village of S. Rayavarammandal, Visakhapatnam district to provide safe drinking water. During RBF investigations, groundwater and river water samples were collected from 17 villages of S. Rayawaram Mandal and analyzed for physico-chemical and bacteriological parameters and thus confirms that most of the groundwater samples are saline and surface water is contaminated by Total Coliform. Therefore an alternative drinking water source has been investigated as RBF well. Total four Electrical Resistivity Tomography (ERT) surveys have been conducted along and across the Varara river. Based on ERT results, suitable location has been identified and further, Vertical Electrical Sounding (VES) survey was also conducted in the same location to find the depth of each lithological unit at proposed RBF well. Both ERT and VES surveys are delineated the river-aquifer interaction and seepage zones with the resistivity values in the range of 14-20 Ohm.m from the depth of 7-30 m b.g.l. Based on ERT and VES surveys, the RBF well has been drilled up to the depth of 30 m b.g.l on the Varaha river banks and yields better quality of drinking water supply as compared to the shallow groundwater. The RBF method yields very good results when the river is perennial or this method also explored nearby any water body with favorable hydrogeological conditions. RBF wells provide an alternative, sources of drinking water with minimum water treatment facilities.

NGRI-AHI Young Hydrologist Award Lecture 2015-16 - *Vimal Mishra*

Depleting groundwater and increasing droughts: risks of water scarcity in India

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India experienced some of the most detrimental droughts during 1901-2017 that affected all aspect of human lives. Droughts occurred in the late 18thand early 19thcenturies were highly damaging due to low lack of irrigation facilities in India. Crop yields were lower and any widespread drought event posted a great risk to human lives. After the green revolution, the food production and irrigation facilities have improved in India. Canal network in north India was established in many parts by 1940s. However, groundwater played a major role in enhancing food production and fresh water security in India after the green revolution. The analysis of great droughts in the history 117 years suggests that detrimental droughts continue to occur in India as before. However, the enhanced groundwater based irrigation and water management approaches reduced the impacts of droughts in the recent decades. The rapid decline in groundwater in India poses challenges for the future food security in one of the most populated regions of the world. Therefore, the current and future water management options should consider reducing the groundwater depletion in India.

Rain Response Releases In Krishna Basin

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Krishna basin is characterised by high rainfall in upper reaches interspersed by rain shadow region with low rainfall and increase in rainfall towards Bay of Bengal. Most of the rainfall is received during southwest monsoon. Many dams have come up across upper catchments of Krishna river which held water up to later stages of monsoon. The downstream flow to the river is being delayed. The rain shadow regions which are depending on flows from upper Krishna are not receiving water in time to tide over dry spells. The releases are taking place after dams are filled up to brim, which is not happening until end of August as occured during this year. The opportunity cost of holding water is very high, as crops have withered in Rayalaseema and lower reaches due to prolonged dry spells. Analysis is done in the paper for upper Krishna of the cost of holding water taking into account daily cumulative rainfall from IMD, inflows in to Almattti and dry spells experienced in Rayalaseema region. By the time water is released due to floods it is too late and crops are in irretrievable condition. Nation is paying high cost in terms of GDP without a holistic policy of water releases in large basins due to various constraints. Intelligent water management needs dynamic approach of Rain Response Releases (RRR) which is brought out in the paper taking case study of upper Krishna.

Is the Decline in Groundwater Levels in India being underestimated? - *P.N Ballukraya*

