INDIAN GEOPHYSICAL UNION

55th Annual Convention on

Changing Water Cycle & Water Resources

December 5-7, 2018

Venue:
RABINDRANATH TAGORE UNIVERSITY, BHOPAL

Jointly Organized By

IGU & RNTU

Rabindranath TAGORE UNIVERSITY
MADHYA PRADESH, BHOPAL

ABSTRACTS

SCIENCE ON THE EDGE

ESSO- National Centre for Polar and Ocean Research (NCPOR)

under the Ministry of Earth Sciences is a nodal institution studying the Polar Regions and surrounding oceans.

ESSO-NCPOR (formerly National Centre for Antarctic and Ocean Research- NCAOR), India's one of the premier R & D institution was dedicated to the nation on 5th April, 2000. Being a nodal agency for coordinating and implementing the Indian Polar Science Programs, NCPOR organizes and participates in scientific expeditions to Arctic, Antarctic, Himalaya (Three Poles) and Southern Ocean (SO).

Indian Antarctic Program

Indian Arctic Program

Himalayan Expedition

Southern Ocean Expedition

Major Thurst Area

- ❖Climate change studies
- ❖Ocean-Atmosphere Interaction
- ❖Ice core studies
- ❖Polar Limnology
- ❖Himalayan Glaciology
- ❖Paleoclimatology and Paleoceanography
- ❖Southern Ocean Processes
- ❖ Microbial Biodiversity and Biogeochemistry
- ❖Exclusive Economic Zone Survey
- ❖Extended Continental Shelf Mapping
- ❖Environmental Impact Assessment
- ❖ Exploration for Hydrothermal Sulphide Mineralisation
- ❖Polar Remote Sensing

Achievements

- ✓ NCPOR is truly trans-hemispheric organization working on all poles and oceans.
- ✓ Successfully launched 37 scientific expeditions to Antarctica, 10 expeditions to Southern Ocean and 11 expeditions to Arctic
- ✓ Established two permanent and over-wintering research bases in Antarctica (Maitri and Bharati); 'Himadri' research base in Svalbard, Arctic and 'Himansh' research base in upper Himalaya
- ✓ Established India's first and only Ice Core Laboratory
- ✓ Undertook India's first scientific expedition to the South Pole
- ✓ Deployed India's first multi-sensor mooring in the Arctic called IndARC within Kongsfjorden, Svalbard

ESSO

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Website: *http://www.ncaor.gov.in*
Facebook: *https://www.facebook.com/ncaor/*
Twitter: *https://twitter.com/ncaor_goa*

Please join us to explore and understand the Polar Regions and surrounding oceans for the benefit of mankind

Indian Research Base in Antarctica- Maitri

ABSTRACTS

55th Annual Convention

on

"Changing Water Cycle & Water Resources"

Venue:

Rabindranath Tagore University

Bhopal

Sponsored by

National Centre for Polar and Ocean Research (NCPOR), Goa

Oil and Natural Gas Corporation Limited (ONGC), Dehradun

Indian National Centre for Ocean Information Services (INCOIS), Hyderabad

National Center for Earth Science Studies (NCESS), Thiruvananthapuram

CSIR-National Geophysical Research Institute (CSIR-NGRI), Hyderabad

CSIR- National Institute of Oceanography (CSIR-NIO), Goa

Physical Research Laboratory, Ahmedabad

Indian Space Research Organisation, Bengaluru

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Message

The Indian Geophysical Union (IGU) has organized 54 annual conventions on various themes at research organizations, universities and academic institutes. IGU has provided a platform for dissemination of knowledge of earth system science through Plenary lectures, Invited talks, Oral/poster presentations, Special talks on current topics of interest in the earth sciences having societal relevance. The present convention "Changing Water Cycle & Water Resources" is being jointly organized by IGU and Rabindranath Tagore University, Bhopal during December 5-7, 2018. I am sure deliberations of the Annual Convention is likely to enrich our understanding on the impact of changing water cycle on existing water resourcesand climates as well as to provide insight on other natural resources, geodynamics, earthquakes and hazards with a view to meet societal requirements.

It is gratifying that her excellency Hon'ble Governor of Madhya Pradesh has kindly agreed to inaugurate the Annual Convention. A response from more than 200 delegates and participation of dignitaries is a positive stride towards the success of this program. It is indeed an honour to welcome esteemed dignitaries, delegates, speakers, sponsors, invitees and exhibitors to the 55th convention of IGU and wish an enriching participation. I wish the convention a grand success..

(Prof. Shailesh Nayak)

November22, 2018
Bengaluru

Shri Santosh Chaubey
Chancellor, Rabindranath Tagore University
Raisen - 464993

Rabindranath TAGORE UNIVERSITY
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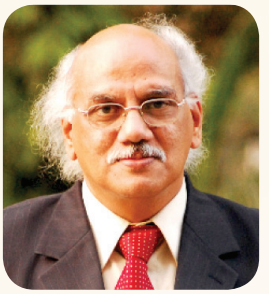
Message



It is a great pleasure for the Rabindranath Tagore University, Bhopal to jointly organize with the Indian Geophysical Union (IGU) its 55th Annual Convention on the focal theme of 'Changing Water Cycle & Water Resources' from December 5 to 7, 2018. I am also glad that Her Excellency Hon'ble Governor of Madhya Pradesh and Visitor of this University has very kindly agreed to visit our University to inaugurate the Annual Convention. I am confident that it will benefit and motivate young Earth Scientists who have the great opportunity to interact with the eminent academicians and professionals visiting our University on this occasion. I am sure that participation in the Convention would be fruitful and memorable for all.

I wish the 55th convention of IGU every success.

(Santosh Chaubey)

November 22, 2018
Bhopal

PREFACE

The Indian Geophysical Union(IGU) started in 1963 with the blessings of the-then luminaries like Prof K.R. Ramanathan, Prof. S. Bhagavantham, Prof. M.S. Krishnan and Dr. S. Balakrishna. It has always provided a platform for dissemination of knowledge, sharing thoughts/views, interaction between young geo-scientists/researchers and experienced geoscientists, understanding societal problems and finding feasible solution, and discussion on current topics and recent phenomena, which are required for the development of society. As done in the past, IGU will continue its activities with a view to serve the Earth Scientific Community of India.

IGU has been organizing annual conventions at different organizations/institutes, and the 55th convention is being jointly organized by IGU and the Rabindranath Tagore University (RNTU), Bhopal during December 5-7, 2018. Though the main theme has been chosen as "Changing Water Cycle & Water Resources", the three-day convention encompasses sessions on other important issues of the Solid Earth Geosciences, Marine Geosciences and Atmospheric, Ocean & Space Sciences. Additionally, IGU conducted a pre-conference workshop on "Hard Rock Hydrogeology and estimating Groundwater Balance/Budget under Changing Climate" for the benefit of students and researchers on 4th December, 2018 at RNTU, Bhopal. Special thanks are due to Dr. Shakeel Ahmed, Chair Professor at JMI, Delhi and the Course coordinator and other team members.

The IGU has always encouraged the young researchers for improving their research capabilities and widening their knowledge globally. It provides an opportunity for presenting the geo-scientific works, getting feedback from the peers, knowing the research and/or discoveries on latest topics or recent phenomena, and networking with eminent geoscientists of other institutes/organizations for further advancement. The senior scientists are hereby requested to provide guidance and instill their vast experiences into young researchers, and the young researchers are advised to reap the fruits through interaction.

Besides 3 plenary, 2 special,2 award and 2 memorial lectures and 3 invited talks, we have 55 oral and 56 poster presentations spread over the three-day convention. Even though three-hours(15:15-18:15 Hrs.) on 6th December have been dedicated for posters, these will remain displayed from the 5th afternoon to 6th evening of December, 2018 for enabling better projection and fruitful interaction among the presenters and delegates. It has been a common practice to recognize 3 students and 3 researchers with the IGU-ONGC Best Poster Awards. A special session on 'Young Researchers Program' has also been arranged with a view to venture their scientific caliber and get recognized with the Best Presenter Award and a Runner-up. IGU inspires the first and second rank holders of M.Sc. Tech. students in Applied Geophysics from different universities by providing them with travel support, fee-waiver and free accommodation

from Prof Jagdeo Singh and Dr. S. Balakrishna Memorial Grant to participate in the convention. It also encourages 4 Young Women Researchers with travel support, fee-waiver and free accommodation from the Anni Talwani Memorial Grant. As usual, IGU honours both the young and senior geo-scientists for their excellent contribution to Indian Earth Sciences through 5 National Awards/Prizes, 5 Memorial/Endowment Lectures and IGU Fellowships. Only 2 Memorial Lectures are presented in this convention. The remaining lectures and some special talks will be arranged as a part of activities by 7 Students Chapters of IGU at NCAOR-Goa, IIT(ISM)-Dhanbad, CSIR-NGRI-Hyderabad, IIT-Roorkee, IIT-Mumbai, Andhra University-Vishakhapatnam and RNTU-Bhopal. The Students' Chapters organize Quiz competitions, Memorial/Endowment Lectures, 'Interaction cum Poster Presentation' round the year.

The extracts of the deliberations are brought out through an abstract volume and sometimes by a proceedings volume. Besides, IGU has been publishing its own journal during the last 22 years, which provides an opportunity for scientists/researchers to publish their scientific works. To encourage the authors, IGU also bestows the best paper award among the papers published in its journal in a calendar year. The journal has its own website **www.j-igu.in** and delegates are requested to visit this site for further details and submit their full papers for publication.

We salute both the past and present members Executive Council (EC) of IGU for their suggestions and guidance to the sustainable development of IGU over the past 54 years. Thanks are also due to the Fellows and Members for their continued support. At present we have 920 members and a Drive is on to increase the Number. The visibility has been increased by associating with other geo-scientific associations like the AGU and SPG. Efforts are on to make IGU an internationally reputed scientific society, and to organize special talks on topics of region specific, current interest and relevance to societal welfare.

We place on record our sincere thanks to Prof. AK Gwal, VC of RNTU and the Chairman of Local Organizing Committee, Dr. Suryanshu Choudhary, the Convener of Local Organizing Committee for their devotion coupled with the logistic and financial support in organizing the 55th Annual Convention at their University Campus. We are indebted to Prof. Shailesh Nayak, President of IGU for his invaluable suggestions and meticulous supervision for this convention. We are also grateful to Prof. Harsh Gupta, Prof. V.P. Dimri, Dr. Sateesh C Shenoi, Prof. Talat Ahmad, Dr. V.M. Tiwari, Dr. O.P. Mishra, Dr. N.P.C. Rao, Prof. M. Radhakrishna, Prof. S.K.G. Krishnamacharyulu, and other members of the EC of IGUfor their unequivocal guidance. We also thank the chair persons for technical sessions for accepting to conduct various sessions, as per suggested schedule. Special thanks are due to Mr. Rafique Mohammad Attar, Treasurer of IGU for executing various works related to this Convention throughout the year. Finally, I wish to thank Mr. Satendra Singh and all others who have worked behind the scene for organizing the three-day convention.

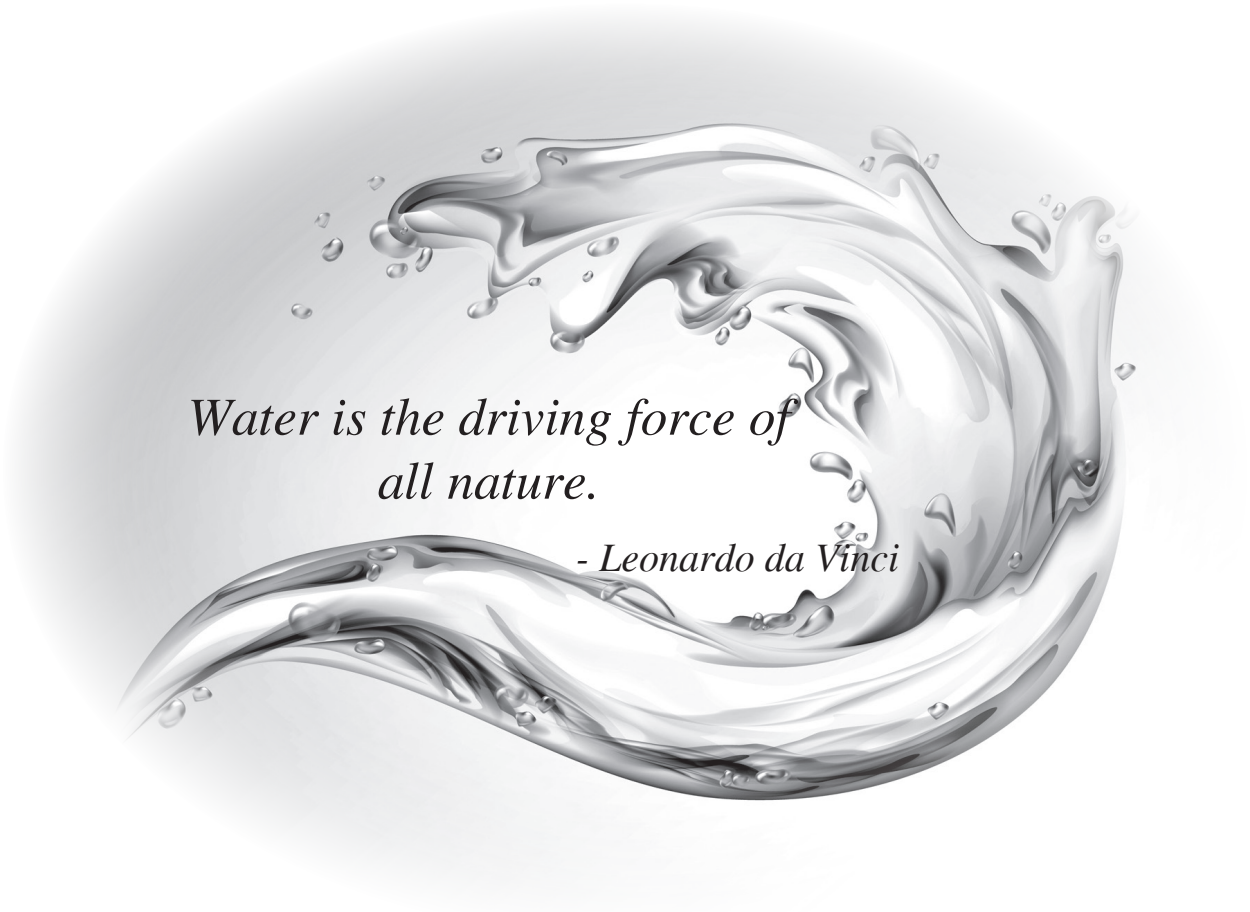
No convention can be organized without budget. The convention is co-sponsored by National Centre for Polar and Ocean Research (NCPOR), Goa; Oil and Natural Gas Corporation Limited (ONGC), Dehradun; Indian National Centre for Ocean Information Services (INCOIS), Hyderabad; National Center for Earth Science Studies (NCESS), Thiruvananthapuram; CSIR-National Geophysical Research Institute (CSIR-NGRI), Hyderabad; CSIR- National Institute of Oceanography (CSIR-NIO), Goa; Physical Research Laboratory (PRL), Ahmedabad; Indian Space Research Organization (ISRO), Bengaluru; National Remote Sensing Centre (NRSC), Hyderabad; National Environmental Engineering Research Institute (CSIR-NEERI), Nagpur and Central Institute of Mining and Fuel Research (CSIR-CIMFR).

It is gratifying that Smt. Anandiben Patel, H.E. Hon'ble Governor of MP has kindly agreed to be the Chief Guest and inaugurate the Convention. It is also heartening to note that Shri Santosh Chaubey, Chancellor of RNTU, Bhopal, Prof. R.J. Rao, VC of Barkatullah University, Bhopal and Dr. Navin Chandra, DG of MP Council of Sci. & Tech have also agreed to grace the functions of the 55th IGU. This shows the importance of this convention. We are sure that it will make a memorable event of 'water cycle and its impact on water resources' to the cause of society. Finally, we solicit cooperation of esteem delegates for uninterrupted conduction of sessions and better presence of delegates. We request the speakers and session-chairman to restrict to the time allocated for presentation. Delegates are requested to contact Dr. ASSSRS Prasad or Mr. Md. Rafique for any help and assistance.

Wishing the IGU-2018 at RNTU, Bhopal a resounding success.

Kalachand Sain
ASSRS Prasad

December 5, 2018


Water is the driving force of all nature.
- Leonardo da Vinci

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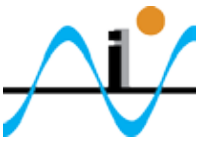

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INDIAN GEOPHYSICAL UNION
HYDERABAD

RABINDRANATH TAGORE
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MADHYA PRADESH

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SOLID EARTH GEOSCIENCES

3D CRUSTAL RESISTIVITY STRUCTURE IN THE AFTERSHOCK ZONE OF THE 2001 BHUJ EARTHQUAKE AND ITS CORRELATION WITH AFTERSHOCKS PATTERN

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The aftershock activity of the 26 January 2001 Bhuj earthquake ($7.7M_w$) in the Kutch region of India is found to be unique for an intraplate earthquake due to its vigorous and persistent behavior. The aftershock events shows a V-shaped pattern and N/NE migration along the western margin of the Wagad uplift located to the northeast of the mainshock. 3D crustal resistivity structure of this aftershock zone is investigated, using magnetotelluric (MT) data, to understand the subsurface geometry of faults/lineaments, which could provide critical inputs to evaluate and strengthen the earthquake generation mechanism and aftershocks pattern. The 3D conductivity structure showed a highly heterogeneous upper and middle crust, characterized by a mix of conductive (<30 Ωm) and resistive to moderately resistive (>300 Ωm) structures. The enhanced conductivity zones imaged by MT shows spatial correlation with the surface trace of various faults/lineaments and are interpreted as fluid enriched zones in the crust, which play a critical role in earthquake triggering. The study indicate significantly higher fluid enrichment in the crust below two minor faults, Khadir Transverse Fault (KTF) and Manfara Fault (MF), which are hitherto considered to have an insignificant role in the seismogenesis of the area. The aftershock events seem to occur mostly on the resistive parts of the crust, and its pattern shows good alignment with the anomalous conductive zones associated to the above two faults. The results provide a strong clue to infer that the KTF and MF have a vital role in the observed aftershock activity and control the V-shaped aftershocks pattern.

CRUSTAL STRUCTURE OF THE CHAMBAL VALLEY VINDHYAN BASIN DEPICTING ITS MARGINAL FAULTS IMAGED FROM THE DEEP SEISMIC REFLECTION STUDIES

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The continental crust experienced the extensive development of the intracratonic basins in the different parts of the world during the Meso- Neoproterozoic period. The Vindhyan basin located in North –Western India with long depositional history is one of the largest intracratonic basins. Due toits vastness in both space and time, it is an ideal platform to understand tectonic historyand sedimentology of the ancient crust. It is divided into two parts,namely,the Chambal Valley sector and the Son Valley sector. Large-scale geophysical studies were carried out in the Son valley sector. However, limited investigations were observed inthe Chambal valley sector. In this connection, here we present results obtained from the deep seismic reflection experiment in Chambal valley sector. Our study using the Common reflection surface stack imaging approach clearly reveals 7.5 km thick of proterozoic sediment and 1.5 km thick volcanic sequence, followed by granitic-basement at 9.0 km depth and variable crustal thickness in the Chambal valley sector from 40 to 44 km. We could also image a crustal-scale regional tectonic feature i.e. NW-dipping Great Boundary Thrust (GBT) that outcrops at Bundi, and a NW dipping reflection band continuing from 9 to 30 km depth beneath the

Bundi - Kota profile-segment, being termed here as Chambal thrust. The basin is thin in NW side at GBT and thicker in SE. We interpret features of the basin because of development of peripheral bulge due to extensive thrusting and post collisional extension duringthe Aravalli orogeny. We have seismically imaged the basement of Hindoli group of rocks for the first time. Our study also reveals a 9-12 km thick lower-crust indicating mafic-underplating, which is an important post-collisional process in the region.

SCALING LAW BETWEEN SEISMIC MOMENT AND CORNER FREQUENCY OF TRIGGERED EARTHQUAKES IN THE KOYNA-WARNA REGION, WESTERN INDIA

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The precise determination of the stress drop, and scaling of source parameters are important for understanding the earthquake source processes and seismic hazard assessment. The dislocation process of most of the earthquakes at source is complex. Here, we investigated the scaling law between the source parameters for the reservoir triggered earthquakes, which are mostly small magnitude events from Koyna-Warna region, prominently known for its reservoir triggered seismicity located in the western India. A large number of P-waveform have been used, recorded at the borehole and surface seismometers. After doing the effective corrections for attenuation and sites effects, the retrieved spectra are inverted to estimate the source parameters. The inversion results yield optimal fit between the observed and theoretical spectra for a source model for $w^{3.6}$. It is further validated the findings using independent method by Spectral ratio. The model obeys the self-similarity predicts realistic range of stress-drop and source radii. Our results suggest that the rapid decay of higher frequency components of triggered earthquakes governed by different dynamic rupture processes compared to the normal earthquakes. The complexity of the regions originates from the strong spatial heterogeneity of the medium due to the repetitive occurrence of seismicity within the granitic basement.

SPATIAL AND TEMPORAL BEHAVIOUR OF IONOSPHERIC VTEC DURING THE SHALLOW EARTHQUAKE OF NEW ZEALAND (M 7.8) ON 13TH NOVEMBER 2016

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We here by presenting the results of the Ionospheric VTEC during October 01 to December 31, 2016 in order to identify ionospheric anomalies during the New Zealand earthquake of M 7.8 on 13th Nov 2016 with a focal depth of 15.7 km. The data of 25IGS GPS permanent stations are used for this analysis. These IGS GPS stations cover both the nearer and far distance from the epicentre of the earthquake where we can expect significant ionosphere variations in association with this shallow significant earthquake. The global planetary index, Dst, Solar Irradiance (F10.7) and AL reveals the signature of small magnetic activity during October 01 to November 05, 2016. We considered the data during November 6-20, 2016 which covers the duration of 7 days before and 7 days after the earthquake to study the pre and post seismogenic effects. Spatial variation of VTEC observed to be enhanced at nearest stations than far stations. In order to see the temporal variations of VTEC, we determined Upper Bound (UB) and Lower Bound (LB) of VTEC time series. We observed more enhancement of LB over the observed VTEC at nearest stations than far stations. Dynamic spectra and

temporal variations at different frequency bands reveal the strong band at 22 to 30mHz which may indicate the rise of 5th Schumann resonance band before the event time. We compared variations in VTEC of 3 quiet days and 3 days during this earthquake. We found that the TEC shows significant deviations from the quiet time behavior at all locations in response to this earthquake. Latitudinal variations of VTEC at each 30 min interval from 00:00 to 15:30 UT on 13th Nov 2017 and 12th Nov 2017 from -12.5to 44.5^{0} latitudes over the epicentre of New Zealand event are compared which clearly indicate the enhancement of the TEC signal just before the earthquake. In order to observe the spatiotemporal characteristics of TEC and resultant modifications, we prepared the TEC maps with all these 25 GPS stations at each 30 min intervals from 00:00 to 15:30 UT of earthquake day. The TEC values seems to be normal during 00:00 to 04:30 hrs and later, it is showing the increasing trend. The TEC is found to reach the maximum value around 08:30 UT onwards till earthquake time (11:03 UT) in the New Zealand area. The VTEC is found to be a promising tool for monitoring the earthquake precursory signatures just before earthquakes.

GEOPHYSICAL INVESTIGATION FOR COPPER AND GOLD MINERALIZATION IN DHANI-BASRI AREA, DAUSA AND ALWAR DISTRICTS, RAJASTHAN.

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Today, there is a challenge before geoscientists to discover new mineral deposits by an exploration technique, which have low risk, consumes less time and also cost effective. Towards reaching this goal, geophysical methods with the phenomenal improvement in the design and development of equipment, methods and precision of data acquisition, processing and interpretation, play an indispensable role. Geophysical surveys comprising SP, magnetic, IP (TD) cum resistivity, gravity and resistivity sounding have been carried out in Dhani-Basri area in Dausa and Alwar districts, Rajasthan. Rocks exposed in the area have indicated presence of isolated outcrops of quartz-sericite mica schist, quartzite and metasedimentary within the Banded Gneissic Complex (BGC). The mineralization in Dhani-Basri area shows intense shearing, silicification and ferruginization. Results of integrated surveys have presented in the form of contour maps to identify the significant anomaly zones for mineralization viewpoint. IP survey has delineated seven anomaly zones out of which zones 1, 2 and 3 are trending in N-S to NW-SE directions while zones 4, 5, 6 and 7 are trending NW-SE direction. IP chargeability values of zone 1, 2 and 3 are ranging from 16-22 mV/V. Zone 1 supported with low SP value, which are ranging from -100 to -200 mV corroborates well with the Dhani-Basri proved deposit whereas zone 2 and 3 have no support of SP, magnetic and resistivity responses. IP chargeability values of zone 4, 5, 6 and 7 are ranging from 15-24 mV/V and strike length are varies from 400-1500 m and well corroborated with other geophysical anomalies. The peak chargeability value of zone 5 is observed as 30 mV/V over a background value of 10 mV/V. Chargeability cum resistivity pseudo-section shows depth persistence of the inferred conductors based on the opening of the contour downward. These chargeability zones are associated with low SP, low resistivity and moderate magnetic responses. The results of gravity survey have been presented in the form of Bouguer anomaly profile and contour map. The anomaly profiles reflects a zone where borehole already intersected a mineralized zone. It also indicates a high Bouguer gravity anomaly, which is corroborated with the high chargeability response. The anomaly contour map indicates a fault zone depending on the trend of the contour, which corroborates well with the regional schistosity. Gravity high closure is observed mainly for metamorphic content below

the alluvium cover. The results of Schlumberger resistivity sounding are presented in the form of geo-electric section. The section has brought out different subsurface layers characterized by different resistivity values. The interpreted layers are top soil, hard rock/fractured granite-gneiss and Archaean basement. The thickness of the hard rock varies from 6.6-30.6 m at a depth level of 1.1-28 m which is followed by high resistive basement at a depth level varies from 7-32.25 m.The steep gradient of basement could possibly be attributed to a fault zone. Status of the subsurface host lithology has been identified for use as tool for prognostication of base metals in the Dhani-Basri Group of rocks. The SP, magnetic and gravity data picked up structural/lithological trend. Test boreholes are recommended in each zone of 2, 3, 4, 5, 6 and 7 to find out the nature of the causative sources based on the chargeability anomalies.