In the hundreds of over-exploited blocks (groundwater) in the hard rock areas of India, the depth of the borewells has been steadily increasing over the years. While it was about 50 m in the early seventies, the average depth in many of these heavily over-exploited blocks has reached 300 m or so at present. Such deepening is the result of the shallower water-bearing zones getting steadily de-watered over the last 4-5 decades. However, published reports from many of these areas do not show any commensurate increase in the depth to groundwater levels. For example, the information booklets published by the ministry of water resources on the status of groundwater in the districts of Bangalore rural, Ananthpur, Coimbatore, Salem, Hyderabad or Bengaloru city all show that the groundwater levels are mostly within 50 m bgl while the newly drilled borehole depths are in the range of 300 – 400 metres. Such a paradox is not easily explained and to understand the same a study was carried out in Doddaballapur as well as Bengaloru city areas using borehole camera video scans. Examination of over 100 such videos clearly established that the groundwater levels at present are generally 200-250 m below ground level here. Such a wide variation with the published data is probably due to the fact that in these areas, the *measured* groundwater levels are in general directly related to the borehole depth, in that deeper borewells have deeper measured groundwater levels, up to a point. It was observed that the current recharge enters the existing borewells at depths of about 40-60 m and then cascades down the borehole shaft, as free flow, till it meets the water level in the well. This water escapes the borewell through the lowest de-watered joint exposed in the borewell, thus preventing any rise in water levels. Only in borewells which are >250 m deep and are presently productive, there is no further commensurate decline in the measured levels, since these borewells have water-producing joint in them (below the water level) and therefore, there is no further downward movement of the recharging waters. It was also noticed that a large number of de-watered joints are present in these borewells, between the water level and the joints at which recharging waters enter the bore at present, indicative of the presence of a thick de-watered rock matrix in between. This situation, wherein the range of measured groundwater levels even within a micro watershed is 25 to 300 m bgl, points to the need for selecting groundwater level monitoring wells after careful study. It may very well be necessary to select ONLY currently producing borewells as monitoring wells and that using borehole scans be a good idea to ensure that there are indeed producing joints in such borewells at the time of measurement. It is possible, indeed probable, that this condition may be true in most of the over-exploited fractured rock aquifer systems in south India and therefore, there is a need to rethink the entire groundwater monitoring projects in light of the above facts.

Future of Exploration Geophysics: An automated approach to seismic interferometry with ambient noise

Jay Pulliam

W.M. Keck Foundation Professor of Geophysics

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Ambient noise seismic interferometry (SI) can be an inexpensive complement to active-source seismic exploration. In a typical SI approach, one seismic node serves as a "virtual source" and the others as receivers and the "virtual source gather" (an empirical Green's function) that is obtained by cross-correlating and stacking signals recorded at each node represents the seismic response of the subsurface structure between the virtual source and the receivers. SI techniques can be used for a variety of applications, including reconstructing the Earth's layering, seismic tomography, monitoring subsurface changes in, for example, volcanoes or reservoirs, and retrieval of surface wave group or phase velocities in the form of dispersion curves

A variety of real-world challenges, including off-line noise sources, uneven distributions of sources, and large amplitude waves that obscure more useful waves, often impede the convergence of SI techniques to accurate Green's functions. Our approach to surmounting these obstacles, and to minimize the required deployment duration required, involves automated processing in the field. In-field (or "at the edge") processing allows us to establish convergence criteria and continually evaluate the criteria in situ, and only terminate the data acquisition when we know we have achieved success. We embed a small, inexpensive (Raspberry Pi 3) processor with each node, create a wide-area WiFi network in the field, populate a decentralized databased with continuous ground motion data, perform distributed "correlate and stack" processing on the many processors, and, finally, store the results for successive time periods in the database. Analytic tools can then assess the stacks for "quality" or "convergence".

Numerous challenges were overcome in the development and testing phases of our automated seismic array. I will present an overview of our strategy, a description of our solutions to the various challenges, and results from applications to existing geothermal fields in Nevada USA and additional deployments in Texas USA.

Water resources of India: Future Perspective

P.P.Mujumdar

Some Water Harvesting Structures to Reduce Seawater Intrusion into Coastal Aquifers along the Andhra Pradesh Coast

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Coastal Andhra Pradesh has second largest coast line in the country with a length of 974 km abutting 9 districts on the land ward and Bay of Bengal on the sea side. Saltwater intrusion occurs in virtually all coastal aquifers, where they are in hydraulic continuity with seawater. The channels and canals provide conduits for salt water to be brought into fresh water marshes. But salt water intrusion can also occur as the result of a natural process like a storm surge from a severe cyclone. Most often, it is caused by groundwater pumping from coastal wells, or from construction of navigation channels. There are about 50 major, medium, small rivers and streams that join with Bay of Bengal along and within A.P coast line shown in fig.1. Saltwater intrusion is predominant in the deltaic regions to the extent 30km to 40km inland during pre-monsoon period in the Krishna and Godavari deltas mainly due to back water through rivers, distributaries, creeks and aquaculture. In the medium rivers like Vamsadhara, Nagavali and Penna backwater flows may be 5km to 10km along the medium rivers and less than a kilometre As a result seawater also intrudes into groundwater adjacent to these water bodies and water quality in the bore/ open wells on either side of the river get brakish or saline. The boundary of probable influenced area towards the land is shown with red line boundary.