MAPPING DEEP SEATED FAULT STRUCTURE AND ITS VALIDATION BY A BOREHOLE DRILLING FOR GROUNDWATER EXPLORATION, EXPLOITATION AND DEVELOPMENT

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High resolution geophysical methods produce indirect evidence for favourable subsurface geological structures, which could hold water under the different hydrogeological conditions and acts a potential water zones for exploration. A major deep seated fault (**F-F**) is mapped and delineated from resistivity tomography model towards the southern side of the profile, and this fault structure separates between the low resistivity 100-200 Ohm×m and the high resistivity >17 kOhm×m geological formation with a large resistivity contrast. The fault, which is extended up to 230 m depth, is the potential and a unique target for groundwater exploration all along the fault plane and towards the southern side but there is no prospect for groundwater exploration towards the northern side of the fault, where there is a highly massive quartzite resistive formation as studied in Andhra Pradesh, India. The potentiality for groundwater of the inferred fault is confirmed by a borehole drilling up to 154 m depth, which encountered groundwater at a depth of 124 m bgl at the contact of shale and quartzite rock formation and the static water level measured is at 18.14 m bgl is now under unconfined condition and at a normal atmospheric pressure. This is a unique and a new finding delineated the sedimentary rock (shale) as well as metamorphic rock (quartzite), where these two classes of rock have a wide range of resistivity variation and a very distinct hydrogeological property. A conceptual geological model is prepared up to 230 m depth based on the borehole lithology as well as the resistivity distribution of the models of the studied area, which explain and illustrates the geological sequences of various formations, delineated the major fault structure and the implication for the deeper groundwater resources. It shows the detailed geological tectonic set up and the hydrogeological variation all along the fault zone. The geological model depicted the main fault structure, the weathered and fractured limestone, shale & quartzite formations all along the fault, various types of limestone, shale, weathered quartzite and the massive thick quartzite rock towards the north of the fault plane. The borehole (BH) drilled up to 154 m depth encountered water in pink shale and weathered quartzite at a depth of 124 m, which is under confined condition and with a high pressure within the subsurface rock strata. The implication of the study exemplify the hydrogeological scenario as well as delineated the major fault zone, mapped through high resolution electrical tomography, is the main target for groundwater exploration and exploitation and is the major source of groundwater resources for sustainable development in the present geological setting.

MAPPING THE CRUSTAL THICKNESS IN SHILLONG-MIKIR HILLS PLATEAU AND ITS ADJOINING REGION OF NORTHEAST INDIA

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In this study we have tried to detect and collect later phases associated with Moho discontinuity and used them to study the lateral variations of the crustal thickness in Shillong -Mikir Hills Plateau and its adjoining region of northeastern India. We use the inversion algorithm by Nakajima et al., (PEPI 130:31-47, 2002), having epicentral distance ranging from 60 km to 150 km. Taking the advantage of high quality broadband data now available in northeast India, we have detected 1607 Moho reflected phases (PmP and SmS) from 300 numbers of shallow earthquake events (depth ≤ 25 km) in Shillong-Mikir Hills Plateau and its adjoining region. Notably for PmP phase, this could be identified within 0.5 to 2.3 s after the first P-arrival. In case of SmS phase, the arrival times are observed within 1.0 to 4.2 s after the first S-arrival. We estimated the crustal thickness in the study area using travel time difference between the later phases (PmP and SmS) and the first P and S arrivals. We also investigated the seismic shear-wave velocity structure of the crust beneath eleven broadband seismological stations of the Shillong-Mikir plateau and its adjoining region using teleseismic P-wave receiver function analysis. The inverted shear wave velocity models show ~34-38 km thick crust beneath the Shillong plateau which increases to ~39-41 km beneath the Brahmaputra valley and ~46-48 km beneath the Himalayan foredeep region. The results shows that the Moho is thinner beneath the Shillong Plateau about 35-38 km and is the deepest beneath the Brahmaputra valley to the north about 39-41 km, deeper by 4-5 km compared to the Shillong Plateau with simultaneous observation of thinnest crust (~33 km) in the western part of the Shillong Plateau in the Garo Hills region.

INFLUENCE OF RAJMAHAL VOLCANISM ON THE ARCHITECTURE OF WEST BENGAL SEDIMENTARY BASIN FROM SEISMIC TOMOGRAPHY

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The breakup of the east Gondwana due to the Kerguelen hotspot activity and Rajmahal volcanism during the upper Jurassic – lower Cretaceous period have profound influence on the structure and tectonics of the region in general and architecture of the West Bengal basin in particular. We aim to understand the impact of east Gondwana breakup on the formation of West Bengal sedimentary basin from seismic refraction tomography. The velocity images, as revealed by traveltime tomography along four controlled source seismic profiling, each of ~100 km long, show smooth variation of Recent, Quaternary and Tertiary sediments with velocities from 1.8 to 4.3 km/s, deposited over the Rajmahal volcanic rock or Traps (4.8 km/s velocity)followed by the basement, defined by 5.9-6.2 km/s km/s. It must be stated that the high-velocity volcanic rocks have concealed the low-velocity Permo-Carboniferous Gondwana sediments, which couldn't be delineated by refraction tomography. Of course, it didn't hinder to provide the tectonic implications of the study area. The pseudo 3-D configuration,as generated from the results along four profiles, shows that the basement is shallow in the North & West and deep in the East & South. The depth of the basement on stable shelf of the

basin in the west gently increases from ~ 1 km to ~8 km and then dips to 16 km within a short distance in the east, representative of a passive rifted margin. The study identifies a regional feature, known as the Shelf break or the Hinge zone, where stable Indian shield ends and a sharp increase in sediment thickness occurs. This might have been evolved during the breakup of east Gondwana with the separation of India from the combined Antarctica-Australia at ~130 Ma and demarcates the boundary between the continent and proto-oceanic crust. The Rajmahal Traps might be associated with the rifting and generation of passive margin due to mantle plume activity. Thick (~10 km) high density (3.05 g/cc) materials, known as the 'magmatic underpalting', have been delineated at the base of the crus. The regional gravity map of the Bengal basin clearly shows the Hinge zone with a linear gravity high that is compatible with the results from seismic data. The gravity high in the deep basinal part is explained by the Moho upwarp.

TOMOGRAPHIC IMAGING OF SUB-TRAPPEAN GONDWANA SEDIMENTS AND BASEMENT CONFIGURATION ALONG THE KUVARI-SHAHDOL SEISMIC REFLECTION PROFILE IN THE REWA BASIN OF CENTRAL INDIA

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Rewa basin of Central India is one of the poorly understood sedimentary basins in the world with potential hydrocarbon bearing sub-trappean Gondwana sediments deposited in a typical rift environment followed by masking due to basalt flows related to the Deccan volcanism (~ 65 Ma). To delineate the sub-trappean Gondwana sediments infested with several dykes and sills along with the basement configuration and complex subsurface geological structures, we have derived pre-stack depth migration (PSDM) seismic image with tomographic velocity model using common-depth-point (CDP) seismic reflection data acquired along the N-S trending 127 km long Kuvari-Shahdol profile in the south Rewa basin. The stack section obtained using conventional velocity analysis and seismic data processing fails to provide good result although pre-stack time migration (PSTM) show some improvements, but could not able to image the complex geological structures in this sedimentary basin. Hence, a robust tomographic velocity modeling technique is adopted to image fine-scale subtle subsurface geological structures with smooth velocity variations, which clearly depicts the presence and extension of basaltic trap with numerous dyke intrusions, alternate horsts and grabens with deposition of thick (>5.0 km) hydrocarbon bearing Gondwana sediments overlained by highly heterogeneous basalts (<2.0 km thick). The PSDM image show all the subsurface geological structures constrained by the tomographic velocity model indicating highly fractured basement interspersed by the Gondwana sediments due to intense tectonic activity in this rift basin. This seismic image is well constrained in which all the reflection events are flattened having minimum residual moveout (RMO) in the common image gathers (CIG's) obtained with the help of robust tomography using constrained velocity inversion (CVI) and Kirchhoff PSDM technique. The presence of numerous faults cutting across the Gondwana sediments deposited in the basin having alternate horst and graben structures with basement undulations bearing fractures through which Gondwana sediments have been interspersed with deeper penetration. This indicates presence of deep seated hydrocarbon reservoir with an excellent trapping mechanism of basement cover forming a Type 1 (based on the mechanical behavior of pre- and syn-rift settings) rift basin corroborated by the nature of Bouguer gravity anomaly of the study region. The large basement faults facilitate as the conduits for the emancipation of volcanic lavas forming dykes and sills in this region, which are considered as lower crustal mafic rocks due to the Deccan volcanism. The basin architecture

has been presented with deep basement faults and presence of pre-rift, syn-rift and post-rift strata with basalt covers as trap in this region indicating complex tectonic settings of the Late Cretaceous Volcanic Province (LCVP) of Central India.

GROUNDWATER MODELLING USING VISUAL MODFLOW IN THE OSMANIA UNIVERSITY CAMPUS, HYDERABAD, TELANGANA

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Groundwater modelling is the simplified representation of the complex aquifer system and it is used to map the groundwater flow of present and future scenario. In the present study, geological, hydrogeological data of Osmania University campus, Hyderabad is collected and physical property values are determined on systematically collected rock samples from the campus. The entire area is modelled using MODFLOW software. A steady state finite difference model, MODFLOW using 16 observation wells has helped to quantify groundwater picture in the Osmania University campus. The model sensitivity was tested by changing the parameters for the period 2014-2015 post monsoon. Results of the study shows that groundwater levels will fall more than 40m by 2020 if the present rate of exploitation continues. It is therefore suggested that groundwater resources be augmented through artificial recharge. Further the results suggest that a reduction of 40% utilization of groundwater by resorting to rain-water harvesting in the study area will increase the groundwater level in future. The model results represent a base for future groundwater yield and helps for groundwater management in the study area.

RELATIVE PALAEOINTENSITY RECORD OF THE GEOMAGNETIC FIELD FROM SEDIMENT CORES OF KRISHNA-GODAVARI DELTA, EAST COAST OF INDIA.

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Knowledge of secular variations of geomagnetic field strength provide a better understanding of geodynamo and to develop a method for determining past geomagnetic field. As no relative palaeointensity (RPI) data is available from Indian sediment samples, an attempt has been made to deduce preliminary results to compare with global palaeointensity model CALS10k.1b. In the present study, pseudo- Thellier technique was applied to obtain RPI according Tauxe et al. (1995) using sediment cores from Viswesarayapuram village, Godavari delta region, east coast of India.This method involves in measurement of intensity of natural remanent magnetization left (NRM_{left}) after AF demagnetization versus intensity of anhystereticremanent magnetization gained (ARM_{gained}) at the same peak on a set of samples. For each sample, it needs to plot NRM intensity left versus ARM intensity gained at the same peak field and the parameters are linearly related. From Arai plot, one can determine the best fit slope, m_a (where 'a' indicates ARM) with linear regression and an error estimate using jackknife resampling procedure (Kok 1998). The jackknife resampling procedure calculates the slope through every possible combination of at least four data points, starting at fields higher than 30mT. All possible slope values are plotted in histogram where 90 percent of these slope values would lie between dashed lines. The solid line represents the best fit slope and dashed lines point out the upper and lower limits for

possible m_a values. We used 30 mT field steps and higher, because the NRM left at lower steps might still be suffering from a viscous overprint. Samples are dominated by pseudo single domain grains and contains magnetite and titano magnetite mineral rich behaviour as the suitability was checked by mineral magnetic analysis. RPI experiments were conducted on 128 samples by the pseudo-Thellier method. Full set of demagnetization steps at fields of 5 mT, 10 mT, 15 mT, 20 mT, 25 mT, 30 mT, 35 mT, 40 mT, 50 mT, 60 mT, 70 mT, 80 mT, 100 mT and 125 mT are applied on 33 samples from VP core. Selected set of demagnetization steps at fields of 10 mT, 20 mT, 30 mT, 40 mT, 60 mT, 80 mT, and 125 mT are applied on remaining samples of the profiles. The best fit slope (m_a) is obtained in the interval of 30-80 mT, from the Arai plot, the NRM intensity left after demagnetization versus the ARM acquisition intensity by using jackknife resampling procedure. These results are well compared with the three conventional normalization methods (NRM_{20mT}/ARM_{20mT}, NRM_{20mT} /IRM_{20mT}, NRM_{20mT} /χ) to minimize the environmental contamination of the palaeointensity signal.

PRE-DRILL PORE PRESSURE PREDICTION USING DENSITY AND SEISMIC DATA BY INTEGRATED APPROACH: A NEW TECHNIQUE

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Proper well design is most important in wildcat drilling for blow out prevention in high pressure and temperature reservoir. Pore pressure places an important role to calculate fracture pressure gradient and to design a safe and economically viable well in geological complex basin. In this study density and seismic data are used for the prediction of pore pressure in high pressure and temperature reservoir. The pore pressure predicted by modified Eaton's method are excellently matched with offset well data (RFT). A new method is proposed for the prediction of pore pressure and the predicted pore pressures by it are excellently matched with the pore pressure predicted by modified Eaton's method. It has been observed that pore pressure predicted by our proposed method is excellently matched with offset well data (RFT) too. Comparatively it has been observed that in the new method, normal velocity data from compaction trend is not the necessary input, thus the error caused by normal velocity has been eliminated whereas in the modified Eaton's method the normal velocity may cause the error. The new method has been successfully applied to seismic data and density data and turned out to be reliable to repeat formation test data, it provides a new way to predict pore pressure and contributes to exploration and exploitation. The new method we proposed here has potential to perform better in pore pressure prediction than modified Eaton's method.

ESTIMATION OF Q_A AND Q_B OF GARHWAL AND KUMAUN HIMALAYA, INDIA: A COMPARATIVE STUDY

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In the present work, attenuation study is carried out for Garhwal and Kumaun region of North-West (NW) Himalaya, India. The Garhwal and Kumaun regions are seismically very active and lie in the seismic gap of major earthquakes. In this work, an attempt is made to compare the attenuation characteristics of the Garhwal and Kumaun Himalaya by estimating quality factor (Q) values of body waves (Q_α and Q_β) using the strong motion data. The local earthquakes recorded on strong motion

network installed in these two respective areas i.e. five stations in Garhwal and seven stations in Kumaun regionare utilized for the analysis. A total of 39 and 85 earthquakes occurred in Garhwal and Kumaun region, respectively within the epicentral distance of ≤ 65 km are considered for the present work. The events used for Garhwal and Kumaun region have depth in the range of 2-25 km and 2-35 km, respectively. The extended coda-normalization method is adopted to estimate P-waves and S-wave quality factor values for both Garhwal and Kumaun region. The different central frequency range of 1.5, 3, 6, 9, 12, 18 and 24 Hz are utilized to compute frequency dependent quality factor relation. Attenuation relation of form, $Q = Q_o f^n$ (in which 'Q' is quality factor and 'f' is frequency), where Q_o corresponds to Q value at 1 Hz and 'n' is frequency relation parameter and the frequency dependent relation is developed at each individual recording stations of both region.

It is observed that the Q_o values for the P and S wave varies from 52to 55 and 77 to 85, respectively for Garhwal region, whereas Q_o values for the P and S wave varies from 23 to 37 and 42 to 59, respectively for Kumaun region. The low value of Q_o (<200) and high n (>0.8) values clearly indicate that both region are seismically active and highly heterogeneous. In the present work, the ratio Q_β/Q_α is greater than one, which also represent heterogeneity in the present study region. The average frequency dependent relation is obtained by using the relation from each individual station as $Q_\alpha=(53\pm2)f^{0.820\pm0.001}$ and $Q_\beta=(80\pm6)f^{0.810\pm0.007}$ for Garhwal region and $Q_\alpha=(31\pm5)f^{0.810\pm0.022}$ and $Q_\beta=(52\pm7)f^{0.810\pm0.003}$ for Kumaun region. It is found that Kumaun region has low value of Q_α and Q_β as compare to Garhwal region,which means Kumaun region has high attenuated medium than Garhwal region. It is concluded that Kumaun region has high seismic hazard potential as compare to its adjacent Garhwal region. The output of present work may prove to be very useful for the preparation of seismic hazard, source studies and simulation of strong motion record, which are required for seismic hazard mitigation and assessment of the region.

ASSESSMENT OF GROUNDWATER QUALITY AND SALINITY DYNAMICS IN THE CENTRAL GODAVARI DELTA, ANDHRA PRADESH

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Central Godavari Delta is located in the East coast of Andhra Pradesh along the Bay of Bengal. Ample surface water is made available for irrigation and aqua culture through well distributed canals drawn from Godavari River since last 150 years. Groundwater in the area is highly saline though the groundwater levels are very shallow ranging from 1 to 3 m below ground level. Integrated Electrical Resistivity Tomograms (ERT), hydrochemical (pH, TDS, Ca^{2+}, Mg^{2+}, K^+, F^-, Cl^-, SO_4^{2-}, NO_3-, HCO_3- and CO_3-), isotopic (Br- and $\delta^{18}O$) and density dependant solute tranport (SEAWAT) modelling studies have been carried out for four years (2006, 2007, 2014 and 2015) to identify the salinity sources and to understand the possible extent of seawater intrusion. The integration of all these data sets revealed that coarse grained sands exhibits resistivity of 4-20 Ωm forming the surface layer, clay layer exhibits < 1 Ωm mostly present as the second layer at many locations. However, similar resistivity values are also associated with soils saturated with sea water. Clay with fine sand occurs as the third layer with a resistivity of 1- 4 Ωm. The different mixing models ((TDS vs. (Na^{2+}+ K^+) and (Ca^{2+}+Mg^{2+}), (Na^+-Cl^-) vs. Ca^{2+}+Mg^{2+}-HCO^{3-}-SO_4^{2-})) and ionic ratios (Na^{2+}/Cl^-, SO_4^{2-}/Cl^-, Mg^{2+}/Ca^{2+}, Mg^{2+}/Cl^- and Cl^-/Br) and $\delta^{18}O$ does not reflect any modern seawater signatures. These models indicated that salinity in the shallow wells is due to dissolution of evaporitic minerals and ion exchange processes. In the pumping wells the salinity is due to upconing of entrapped sea water that belongs to Palaeo origin and wells located near the coast and mudflats is due to physical mixing of marine water. The estimated regional

groundwater balance using SEAWAT model indicate significant amount of submarine groundwater discharge as outfall to the Bay of Bengal. Assuming observed hydrological conditions, no considerable advance in seawater intrusion would be expected into the delta region.

DEVELOPMENT OF GROUNDWATER FLOW MODEL USING VISUAL MODFLOW CLASSIC INTERFACE: A CASE STUDY IN A PART OF CHOUTUPPAL MANDAL, NALGONDA DISTRICT, TELANGANA

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Recurring droughts and increased exploitation of groundwater to meet the growing needs have resulted in the decline of regional groundwater level and dry weathered zone in a part of the Choutuppal Mandal, Nalgonda district, Telangana. In order to evolve future pumping schemes, a preliminary steady state groundwater flow model has been developed by using Visual MODFLOW Classic Interface (Build: 4.6.0.168). Well inventory data has been reviewed from the existing 20 observation wells and a base map has been prepared to assess sub-surface structures. The area spreading about 0.43 km^2 is conceptualized as a two layered model consisting of a weathered layer overlying a fractured aquifer. The model has been divided into grids of 10m×10m in each layer. Integrated finite difference method is used to discretize the groundwater flow equation and simulate groundwater flow with the help of calculated parameters along with the boundary conditions and acting stresses. Results shows that the computed groundwater level contours are in good agreement with the observed heads and groundwater is flowing from south to north.

MANTLE METASOMATISM, CRUSTAL LOW VELOCITY ZONES AND EARTHQUAKE NUCLEATION

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Earth's compositional structure has been changing continuously since anciet era, due to ongoing thermo-geodynamic processes and influx of magmatic and hydrothermal fluids from the underlying buoyant mantle. Mantle metasomatism is one such geological process that envolves mass infiltration of the gaseous fluid-rich hydrothermal solution , which cause widespread chemical alteration, replacement and further additions of the minerals under high stress and strain conditions. It normallyoccurs during the course of retrogressive metamorphism, wherein P and T continuously shifts to lower grade due to exhumation of the mafic crust. After effects of such processes can be seen in the form of biotitization, saussuritization, sericitization, chloritization and uralitisation, apart from iron inrichment. Such metasomatic changes lead to sharp velocity drops (specially in P-waves) at mid to lower crustal levels. Our laboratory measurements indicate that the velocities candrop as much as 15% in metasomatised high density mid crustal rocks. Such low velocity zones have been frequently discovered below many geological terrains of India and also elsewhere in the world, including seismogenic regions of the Deccan Volcanic Province, like Koyna, Killari, Jabalpur and Kachchh. We feel that the earthquake nucleation in these areas are related to pervasive metasomatic alteration of insitu rocks, which is fluid and halogen controlled and cause considerable change in basic fabric and composition of the rocks during its recrystallisation, thereby making it considerably weak and earthquake-prone.

ENHANCING SIGNAL-TO-NOISE RATIO OF CONVERTED SEISMIC WAVE DATA USING THE SEISLET TRANSFORM

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The converted wave data (P-to-s / S-to-p), commonly termed as receiver functions, contain noises of various origins. Such noises may influence the modeling and may sometimes lead to over interpretations of the data. In order to suppress noise, we use a robust sparsity enhancing tool, i.e. the Seislet Transform (ST), to process receiver function data by applying regularization in the seislet domain. Basically, the ST is primarily characterized by the plane wave destruction method combined with the wavelet-lifting scheme. As a result of which locally dominant event slopes are obtained precisely and the components of lifting scheme such as update and predict operators participate in decomposing the data into multiscale orthogonal basis and the basis-functions are oriented along the dominant phases/events following the local linearity. Therefore the seislet transform attains the highest compressional capability as a result of which signal can be effectively compressed in the small scale and the random noise spreads in the whole transform domain. Since the signal and noise have different characteristics, signal and noise separation in the seislet transform domain is achieved by simply applying a structural filtering approach i.e. the thresholding operator. Thus the denoising research stands as a major inherent component in the seislet transform domain. The inversion results of both the synthetic and field examples from the Hi-CLIMB network and station HYB from the Indian shield show an excellent performance over the original data sets.

THE ROBUST ESTIMATION OF FAULT PARAMETERS FROM BOUGUER GRAVITY DATA: A CASE STUDY FROM EASTERN INDIAN SHIELD

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The robust estimation of fault parameters, such as position of the fault, thickness of the fault, and density contrast of the fault from the host rock, depth of the fault and orientation of the fault from gravity anomaly data is one of the hallmarks of gravity interpretation. Interpretation of gravity data is difficult due to inherent non-linearity and non-uniqueness. Here, we implement damped least-squares-based inversion (DLSI) powered by singular value decomposition (SVD) and simulating annealing (SA) inversion technique to determine the fault parameters from Bouguer gravity anomaly data. We assume the vertical fault models in the study area guided by geological inputs for forward modeling. As many as five profiles are considered to delineate the shape and geometry of the Malda-Kishangunj Fault (MKF) and three profiles are considered to delineate the Katihar-Nalpamari Fault (KNF). To implement SVD-based local optimization scheme, we have taken initial model parameters based on geological prior information of the study area. Several attempts have been made to obtain a good fit between observed and computed Bouguer gravity anomaly response using SVD and SA with RMS error varies from 0.7 to 3.90 mGal. Present SVD-based inversion results suggest that the average depth of MKF varies from 4.88 Km (Sothern Side) to 20.25 Km (Northern Side). For the case of KNF, using SVD, the average depth varies from 20.66 Km (Eastern Side) to 24.57 Km (Western Side). The SA- based inversion suggests that the average depth of the MKF varies from 4.89 Km (Southern Side) to 20.05 Km (Northern Side). For KNF, the SA-based inversion suggests that the average depth varies from 20.60 Km (Eastern Side) to 25.42 Km (Western Side). In all of the cases, density contrast are found to

vary from 335 Kg/m^3 to 530 Kg/m^3. The obtained solution is able to explain the geological-setting of the study area and consistent with the geological knowledge. We suggest from the present high-resolution gravity survey and data analysis that the majority of the faults are of basement faults and might be appeared to be seated below the basement. This type of information related to crustal features will be useful to understand the seismic hazard of the study area as it is believed that these crustal features are responsible behind the recent enhanced seismicity in the Eastern Indian Shield and surrounding regions.