Two case studies of seawater intrusion along with remedies are discussed. I) Seawater intrusion moved upstream in Gosthani river due to sand mining disturbing the Bheemunipatnam Water Supply. A water harvesting structure - subsurface-cum-surface dyke across the river prevented seawater further upstream. Surface storage of about 2.7km length, 100m to 150m width and 1.0m to 1.m thick water body is created. Since last one and half decade there is no trace of seawater intrusion towards upstream and at the same time it became perennial to Bheemunipatnam. Another sub-surface-cum-surface dyke is proposed at 1.5km downstream side of the above structure to prevent the influence of high tide back water into the river.

ii) Seawater intrusion along the palaeo river course with sand aquifer up to 10km upstream from the coast in Sarada river has been tackled with intrusive dyke through grouting across channel which is at 10m depth, 7m thickness and 50m width.

However, with simple structures like- groins, surface-cum-subsurface dykes in the backwater affected areas in all the rivers is essential to recharge the river beds, storage of considerable amount of base flows and surface run off as well reduce the seawater intrusion towards upstream of the river course.

Himalayan Climate: Uncertainties

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Himalayan region is distinctly known as the "Water tower of Asia" or the third pole of the world for its unique bio-geophysical, climatic and hydrological setup. Besides its importance in influencing the large-scale hydro meteorological systems like monsoon it is abode to a large mass of population under its large trans-boundary extent in Asia. The recent IPCC report suggests that, Himalayas are one of the most vulnerable systems to climatic changes, which may result into the irreversible changes to the hydrology, climate, demography and the underlying ecosystem. With the recent generation of high-resolution climate models, it has been shown that, such changes may have wide range of variability in space as well as time due to unique setup of the Himalayas. Although there are weaknesses in the models, these are capable of reproducing the mean, variability as well as the long-term trend of climatic parameters in more realistic manner than the previous general circulation models (GCMs). In a series of efforts to underline the recent climate changes over Himalayas, regional climate model simulations from COordinated Regional climate Downscaling Experiments South-Asia (CORDEX-SA) has been used. Many of the models are able to represent the mean, seasonal cycle as well as the spatial variability of precipitation as well as near surface air temperature. Also, for the future climate, there exists a wide range of uncertainty pertaining to different model experiments, time slices and the range of scenarios. Interestingly, season specific response to warming with peculiar warming behavior for different altitude regions of Himalayas has been found to prevail during present and future climate. This may have further implications for the climate and hydrology of region and needs proper attention for more organized mitigation and adaptation strategies for future.

A.Vara Prasada Rao, Director, A.P. Groundwater and Water Audit Department

NGRI - AHI Indian National Hydrology Award Lectures:

Ground water exploration and management to serve the society:

S N Rai

Mitigation of groundwater depletion and seawater intrusion by Managed Aquifer Recharge

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Groundwater depletion is a major problem in many regions of the world due to over extraction. The variability in rainfall due to climate change also aggravates this problem. Changes in the rainfall pattern due to climate change leads to several uncertainties in the supply and management of the groundwater resources. Thus, implementation of Managed Aquifer Recharge(MAR)measures and proper maintenance of them would help to overcome groundwater depletion problem. These measures are in great need especially in coastal regions since over pumping of groundwater from coastal aquifers results in seawater intrusion. Hence, improving groundwater recharge in coastal regions will result in mitigation of seawater intrusion. A study based on density dependent groundwater modellingwas carried out to assess possible measures for mitigating the seawater intrusion in a region north of Chennai, India. Mitigationmeasures such as construction of check dams, rejuvenation of water bodies, reduction in pumping etc., were considered during the groundwater modelling. The implications of climate change on variation in rainfall and sea level rise were also considered during modelling. A detailed analysis of the interaction between the surface water and groundwater was carried out to optimise the use of MAR structures as well as integrating the density dependent relation between groundwater potentials and salinity. The construction of new check dams results in additional infiltration along the rivers, which would support the irrigation water demand for the surrounding farmers in the region especially during the dry season. The study proves that greater efficiency can be achieved by a combination of measures including MAR over a larger area of the basin to overcome groundwater depletion and seawater intrusion.