IMPACT OF SOLAR CYCLES ON GROUNDWATER RECHARGE ON DECADAL TO CENTENNIAL SCALE: A CASE STUDY FROM NORTHWEST CHINA

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Assessing the impact of natural and anthropogenic variation on groundwater recharge is essential for modelling groundwater change on decadal to centennial scales. We present here a detailed analyses of Groundwater recharge rate (GRR) time series from dry lands, Badain Jaran Desert of Northwest China of 700 years, spanning over the period 1300-2000AD using the Singular Spectrum Analysis (SSA) with the purpose to examine the acute sensitivity of GRR changes to solar activity/Total Solar Irradiance (TSI). We compare the first three principle modes of GRR with TSI and their spectral content to identify the coherent changes, if any. Our analysis reveals nearly identical spectral peaks, which might suggest the possible direct/indirect link between the TSI and GRR. The precipitation and evapotransiration processes attest the intrinsic link between GRR and solar activity. Further, possible impact of well known ~200y periodic solar forcing on GRR is evaluated using the new Eigen weighted cross-correlation (EWC) analysis followed by the null-hypothesis test. We have found statistically significant EWC between the first three principal modes of GRR with respective modes ofTSI. Our result suggests that only 11.81% of GRR is associated with the solar Suess cycle. The other part of GRR (33.66%) in the first three principal modes is associated with the long term trend in the solar activity. The study concludes that a small fraction i.e., 0.021% of total solar radiation contributing from the second and third Eigen modes of TSI is responsible for the observed 200±10y cyclic groundwater recharge variations. Finally, spectral analysis of the residual (principal modes 4 to 40) suggest statistically significant periodicities 63±10y, 33±3y, 24±2y, which are corresponding to lower order solar periods. The quantification of the underlying linkages would provide useful constraint for modelling the long-term groundwater recharge.

STRUCTURAL HEALTH MONITORING WITH THE HELP OF HORIZONTAL TO VERTICAL SPECTRAL RATIO FOR EARTHQUAKE DISASTER AND RISK MITIGATION

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The potential damages due to earthquakes are not only identified by the magnitude and its epicentre distance to a particular region, but also by the geological and structural conditions of that area. The occurrence of an earthquake in a populated area may cause numerous casualties and injuries as well as extensive damage to property. Earthquakes are by far the most unpredictable and highly destructive of all the natural disasters. India's increasing population and extensive unscientific constructions mushrooming all over, including multi-storeyed luxury apartments, huge factory buildings, gigantic malls, supermarkets as well as warehouses and masonry buildings keep - India at high risk.

During the last 15 years, the country has experienced 10 major earthquakes that have resulted in over 20,000 deaths. As per the current seismic zone map of the country, over 59 per cent of India's land area is under threat of moderate to severe seismic hazard. In this study, we evaluate the dynamic characteristics of the two buildings located in the campus premises of Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand, India. These two academic buildings, six storeyed (new) and one storey (old)are constructed in the years 2016 and 1926, respectively. We compute Horizontal-to-Vertical Spectral Ratio (HVSR) associated with each floor of both of the buildings for structural characterization. Microtremor data are collected using the "Tromino" made by "Micromed", which is equipped with a three component highly sensitive velocity meters. For our study, the data are recorded at each floor of both the buildings during mid-day and mid-night. The instrument is settled on the flat ground in the north-south direction with proper levelling as manufacturer's instructions for the purpose of recording the microtremor data. This method is applied on each floor of the building in order to study the fundamental frequency and floor amplification with their vulnerability.

CRUSTAL DEFORMATION MEASUREMENTS BY GPS GEODESY ALONG NARMADA SON LINEAMENT (NSL): AN INTRAPLATE REGION OF INDIA

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The Narmada Son Lineament (NSL), a major palaeo-rift system in the central India, is seismo-tectonically an active intra-plate segment of India. The ENE-WSW trending NSL comprises of Son, Narmada and Tapti fault systems; which includes Narmada North Fault (NNF), Narmada South Fault (NSF), Son-Narmada Fault (SNF), Tapti North Fault (TNF), Tapti South Fault (TSF). Considering very low amount of internal deformation of the Indian plate, it is required to quantify the deformation based on the continuous mode of GPS stations located within the zone of NSL. Therefore, in the present study, an attempt has been made to understand the deformation and strain pattern of the NSL. Based on the time series analysis of the GPS data between 2009 and 2015, we calculated the crustal deformation and strain rate of the area. Further, the derived displacement has been modeled to understand the fault kinematics and earthquake potentiality of faults along the NSL. In the present study, our focus is mainly towards the western part of NSL, the locale of 1970, Bharuch earthquake (M5.4). The GPS data were processed using GAMIT/GLOBK/GLORG software and analyzed to estimate deformation and strain rate. Further, the fault associated slip rate has been estimated by inverse modeling of observed site motions. The analysis reveals low but significant amount of deformation and strain accumulation in the western segment of NSL. The computation divulges a maximum seismic moment (M_0) of 2.0 x 10^{24} dyne-cm in this part, which corresponds to an earthquake of ≈ Mw 6.0.

GROWTH OF MOUNTAIN BELTS IN CENTRAL ASIA TRIGGERS A NEW COLLISION ZONE IN CENTRAL INDIA

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Several unusual strong earthquakes occurred in Central India along the Narmada-Son Lineament (NSL) zone, far from active plate boundaries. To understand the role of collision processes in the origin of this seismicity, we develop a numerical thermomechanical model of shortening between the

Indian and Asian Plates. We show that during the first 20Myr after the India-Asia Collision most of the mountain building occurred in Himalaya and Tibet. After reaching some critical shortening between India and Tarim, a new mountain system (Tien-Shan) startedto form between the Tarim and Kazakh Plates. After sometime, the shortening of the Central Asia becomes inefficient; the thickened crust in the mountain areas starts collapsing gravitationally; thus imposing strong outward-directed forces preventing further shortening. At this stage (after 36 Myr, i.e. present) a new collision zone nucleates in the continental part of India along the NSL. Various geological and geophysical observations indicate that the NSL is the weakest zone with northward thrusting of the thinner Central Indian lithosphere underneath the thicker northern part of the Indian Plate. We hypothesize that the NSL was reactivated during the final stage of the India-Asia convergence and it will possibly form a new mountain belt within the Indian Continent. This explains how and why there is large stress in the Kutch and Narmada regions.

The results are based on a new seismic model of the upper mantle for India and surrounding regions derived by P-wave tomography. Global travel-time data from the International Seismological Centre corresponding to the time period from 1964 to 2014 and for thousands of earthquakes are used. Worldwide earthquakes recorded in the study area as well as study-area earthquakes recorded worldwide are used. Earthquakes were relocated and outliers were discarded. We defined the depth of the study volume at 1000 km; however, we mostly consider the results down to 700 km depth and at discrete depths. Both P and S velocity distributions are obtained but the P-wave model which is better estimated has been used in the interpretation. The model clearly shows high Vp anomaly in the northern part of India down to 200km depth which is inferred as thicker lithosphere. Lower Vpis obtained in southern part of India. At the western margin of India at 100 km depth, we observe a low Vpanomaly with strongest amplitude beneath the Deccan Traps. We propose that this anomaly represents a zone of thinned lithosphere degraded by the Reunion - Deccan hot spot. In the eastern part of India, we observe another low-velocity anomaly that may be associated with the Rajmahal traps. High Vpstructure beneath the Pamir-Hindukush and a N-S trending high Vpzone beneath the Burmese are observed. Both the zones are associated with intermediate - depth earthquakes. Observance of these Benchmark-like structures as found in several other studies strongly support that our model is stable.

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GEOPHYSICAL AND HYDROCHEMICAL APPROACH FOR LOCATING FRESH WATER LOCATIONS IN A COASTAL TERRAIN

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Integrated geophysical investigation viz., Vertical Electrical Sounding (VES), Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR) were carried out in a coastal terrain at Vizag Steel Plant (VSP), Visakhapatnam, Andhra Pradesh, India for identifying fresh water locations. The entire area was underlain by recent alluvial of varying thickness consists of sand, clay and silt with basement as Kondalite rock formation. Identifying favorable groundwater locations in such a terrain is a difficult task. The area consists of saturated clay, saturated silt and saline water has the same resistivity signature and misleads resistivity data interpretation for identifying and recommending the suitable groundwater locations in a coastal terrain. To overcome these uncertainties, a second

geophysical approach or combinations of geophysical methods become necessary to resolve these resistivity ranges in a more reliable and better fruitful interpretation of sub-surface layers. In order to pin-point the groundwater locations at VSP; VES, ERT and GPR investigations were carried out. Interpreted results of VES, ERT pseudo-section and GPR images (radargram) were correlated with each other to ascertain confidently the geophysical signature of the sub-surface. Combination of geophysical methods gives better resolution or interpretation of sub-surface information before made any recommendations for drilling of borewell. Based on integrated geophysical investigation few borewell sites were recommended and drilled. The observed drilled lithologs was well correlated with the VES, ERT and GPR data. Besides, hydrochemical analysis of water samples was carried out from the existing borewells. Total Dissolved Solids (TDS) and chloride concentration were ranges from 189-3398 mg/l and 5-1610 mg/l. The eastern and north-eastern part of the area has elevated concentration of TDS and chloride indicating intrusion of saline water. TDS concentration of drilled borewell was found to range from 400-500 mg/l. The observed yield of drilled borewells ranges from 104-3623 gallons/hr.

A COMPARATIVE STUDY OF SUPPORT VECTOR MACHINES, GAUSSIAN PROCESS, BAYESIAN NEURAL NETWORKS AND ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM IN SEDIMENT DEPTH PREDICTION

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Determination of sediment depth from gravity data and their spatial variability is an important task in any geophysical modeling studies. The present article examines the efficacy of four machine learning (ML)-based regression techniques, e.g., Support Vector Machine Regression (SVMreg) and Gaussian Process Regression (GPreg), Automatic Relevance Determination-Bayesian Neural Networks Regression (ARD-BNNreg) and Adaptive Neuro-Fuzzy Inference System Regression (ANFISreg) for prediction of sediment depth. Geo-spatial co-ordinates, latitude and longitude are used as inputs for the SVMreg, GPreg. ARD-BNNreg and ANFISreg models and sediment depth derived from 2D radially averaged power spectrum analysis of gravity anomaly data are used as a target for the experiment. Comparative analysis suggests that the performance of the GPreg, and ARD-BNNreg are better than that of SVMreg and ANFISreg models when several statistical performance measures (e.g., Pearson's correlation coefficient, mean square error (MSE) and mean absolute error (MAE), index of agreement (IA) and reduction of error (RE)) are considered. Further, the spatial variability analysis based on ML-regression in conjunction with ordinary kriging (OK) can produce spatial variability of sediment depth with fair accuracy and offer a robust means for predicting sediment depth. The present results could be useful in mapping basement undulation, buried faults and/or subsurface faults for gaining deeper insights into the seismic hazards in the study area of Eastern Indian Shield.

HYDROCARBON BEARING FACIES DETECTION THROUGH GEOBODY CAPTURING IN CARBONATE RESERVOIR – A CASE STUDY FROM RAJASTHAN BASIN, INDIA

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In challenging geological environment of carbonate reservoir quantitative interpretation will play major role for detection of hydrocarbon bearing facies. In current study the same approach was adopted through geobody interpretation towards detection of hydrocarbon bearing facies in Rajasthan

basin. Rajasthan basin is consisting with 3 major sub-basins – i) Bikaner-Nagaur sub-basin ii) Barmer-Sanchor sub-basin and iii) Jaisalmer sub-basin. Current study was carried out in the Jaisalmer sub-basin region. The limestone formation of Jaisalmer sub-basin was primary target for this study. Two wells are drilled in this study area and eventually both the well was turned to dry well. Although few residual oil signature was shown in the drill cuttings in one of those wells. The signature of residual oil was encouraging factor to carry out this study. Two seismic based volume attribute was used as initial volume for this study. Coloured and Genetic inversion was considered as seismic volume based attribute. In geobody interpretation primarily amplitude and frequency based variation of seismic data was captured with changes of lithology. To capture these changes in seismic data quantitative well to seismic tie was carried out to analysis the wavelet variation in limestone reservoir formation. The coloured inversion is identified as band limited inversion which can be estimated through convolution process. The inversion process was run based on functioning of single operator. The average value of Earth impedance and average value of seismic frequency spectrum was correlated with amplitude spectrum of the operator. Genetic inversion (GI) was also used as seismic volume based attribute for initiation of geobody interpretation process. This inversion result was estimated based on neural networking process through solving of nonlinear optimization difficulty. To get the nearly true result of subsurface geology through artificial intelligence method global optimization techniques was used in GI study where non-local optimization restriction was included. The full GI result was adopted based on probabilistic approaches mainly through three stages such as adoption of data, crossover and finally mutation of the same data. Both the attribute based result was correlated with well log signature and petrophysical relation was established with acoustic properties from seismic based study. The study was also supported by petroleum system modelling towards capturing the oil maturation in the study area. To get the areal extension of the hydrocarbon bearing limestone facies, geobody interpretation was adopted. The geobody interpretation was controlled by coloured and GI inversion. The result has shown that there are several discrete limestone facies in the study area which are potential party for hydrocarbon production cumulatively as a part of marginal field production from carbonate reservoir of Indian onshore sedimentary basin.