Understanding and Combating Cyclone Hazard in India: *M. Mohapatra*

Understanding and Combating Cyclone Hazard in India

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India received worldwide accolades due to remarkable improvements in cyclone warning services by India Meteorological Department (IMD) leading to significant reduction in human deaths to less than 100 in recent years like cyclone FANI in 2019 (64), TITLI in 2018 (78), HUDHUD in 2014 (46) and PHAILIN in 2013 (21) as compared to thousands in the past like Odisha Super Cyclone in 1999 (10,000). There is also decrease in area of evacuation by 300 km in 10 years, hence evacuation cost by 60 percent and decrease in ex-gratia paid by Govt. to survivors by about 99 percent as compared to 1999. This has been possible due to modernisation of cyclone warning services of IMD leading to improvement of forecast accuracy alongwith increase in lead period and service delivery. The track errors decreased by more than 40 percent and landfall error decreased by 50 percent by 2018 compared to 2010. The error in intensity forecast is also less (10 to 15 knots for 24 to 72 hr forecasts). The accuracy of adverse weather warning including rainfall, storm surge and gale wind also improved significantly. The above upgradation was taken up addressing all components of early warning, viz., (i) policy & planning, (ii) vision & strategy, (iii) observations, (iv) monitoring, (v) analysis, (vi) modelling, (vii) forecasting, (viii) warning generation and dissemination, (ix) capacity building, (ix) confidence building and (x) outreach. The Vision-2020 was prepared in 2010 to improve cyclone forecast accuracy by 20% by 2015 and 40% by 2020. The SOP for cyclone monitoring and forecasting services by IMD was modified along with the guidelines of NDMA. The new technologies were introduced such as (i) modernised observing systems like automated weather station(AWS), high wind speed recorders, ocean buoys, Doppler weather radar(DWR) and satellite based monitoring tools; (ii) digitised forecasting platform and decision support system (iii) new versions of global and regional deterministic and ensemble prediction systems, storm surge and coastal inundation models. The new methodologies were introduced leading to (i) extension of lead period of cyclogenesis forecast from 1 day in 2008 to 3 days in 2014 and 5 days in 2018 (ii) cyclone track and intensity forecast from 24 hrs in 2008 to 72 hrs since 2009 and to 120 hrs since 2013. Also (i) extended range forecast (for next two weeks) for cyclogenesis, (ii) fishermen warning for entire north Indian Ocean in both graphic and textual form, (iii) district-wise impact based forecast and warning in color coded form were introduced since 2018. In addition, the research and capacity building including forecast demonstration project, documentation of each cyclone, development of dedicated website and cyclone e-Atlas were other significant steps. However, there is still scope to further improve (i) observational network including buoys, DWR and AWSs along the coast, (ii) global & regional models with better data assimilation, (iii) meso-scale assimilation of DWR and INSAT 3D data for regional model with 3/1 km resolution along with coupling of Ocean, land and atmospheric processes, (iv) real time impact based warning product generation & risk mapping and (v) warning dissemination to remote areas, especially deep seas.

Mineral Prospects of India: Present Scenario and Challenges

B.K.Sahu

Current Practices & Advances in Geoscientific Laboratory Investigations in Hydrocarbon Exploration

Dr. Sudhir Shukla

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From the days of reconnaissance survey to the modern day high-end workstation based interpretation and multidisciplinary, synergistic & domain specific research, oil exploration and development has come up long way both in terms of precision, time as well as quality management. Geoscientific laboratory investigations and R&D efforts including innovation and technology induction have been fundamentally important during all times i.e. the drilling of exploratory / parametric wells so also the field development & production. The advancement in the technology in the lab domains is more towards the hardware / software and machination side which is directly connected to instrumental / vendor progress. The advancements in the processes and techniques is difficult in basic data generation and primarily originated in-house in the E&P companies and later on put to test by other researchers world over. In the domain of Geology, Sedimentology, Biostratigraphy, Chemostratigraphy, Remote Sensing, Geochronology help evaluate the source, reservoir and seal facies in any stratigraphy by incorporating reservoir characterization, high resolution multimicrofossil biostratigraphy, linking chemo./chrono-Zones to biostratigraphic Zones, paleoenvironmental and paleogeographic mapping. Structural modeling linking Remote Sensing data / image based mapping, Synthetic Aperture Radar (SAR) applications for offshore hydrocarbon seepage detection, Geochronological dating (TRITONThermal Ionization Mass Spectrometer (TIMS) also relate to reservoir characterization, dating of source rocks, geochemistry, HC migration and Oil-Oil and Oil-Source correlations based on various isotopic attributes. Higher level Integration with microfacies, wireline logs and high resolution seismic & sequence stratigraphy builds up basinal model.

In E&P companies, domain specific research and expertise needs to be developed on priority with more and more real time analysis and innovative solutions to the existing geological problems. Geosteering / biosteering applications to cut costs and enhance production are extremely useful in inclined or horizontal drilling cases. Tip calibrations are applied to the tips and/or to the nodes of a phylogeny. Better accuracy and precision achieved by calibrating fossil

tips (FAD/LAD; Acme etc.) with morphological data and phylogenetic leads to Total Evidence Dating. Process response approach in sedimentation history strengthens basinal evolution through geological time initially focusing on the basin architecture, high resolution biostratigraphy, paleogeography and sedimentation history followed by the event correlation. Amongst the unconventional resources, Shale Gas potential and evaluation by conventional coring, on-site desorption, long-term desorption in laboratory; Gas hydrate exploratory research in association with other agencies; evaluation of CBM Potential of Gondwana and

Tertiary coal and assessment of depocenters for BCG / Tight Gas / Deep Gas are essentially supported by the geoscientific laboratory inputs both for current assessment and future feasibility of exploration in new areas.

Blue Economy India Deep Sea Mission

Shailesh Nayak

Climate Change and Consequences

B.N. Goswami

Integrated Water Resource Management: *Pandith Madhnure, Director, Telangana State Groundwater Board*

Anik, Director, Sustainable Water Future Programme, Future Earth

Barton

Geophysical Mapping for Regional Tectonics as Guide for mineral Exploration

Bijendra Singh

2nd Triennial Congress of FIGA

Workshop on

" Synergic Management of Water Resources in Changing Climate"

12th & 13th October, 2019, NGRI, Hyderabad

1. Water resources status and management in India, *Prof. P. Rajendra Prasad, Andhra University, Vizag*
2. Climate change impact on coastal aquifers and numerical modelling, Prof. L. Elango, Anna University, Chennai
3. Challenges and remedies in Waste Water treatment towards improved circular economy, Prof. A.B. Gupta, MNIT, Jaipur
4. Trends in rainfall and peak flow estimates by modelling, Mr. Anndaruban & Dr. L. Elango, Anna University, Chennai
5. Urban Water Distribution and Management, Prof. M.S. Mohan Kumar, IISC, Bangalore
6. Hydrological modelling using soft Computing techniques, Dr. YR Satyaji Rao, NIH, Kakinada
7. Geospatial techniques in Water Resources Management, Dr. Girish Gopinath, CWRDM, Kozhicode
8. Ground Water Quality in hard rocks, Prof. B. Venkateswara Rao, JNTU Hyderabad
9. Surface and Ground water quality, Dr. K. Rama Mohan, NGRI, Hyderabad
10. Application of geophysical methods in water management, Dr. Subash Chandra., NGRI, Hyderabad
11. Use of bore hole camera video scan in hard rock hydrogeology, Prof. P.N. Ballukraya, Mangalore
12. Surface water resources – Status and Management, Prof. V.V. Srinivas, IISC, Bangalore
13. Monsoon variability and predictability and its relevance's to water resources, Dr. A.K. Sahai, IITM, Pune
14. Impact of Land use land cover changes on ground water dynamics in parts of Western Ghats- Dr. B. Purandara, NIH, Belgaum
15. Climate projection and downscaling, Dr. K. Palanivelu, Anna University, Chennai