PALEOMAGNETIC, ROCK MAGNETIC, MAGNETIC FABRIC AND PETROLOGICAL INVESTIGATIONS ON THE NEWER DOLERITE DYKES OF SINGHBHUM CRATON: IMPLICATIONS ON THE PRECAMBRIAN MAGNATISM IN THE INDIAN SUBCONTINENT

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For Paleomagnetic, rock magnetic, low field anisotropy of magnetic susceptibility (AMS) and petrological investigations, around 90 oriented block samples from 21 dolerite dykes situated in and around Seraikela, Chaibasa, Tiring and Rairangpur regions (south of Tatanagar town); and 91 oriented block samples from 17 sites situated in and around Ghatgaon, Dhenkikot and Harichandarpur regions of Keonjhar, Singhbhum Craton were collected. Petrological studies revealed that the newer dolerite samples are mostly doleritic in nature and containing calcic-plagioclase and clinopyroxene. The essential mafic minerals are pyroxenes, plagioclase and amphibole. Plagioclase was in the form of euhedral to subhedral tabular grains. Texturally they are characterised by ophitic to sub-ophitic. Plagioclase varies in composition from anorthite to albite. Sericitization was observed in fine grained plagioclases. The clouding effects of plagioclase have been observed in all the thin sections indicating a post formation regional thermal event. For palaeomagnetic studies, around 1868 standard sized (diameter = 2.54 cm and length = 2.22 cm) specimens were prepared from the collected 181 dyke samples. Natural remanent magnetization (NRM) directions along with magnetic susceptibility have been measured on

all the specimens. The mean values of NRM intensity and magnetic susceptibility were found as 3.79 A/m and 1192.36 x 10^{-6} SI units respectively indicating the strong magnetic component presence in these samples. To isolate the characteristic remanent magnetization (ChRM) directions, AF and thermal demagnetizations techniques were applied on the selected specimens. From the yielded demagnetization data sets, two groups of ChRM directions belonging to Precambrian age were observed. The low field AMS study was performed on 1829 specimens belonging to 38 dykes samples. For these measurements KLY-2 Kappabridge has been used and the generated data was analysed with the ANISOFT software to convert the raw information into data which can be interpreted in the form of graphs and stereoplots. Low field AMS data sets were used to understand the magnetic fabric and to infer the magma flow directions along with possible magma chamber locations. In most of the dyke samples, the flinn diagram (plotted as magnetic foliation (F) vs lineation (L)) and the Jelinek plot (plotted against degree of anisotropy (P′) vs shape parameter (T)) shows the presence of Prolate and Oblate shaped magnetic grains in equal proportion. "Normal" magnetic fabric (magnetic foliation planes parallel to dyke orientations) has been observed in majority of the dykes (Fig.4) samples indicating NW-SE directed magma flow directions. Rock magnetic experiments such as Lowrie-Fuller test and IRM experiments revealed that magnetite of SD+PSD types were the major magnetic minerals in the dykes samples which were carrying the ChRM directions.

TELESEISMIC RECEIVER FUNCTION ANALYSIS ACROSS DECCAN VOLCANIC PROVINCES AND EASTERN DHARWAR CRATON: SEISMIC EVIDENCE OF MODIFIED CRUST

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The Indian subcontinental crust has undergone many geodynamic processes during its geological history. In southern India, Deccan Volcanic Province (DVP) and Eastern Dharwar Craton (EDC) are two important geologic terrains. The nature of crustand possible effects of rifting or plume in the formation of the DVP in relation with EDC has been matter of debate from long time. In this view, we have analysed receiver function (RF) to estimate crustal thickness, crustal inter-layering and crustal composition by the data recorded at 18 broadband seismic stations along a profile of about 900km across DVP-EDC deployed during from 05/2015 to 10/2016. The estimation of crustal thickness was made using P to S conversion (Ps) and crustal reverberation phases from RF.We have used nearly 1500 three- component seismograms from the earthquakes of magnitude ≥ 5.5 and epicenteral distance 30^0 -95^0 to generate the RFs.

The stacked RFs from the stations over DVP indicates an average delay of 0.35 sec in Ps arrival time compare to EDC domain. It is an indication of thicker crust in DVP as compare to EDC. For determination of crustal thickness and inter-layering, we used two approaches i.eH – V_p/V_s stacking and inversion of receiver functions. We observe the crustal thickness (33-40 km) and V_p/V_s ratio (1.73-1.86) beneath DVP while in the EDC the crustal thickness (32-33km) and V_p/V_s ratio (1.70-1.78). The result of inversion shows, a high V_s ~3.5-3.8 km/s corresponding to the mid-crust is dominated in large portion of crust (upper 24-31km) beneath DVP while EDC shows less (2-9 km). A layer of high velocity V_s ~3.5- 3.9 km/s with varying thickness 8 to 11 km is found in upper part in DVP while this nature of crust is absent in EDC.This prominent high velocity layer in DVP may be interpreted mafic and ultra-mafic nature and thermally modified crust.

LINEAMENT TECTONICS AND SEISMICITY OF GANGETICALLUVIAL PLAINS, NORTHERN INDIA

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We have interpreted high resolution satellite images and mapped the geological lineaments of Gangetic alluvial plains of Northern India. These lineaments are correlated with the extension of geological trends such as Aravalli mountain ranges, with major geomorphic features such as straight courses of rivers and streams and abrupt changes in topographic elevations. These lineaments are also correlated with known subsurface gravity features such as Delhi ridge, Faizabad ridge and Saharsa ridge. In southern plains the lineaments emanating from peninsular India are more dominant and gradually diminish with the prominence of lineaments trending in NW-SE direction in the west, to nearly E-W in the eastern part. Correspondence of these lineament sets with the topography indicates that these lineaments are representing surface expressions of nearly vertical faults. Along these lineaments the blocks have relatively moved up and down is confirmed by the changes in facies and thickness patterns in dill hole logs. Remarkable parallelism between the lineaments trending in NNE-SSW with the Delhi ridge has emerged during the present study. Approximately 50 epicenters of moderate and low intensity earthquakes also correspond with this trend. This suggests that Delhi ridge is still active seismotectonically. However, we have found neither any relationship between Faizabad ridge and lineaments nor with the earthquake epicenters in this broad central part. In the eastern part again a good correlation has emerged between NW-SE trending curvilinear along which all the major rivers flow towards the Bay of Bengal, geomorphic features such as the river courses and distribution of alluvial fans. The most outstanding feature observed is a triangular pattern formed by three set of lineaments within which the Kosi fan is confined.

Several clusters comprising a number of earthquake epicenters are seen parallel to the Himalayan trend and emerging ridge close to the mountain front. This significant finding suggests shifting of Himalayan tectonics towards southerly direction with the emergence of subsurface ridge. The margins of subsurface sedimentary sub basins such as Purnia depression can also better be defined by higher density of lineaments.

MARINE GEOSCIENCES

METHANE COLD SEEP ACTIVITY IN THE INDIAN EEZ: PRESENT IS THE KEY TO THE PAST

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The recent discovery by CSIR-NIO of methane gas flare, in association with cold seep ecosystem and shallow (2-mbsf) methane hydrate off K-G basin, has not only placed India in the global cold seep map but also opened up new avenues in the field of hydrate research & development, unique biodiversity/ ecology and bioactive molecules that may have application in therapeutics and bio technology. This discovery has also confirmed the paleo-methane seepage hypotheses earlier proposed by NIO's gas hydrate group. CSIR-NIO carried out a major hydrate exploration program in 2007 on-board ORV Marion Dufresne and subsequently reported past methane seepage events (60-80 ky BP) from K-G basin. Over the years multiple geophysical and geological/ geochemical proxies were developed to understand the past methane seepage indications. It became apparent that occurrences of active seepage sites are possible in the Krishna–Goadavari basin. In 2018, CSIR-NIO formulated strategy using modern tools like water column imaging, parasound sub-bottom profiler, and high resolution seismic and precise seabed sampling protocol on-board ORV Sindhu Sadhana to locate the active cold seeps in suitable geological environments. Following the new experimental protocol, CSIR-NIO discovered several gas flares which are tell-tale signatures methane ebullition from seabed. Precise coring at these site led to the discovery of active cold seeps. The cold seeps are characterized by typical (endemic) macrofauna which are also known as chemosynthetic communities since they have symbiotic relation with microorganisms dependent on methane and/or hydrogen sulfide for their survival. At these restricted seep sites, high concentrations of hydrogen sulfide, abundant in situ formed calcium carbonate, several faunal groups and shallow presence of methane hydrate were observed. The seep sites are distributed over a water depth of 900 to 1900 m. In view of the uniqueness and endemic nature of the cold seep community, they have received wide-spread global attention. We present here the detailed observation on geochemical and geological data and compare them with paleo seepage records in order to establish the genetic links.

LITHOLOGY PREDICTION FOR THE GAS HYDRATE SEDIMENTS USING ARTIFICIAL INTELLIGENCE: A CASE STUDY FROM KRISHNA-GODAVARI BASIN, OFFSHORE INDIA (NGHP EXPEDITION-02)

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Downhole geophysical logging provides high-resolution geological and physical property data on the stratigraphic section as penetrated by industry and scientific boreholes. In this study, we have used multi-layer feed forward (MLF) network technique to accurately identify and characterize the lithological composition of stratigraphic beds of various thickness (thick beds of the order of 10 m; thin beds up to 0.3048 m) through the analysis of gamma-ray (GR), bulk density (RHOB), sonic transit time (Δt) and thermal neutron porosity (Φ) downhole logs. The results using the log data from the National Gas Hydrate Program Expedition 02 (NGHP-02) demonstrate that this non-traditional technique is superior to traditional log interpretation procedures and can predict formation lithology's where core data is unavailable as well as discriminate the finer beds. The (MLF) network predicted lithology's in this study matches reasonably well with the core derived interpreted lithology's, and thus this approach can be used to quickly yield accurate information on subsurface lithology's not only in the Krishna-Godavari Basin but also in many other regions.

KINETIC SPECIATION AND BIO AVAILABILITY OF CD IN ESTUARINE SEDIMENTS TO THE OYSTERS (*CRASSOSTREA* SP.) FROM ZUARI ESTUARY, GOA, INDIA

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The relationships between Cd speciation in the finer sediments and Cd-accumulation in the soft tissues of *Crassostrea* sp. from the Zuari mangrove region, Goa, were evaluated. The competing ligand exchange method was employed to distinguish the labile and inert Cd-sediment complexes. It is observed that labile Cd-sediment complexes in finer sediments increased with the increasing Cd loading in the sediment. A significant positive correlation between the concentration of labile Cd in the finer sediments and Cd concentrations in the soft tissues of the oyster was observed. The dissociation rate constants of Cd-complexes in finer and bulk sediments were very similar. However, there was a difference between the total Cd concentration in the bulk and finer sediments. The environmental factors, such as, pH and salinity of the overlying water column showed no/little influence on bioavailable concentration of the Cd-sediment complexes. The present study suggests that labile Cd-sediment complexes in finer sediment are responsible for bioavailable Cd in the environment and Cd accumulation in oyster system.

MAGNETIC RECORD OF METHANE SEEPAGE AT AN ACTIVE COLD SEEP SITE IN THE KRISHNA-GODAVARI BASIN, BAY OF BENGAL

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Gas hydrate exploration program of CSIR-NIO reported the paleo-cold seep activities from Krishna-Godavari (K-G) basin, Bay of Bengal. Further, magnetic studies on the sediment cores from K-G basin established the linkages between magnetic signals, sediment diagenesis, methane seepages and gas hydrate dynamics (formation/dissociation). Further, we demonstrated the potential of using magnetic methods in combination with geophysical and geochemical proxies to understand the evolution of fracture-filled gas-hydrate system in K-G Basin. In 2018, a multidisciplinary exploration cruise was undertaken to identify the active cold seep sites in K-G basin. CSIR-NIO discovered a cold seep site which showed acoustic signatures in the form of gas flares indicating active methane gas seepage from the seafloor. This discovery provided us an opportunity to conduct the rockmagnetic study on the sediment cores from cold-seep location. The main focus of the present study is to examine the cold-seep related processes by establishing the linkages between magnetic signatures and geophysical and geochemical observations. We present the sediment magnetic record (environmental magnetic, room, low temperature measurements, Hysteresis and FORC diagrams) and mineralogical data (SEM-EDS, XRD) of gravity and spade cores collected from active and non-cold seep sites from the Krishna-Godavari basin. The magnetic susceptibility record from the active methane seep site shows nearly constant values of lower magnetic susceptibility with three distinct peaks. The lower values of susceptibility can be attributed to dissolution of magnetic minerals associated with anaerobic oxidation of methane (AOM) which lead to conversion of iron minerals into paramagnetic iron sulfide (pyrite). SEM-EDS analysis on the magnetic grains from zones of increased susceptibility from the active seep site core confirms the presence of greigite and provide indications on the past occurence of disseminated type gas hydrates at this sediment intervals. In spade cores, fluctuation in magnetite reduction intervals hints out on the underlying complex interactions between sulfate-reduction, methane seepages and bioturbation caused by chemosynthetic communities in the K-G basin.

CHANGING SEDIMENT COMPOSITION OF MANDOVI-ZUARI ESTUARY, GOA DURING THE IRON ORE MINING HALT

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Goa with about 4% of India's iron ore reserves was one of the leading producers of iron up to 2012. By October 2012 a complete stop in mining operations was implemented by law. The iron ore formations of Goa are present in the catchment areas of the major rivers of the state: Mandovi and Zuari (Ma_Zu) Rivers. Estuaries of Ma-Zu Rivers were the main carriers of iron ore from the loading points to the port via barges for the past six decades and have been studied extensively by many researchers. Here we present temporal changes in the distribution of major, trace and rare earth elements (REE) of sediments along Ma_Zu estuaries during the mining halt (2012- 2014).The results shows decreased concentrations of Al, Cu, Co, Pb, Sc, Th, U and REEs during mining halt period in the Ma-Zu estuaries as compared to that during the mining period.In Mandovi estuary sediments Fe, Mn, Ni concentrations were low except in some stations, whereas Ti, Cr, V, Mo concentrations depicted no variations in mining and mining halt periods. The Zuari estuary sediments exhibit higher concentrations of Mn, Ti, Zn, Mo, U in downstream as compared to the upstream stations. The abrupt decrease in Al concentrations from 9.7% to 3.5% in Ma_ Zusuggest that the geochemistry of bottom sediment have changed to the background reference sediments (uncontaminated sediments from a dated core of Mandovi estuary before inception of mining). The decreased elemental concentrations along the estuary during these mining halt periods may be due to the reduced input of mining related anthropogenic materials. Further monsoonal characteristics of the estuaries may also have flushed out contaminated sediments from the river bottom during runoff, reducing the elemental concentration. The element associations show that the source of elements during the study period is predominantly from the lateritic and basement rocks.

ROCK TYPES MAPPING BY THE USE OF BAYESIAN NEURAL NETWORKS: AN EXAMPLE FROM IODP 323 SITE

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Classification of litho-logy/litho-facie plays a fundamental role in gaining deep insights into the dynamics of geological setting of a region. Presently, well log data has been invariably used to infer the rock types/litho-logy in various oceanic setting. However, because of the limited core collection, and complex non-linearity/overlapping well log signal distributions, it is difficult to classify the litho-logy from well log data using linear methods. Here, we propose to use the supervised, e.g., Bayesian neural networks optimized by Hybrid Monte Carlo (HMC-BNN) method to map lithology/rock-types using well log data of a site of the Integrated Ocean Drilling Program (IODP) Expedition 323 in the Bering Sea slope region. We have used P-wave velocity, density, density porosity, resistivity and gamma ray logs of the hole U1339D for our study. The HMC-BNN approach is capable of predicting the types of litho-logy over entire litho-succession at the site U1339D. The performance of the HMC-BNN model is further examined by the statistical performance measures such as mean squared error (MSE), reduction of error (RE) and index of agreement (IA). The maximum value of IA and RE could be 1.0 (for perfect fitting). In the present case, IA and RE value for class Diatom silt, diatom ooze and ash are found as 0.99 and 1.0.Three types of litho-logy associated with Diatom silt, Diatom ooze, Ash layers

are distinguished initially by HMC-BNN approach which stimulates us to take up detailed studies to get deeper insight into the Bearing Sea sediment deposition and sequence. The proposed Bayesian classification method could be useful for analysis of other tectonically complex area of oceanic setting around the world.

CRUSTAL ARCHITECTURE OF NORTHWESTERN CONTINENTAL MARGIN OF INDIA: IMPLICATIONS FOR ERUPTIVE VOLCANISM

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Deccan volcanic province is one of the largest continental flood basalt and has a total exposed area of half a million square kilometers and an approximate volume of one million cubic kilometers on peninsular India. This flood basalt province continues to attract global attention today because of its enormous volume and volcanic eruption straddle the Cretaceous-Tertiary boundary. Further, it had a profound impact on the crustal architecture of the North-Western Continental Margin of India (NWCMI). Therefore, it is necessary to document the areal extent and volume of the eruptions on the NWCMI. An integrated interpretation of geophysical data has been carried out to delineate offshore extent of flood basalt as well as its role in the evolution of NWCMI. The study revealed that the flood basalt has carpeted the entire NWCMI and extends up to the Laxmi Ridge but doesn't occur west of the ridge. The study further revealed that flood basalt is present in the Laxmi Basin irrespective of its crustal nature (continental/oceanic), which is debatable till date. Crustal structure of the region based on the model study show that the Moho depth varies from 14 to 40 km in the region. Maximum Moho depth is observed below Bombay High region (~40 km) and minimum moho depth observed below Gop Basin (~14 km). High density underplated layers are observed below the Laxmi Ridge, Laxmi Basin, Saurashtra Volcanic Province and Surat depression. Our study revealed an extrusive area of $\sim 5.37 * 10^5$ km^2 and volume of $\sim 6.59 * 10^5$ km^3 of the flood basalt in the western offshore region of India, which resulted due to the Reunion Hotspot activity modifying the crustal architecture of the northwestern continental margin of India. The estimated offshore surface area covered by flood basalt in the study region is almost similar to Deccan flood basalt covered surface area on the adjacent onshore region. Whereas volume of flood basalt in the study area is lower by 41% as compared with that of adjacent onshore region.

SEAWATER INTRUSION AND RE-SUSPENSION OF SURFACE SEDIMENT CONTROL MERCURY (HG) DISTRIBUTION AND ITS BIO AVAILABILITY IN WATER COLUMN OF A MONSOONAL ESTUARINE SYSTEM DURING DRY PERIOD

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This study describes the distribution pattern of Hg in a monsoon-fed tropical estuarine system (Mandovi estuary) from the central west coast of India (water column and sediment). The total Hg concentrations in the water column showed a decreasing trend from the downstream to the upstream

of the estuary. The concentration of Hg in the water column of the estuary was much below the concentration recommended by the EPA for aquatic life ambient water quality. The concentrations of dissolved Hg (obtained in this study) are comparable to the dissolved Hg level reported in pristine estuarine systems in the different parts of the world. The dissolved Hg was found to associate with the higher molecular weight fraction of dissolved organic matter (DOM). A significant portion of the total Hg in the water column was found to be associated with the suspended particulate matter(SPM). This study reveals that re-suspension of Hg associated particle and intrusion of Hg bound SPM (by the tide) from the outside of an estuary may increase mobility and bioavailability of this toxic metal within the estuarine systems during the dry season.

The average bio-accumulated Hg concentration in edible oyster was high during the dry period compared to the monsoon period in the estuary. It is suggested that re-suspension and intrusion of Hg (due to tide) might have increased Hg bioaccumulation in commercially important biological species from different tropical estuary during the dry period. This research describes an important process of monsoon fed tropical estuaries which can be useful for policy makers to take proper decision to reduce and control Hg/toxic metals pollution(if any) during the dry period.

STRUCTURAL CONTROL OVER THE OCCURRENCE OF METHANE GAS FLARES IN KG BASIN, BAY OF BENGAL

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Methane hydrate is an ice-like crystalline solid in which methane gas is trapped within the cage of water molecules at high pressure and low temperature. The drilling expeditions worldwide have recovered several fracture-filled gas hydrate deposits,e.g., Krishna-Godavari (KG) basin, India; Ulleung basin, Korea; Gulf of Mexico, USA; Hikurangi margin, New Zealand. One of the characteristic features of these deposits is the efficient gas migration plumbing system provided by the fault/fractures network. The compression regime prevailing in KG basin due to passive shale tectonism has created such favorable conditions for the movement of fluid/gas and the formation of fracture-filled gas hydrate deposits. Therefore, a multidisciplinary cruise was conducted in the KG basin during the 12th Jan to 6th Feb 2018 on board *ORV Sindhu Sadhana* to understand the gas plumbing system responsible for the formation of large gas hydrates deposits. We observed the widespread occurrence of methane flares in the water column images of the multibeam echo sounder over the mounds and toe-thrust sedimentary ridges in KG basin which are the surface manifestation of prevailing shale tectonism in K-G basin. These gas flares are tell-tale signatures of methane ebullition from the seabed. The gas bubbles rise from the surrounding seafloor depth of 1750 m to a depth of 700 m. The box corersamples from the flare regions show the presence of chemosynthetic communities (clams, crab, mussels,and worms)and gas hydrates samples were recovered from the gravity core within2-3 mbsf at 1750 m water depth. The high-resolution seismic data show the presence of 400-500 m acoustic chimneys over the gas flare and the detailed seafloor mapping show the presence of dense faults exposed on the seafloor. These observations suggest that the fault system formed due to shale tectonism provides an effective permeability pathway for the movement of methane gas and can potentially yield significant fracture-filled gas hydrate deposits.

FINE SCALE VELOCITY STRUCTURE OF A BOTTOM SIMULATING REFLECTOR IN THE KRISHNA-GODAVARI BASIN: RESULTS FROM FULL WAVE FORM INVERSION

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The wide spread occurrence of the Bottom Simulating Reflections (BSR) in the seismic data acquired in the Krishna-Godavari (KG) offshore of the eastern Indian margin provides ample evidence for the presence of gas hydrates in the region. Delineation of an accurate, fine-scale velocity structure across the BSR has been a challenge and the technique of 1-D full waveform inversion has great potential to decipher the small-scale velocity variations at selected locations. We have applied this technique at two locations on a seismic profile which clearly shows a strong BSR. The seismic velocity at location 1 shows a high-velocity (1.795 km/s)at the BSR depth of about 1.844km, which sharply drops to 1.4km/s at a depth of 1.990km, clearly indicating the presence of free gas. Interestingly, at location 2, we find two velocity lows, interspersed with a small velocity high 1.575 km/s at 1.574m.

SEISMIC EVIDENCE OF FREE GAS MIGRATION THROUGH THE GAS HYDRATE STABILITY ZONE IN KRISHNA-GODAVARI OFFSHORE BASIN

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Krishna – Godavari (KG) offshore basin, located on the eastern continental margin of India, hosts proven gas hydrate deposits under different depositional environments. In the vicinity of Site NGHP-01-10, an extensive fracture-filled gas hydrate deposits have been reported which are formed due to the focused fluid migration through faults/fractures. In the present study, we perform AVO analysis on the fold-compensation common image gathers (CIGs) obtained using amplitude-preserving Kirchhoff time migration algorithm for two multichannel seismic profiles (Inline and Crossline) acquired in the vicinity of Site NGHP–01–10. Conventionally, the seismic amplitude studies have been limited to the Bottom-Simulating Reflector (BSR). However, we have extended the method to other horizons located within gas hydrate stability zone (GHSZ) to understand the active fluid migration in GHSZ. The basic interpretation of the inline and crossline seismic reflection profiles show the presence of BSR and the fault system (F1–F5) piercing the seafloor in KG offshore basin. We observed two different classes of AVO; class IV and class III AVO for the horizons within GHSZ. The class IV AVO represents fracture-filled gas hydrate while class III AVO represents free gas-bearing sediments. In the present study, we extracted the gradient of class III AVO information for the mapped horizons across the faults F1-F5 to understand the fluid migration within the GHSZ, and compared it with the RMS amplitude extracted from the seismic lines. The negative gradient values which indicate class III AVO ranges from -0.2 to -1.8 for inline seismic profile and ranges from -0.01 to -0.3 for crossline profile. The RMS amplitude and gradient plots show class III AVO anomaly in the vicinity of the major fault system in KG offshore basin. The presence of class III AVO anomaly provides evidence for the migration of free gas along the fault system through the GHSZ. We also observed some methane flares in the water column sonar wedge across the active fault indicating the present day emission of methane gas through the fault system. We propose that the detailed AVO analysis of the horizons within the GHSZ may be a useful tool for understanding methane plumbing system in a gas hydrate reservoir.

ATMOSPHERIC, OCEAN & SPACE SCIENCES

DELINEATION OF IMPACT OF CLIMATE CHANGE ON GROUNDWATER POTENTIAL ZONE BY USING REMOTE SENSING AND GIS

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Groundwater is a dynamic and replenishing natural resource. Due to its hidden nature and its occurrence in complex subsurface formations, exploring knowledge to efficient management of this important resource is still a big obstacle. Climate change has been identified as one of the most significant challenges affecting the mankind today. The climate change and its impact on hydrological processes are of major concern and a great challenge in this changing environment. According to the Intergovernmental Panel on Climate Change (IPCC), increase in greenhouse gas emissions have been associated with an increase in the mean global temperature of 0.3°C-0.6°C since the late 19th century. By the end of the 21st century, greenhouse gas emissions could cause the mean global temperature to rise by another 1.4°C-5.8°C. Remote Sensing and Geographic Information Systems (GIS) process were combined in an attempt to identify groundwater potential zones and effect of climate change on it in a particular part of the Burdwan district of West Bengal during 1987 and 2017. Meteorological data and groundwater data of thirty years (1987-2017)has been collected and integrated into the study. The analysis of data mainly started from the preparation of secondary data to derive some result or decision from those maps or data. The secondary maps were prepared from the primary maps which were directly downloaded from the website if USGS, Bhuvan and other source, and/or prepared from the thematic maps or from some secondary data which has been derived from a large amount of primary data. Various thematic maps were prepared for delineating groundwater potential zones i.e., geology, geomorphology, soil, landuse and land cover, slope, rainfall, temperature, groundwater level, drainage density, and lineament density. Analytic Hierarchy Process was used to investigate a number of choice possibilities and evaluate suitability according to the associated weight of each factor with the help of Pair-wise Comparison Matrix. The thematic layers were finally integrated using ArcMap of ArcGIS software to yield the groundwater potential zone maps of the study area. Study found that, during the period of last thirty years, the groundwater potential zones had remarkably decreased and shifted from its previous position within the study area as rainfall was decreased (around 155mm) and temperature was increased (around 0.47°C) a lot. The present study facilitates the clear shifting of groundwater potential zones over the time as climate has changed in certain proportion as rainfall was decreased and temperature was increased in the study area.