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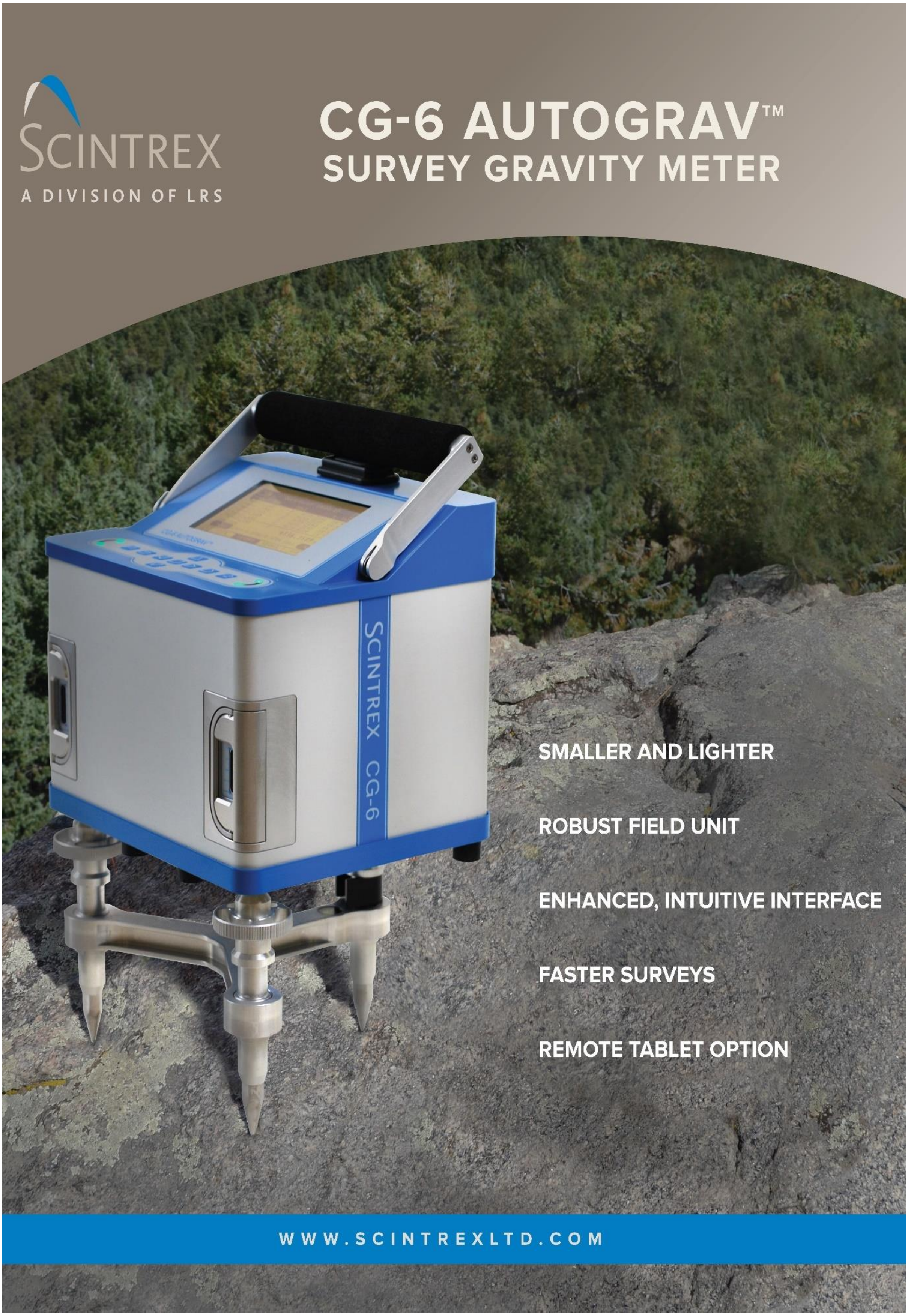


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