CARBONATE ION VARIATION IN DEEP WATERS OF THE EASTERN ARABIAN SEA FROM LGM TO HOLOCENE AND ITS LINK TO CLIMATE CHANGE

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Deep ocean carbonate ion is a critical parameter in investigating carbon reorganisation in the climate system and depicts the role of oceans in modulating glacial to interglacial CO_2 changes of the atmosphere. Sufficient information exists on variation of carbonate ion concentration in Atlantic and Pacific Ocean with only one isolated study in southwest Indian Ocean keeping the North Indian Ocean unexplored. Indian Ocean being unique and dynamic than the other two major oceans, it is important to study its deep water carbonate ion concentration in order to illustrate its role in climate change.

In this study we present carbonate ion concentration [CO_3^{2-}] estimated using B/Ca ratios of benthic foraminifera *Cibicidoideswuellerstorfi*from sediment core AAS -9/21 recovered from water depth of 1800m in Eastern Arabian Sea (EAS). AAS -9/21 core is currently bathed by southward moving High Salinity Deep Waters (HSDW) overlying the northward moving Circumpolar Deep Waters (CDW). Carbonate ion concentration down the core ranges from ~ 53.2- 90.5 μmol/Kg for last 27 Kyr with similar values observed during Holocene and Last Glacial Maximum (LGM) and distinct high during deglaciation. Average carbonate ion concentrations of 63.2, 81.1 and 75.8 μmol/Kgwere noted during Holocene, deglaciation and LGM respectively. This study when compared with southwest Indian Ocean core, Wind 28K (Yu *et. al.*,2010) retrieved from depth of 4147m bathed by CDW, showed similar variation from last 27 Kyr, but showed difference in magnitude of [CO_3^{2-}] wherein AAS-9/21 exhibited lower values than that of Wind 28K. Average deglacial rise in [CO_3^{2-}] of ~ 75.8-81.1 μmol/Kg observed in AAS -9/21 core can be probably due to evolution of CO_2 from deep waters stored during the LGM and resulted in elevated [CO_3^{2-}] as both these parameters are inversly proportional to each other. Also the lower values observed in core AAS-9/21 can be attributed to progressive decrease in [CO_3^{2-}] of watermass orpresence of southward moving HSDW formed by mixture of upwelled North Atlantic Deep Waters (NADW), Indian Deep Waters (IDW) (Kumar and Li, 1995) and low oxygen waters from Oxygen Minimum Zone of Arabian sea. This study indicates the evolution of CO_2 from deep waters of Arabian Sea which contributed to deglacial rise of atmospheric CO_2.

CHARACTERIZATION OF EXPERIMENTALLY PRECIPITATED IRON COMPOUNDS USING EH–PH VARIATIONS, POURBAIX DIAGRAMS AND SEM IMAGES: IMPLICATIONS FOR FORMATION OF HEMATITE SPHERULES IN EARTH AND MARS TERRESTRIAL ENVIRONMENT

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Hematite spherules are present on Meridiani Planum, Mars. Similar Iron oxides concretions are present in various terrestrial environments such as kutch, India. Experiments reported previously are performed to understand the environment of iron precipitation during formation of hematite rich spherules on Earth and Mars. Based on the Eh and pH values variation and plotted Eh–pH/Pourbaix diagram for various experimental vessels containing Mohr's salt and minerals such as calcite, gypsum, siderite and magnesite in separate vessels, it is inferred that the iron precipitation in the gypsum and siderite vessels occurs in increasing acidic and oxidizing conditions. And the iron precipitation in the calcite and magnesite vessels occurs in increasing alkaline and reducing conditions. The reactions occuring between Mohr's salt and suphate and carbonate minerals in separate vessels leads to iron speciation. This is evident from Eh–pH diagrams plotted for various minerals experimental vessels. Reddish brown precipitate present in various experimental vessels of sulphate and carbonate minerals suggests ferric iron precipitation. The SEM images of precipitated iron compounds show formation of fibrous and acicular habit crystals in the experimental vessels.

STUDY OF IONOSPHERIC SCINTILLATION OVER MUMBAI AND ITS CORRELATION TO PRE USING CADI IONOSONDE AT TIRUNELVELI

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Plasma density irregularities in the ionosphere (associated with ESF, plasma bubbles and Sporadic E layers) cause scintillations in various frequency ranges. VHF radio wave Scintillation technique is extensively used to study plasma density irregularities of sub-kilometre size. Indian Institute of Geomagnetism operated a ground network of 13 stations monitoring amplitude scintillations on 244/251 MHz (FLEETSAT 73°E) signals in India for more than a decade under AICPITS. Statistical analysis is done using CADI ionosonde data over Tirunelveli (an equatorial station) during ascending phase of solar cycle 24 (year 2011-12) to study ESF irregularities for Indian region. Occurrence of scintillation at Mumbai and h′F data of ionosonde studied and correlated seasonally. Occurrence of VHF scintillations at Mumbai is lower as compared to equatorial spread F occurrence at Tirunelveli as seen by ionogram. Occurrence statistics of Range and Frequency Spread F is also studied using CADI ionosonde data. Range SPF occurrence is seen much higher as compared to Frequency SPF in CADI ionosonde data.

POSTERS

CRUSTAL ANISOTROPY IN KUMAON REGION, UTTARAKHAND: SHEAR WAVE SPLITTING USING LOCAL EARTHQUAKE EVENTS

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Seismic Anisotropy is the change in the seismic velocity with the direction it is measured. Anisotropy can occur due to stress field in the medium or cracks, joints, fractures and pores. We used Shear Wave Splitting method which is also called Seismic Birefringence. It is used to determine the degree of seismic anisotropy of a medium, when a polarized shear wave enters anisotropic medium, it splits into two perpendicularly polarized shearwaves that travel with different velocities. Most of the Kumaon region in the Himalaya lies in the zone V of seismic zoning map of India. Crustal anisotropy depends upon the regional stress between the stations and geological conditions. In the study region, crustal anisotropy pattern is controlled by tectonic movement which depends upon two major fault zone Main Boundary Thrust and Main Central Thrust and there are many small faults in Lesser Himalaya and high Himalaya. Hence the regional stress in this region might cause a change the crustal anisotropy of the medium. Crustal Anisotropy of Kumaon region have been studied with the help splitting analysis of S-Wave of local earthquakes using cross-correlation method. Splitting parameters Fast Polarization Direction FPD(Φ) and delay time(δt) are determined by this analysis. It is found that FPD varies from station to station depending on the regional stress system as well as geological conditions. The crustal anisotropy of Kumaon region is explored by using local earthquake data of 17 strong motion seismographs established in Kumaon region. By measuring the FPD and delay time at each station, the stress field and deformation of Kumaon region is estimated in the present work.

REGIONAL VARIATIONS AND CORRELATIONS OF GUTENBERG-RICHTER PARAMETERS AND FRACTAL DIMENSION FOR THE HIMALAYAN REGION

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We studied the regional variations of the Guttenberg-Richter(G-R) parameters and the fractal dimension (D_C) to derive a relationship among the parameters for the Himalayan region. We have taken the data of five different major earthquakes events (Uttarkashi-1991, Chamoli-1999, Kashmir-2005, Manipur-2011 and Nepal-2015)in the Himalayan region. We calculated the b value, which is the slope of the frequency-magnitude graph, by using maximum likelihood method and also calculated the fractal dimension (D_C), by using least-squares method and derived a correlation among both the parameters for these five earthquakes. The regional b-value and (D_C) value of these five earthquakes helps us to understand the stress distribution and geological complexity of these regions.

LINEAR AND NON-LINEAR TECHNIQUES FOR INTERPRETATION OF GRAVITY ANOMALY DUE TO BURIED HORIZONTAL CYLINDER

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The gravity anomaly due to subsurface ore body is a function of depth and amplitude coefficient. The amplitude coefficient is related to the radius and density contrast of the buried structure. The gravity anomaly due to complex geological structures is approximated by assuming simple geometrical shapes like sphere, cylinder etc. The techniques have been developed to extract the parameters (depth and amplitude coefficient) from the gravity anomaly profile. These techniques include linear as well as non-linear methods.

The purpose of this study is to compare the linear (least square) and non-linear (Gauss-Newton) methods for the interpretation of gravity anomaly profile due to a horizontal cylinder buried at a depth. The two methods are applied to synthetic (with and without noise) as well as field data. The synthetic data with an error 10% and 20% has been generated. The experiment on synthetic data shows that the Gauss-Newton approach interprets the gravity anomaly profile better than that of least square approach.

ASSESSMENT OF EARTHQUAKE HAZARD OF THE KACHCHH RIFT BASIN THROUGH MODELLING OF SEDIMENT THICKNESSES AND Q_S VS. Q_P RELATIONS

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In general, sedimentary basins are characterised by low-velocity sediments, which play a crucial role in the amplification of seismic waves even from smaller-size earthquakes. The amplification of seismic waves is primarily attributed to trapping of energy due to high impedance contrast between the loose basin sediments and the basement rocks. The Kachchh basin lies in Gujarat district of north-western India, which represents a Mesozoic rift basin that has been experiencing uninterrupted occurrences of earthquakes since the occurrence of the 2001 Mw7.7 Bhuj mainshock. Thus, the estimation of sediment thickness of the seismically active Kachchh rift basin is essential to access the earthquake hazard associated with it. Here, we estimate sediment thicknesses beneath ten broadband seismic stations in the Kachchh rift basin, using the travel-time differences between Sp and S phases and the velocities of P and S waves of the basin sediments. The maximum sedimentary thickness is estimated to be ~ 1.456 at TPR station while the minimum sedimentary thickness is found to be 0.986 km at BCH as well as JMN stations. The contour plot of estimated sediment thicknesses in Kachchh, Gujarat, reveals an E-W trending basin structure with large thicknesses varying from 1.75 to 2.5 km, underlying the Kachchh rift zone. Also, it depicts another zone of large sediment thicknesses (1.5-1.8 km) below the GF zone. The delineated E-W trending zone of large sediment thickness coinciding with the Mesozoic Kachchh rift zone extends 44 km in north-south and 120 km in east-west. The contour plot also delineates two zones of smaller sediment thicknesses (<1.5 km), one is below the region covering BHU, NGR and TPM stations while another lies below the region between the Wagad and Bela uplifts.

Determination of the seismic quality factor (Q) for P waves (Qp) and S waves (Qs) in near-surface earth materials is essential for applying correction associated with the seismic wave attenuation. We estimated Qs vs Qp relations for 12 broadband seismic stations using spectral ratio method, which vary from Qs = 0.467Qp (at TPR) to Qs = 0.779 Qp (at JMN and MND). Results of this study suggest that the sediment of the Kachchh basin is partially saturated. This observation suggests that the Kachchh rift zone is associated with a significant earthquake hazard.

A CASE STUDY ON MIGRATION OF SEISMICITY IN AN RTS ENVIRONMENT AT KOYNA, INDIA

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An earthquake of M_w 4.0 occurred on 3rd June 2017 relatively at a new block, much south of the Koyna and Warna Dams, in the vicinity of the Western Ghat Escarpment (WGE). No M~4 earthquake occurred at this epicentral location since the impoundment of the Koyna Dam in 1962 and Warna Dam in 1985.A total of 124 aftershocks of M_L 0.5 – 3.5 have formed an intense cluster, depth distribution of these events is varying from 2 – 8 km indicated a north-east dipping plane. A double couple normal focal mechanism has been obtained using the P-onset data froma seismic network of 20 stations, which delineated a NW-SE trending fault plane. Two aftershocks of M_W 3.0, 3.5 are also indicating a similar focal mechanism. The obtained fault planes are correlated with lineaments derived from airborne gravity gradiometry and LiDAR studies. The faulting mechanism of the new block is compared with the previous solutions that has validated a tectonic model of alternating cycles of focal mechanisms. Also, analysis of the spatio-temporal distribution of M≥4 earthquakes of Koyna-Warna has revealed a possible migration of seismicity with the occurrence of new block of seismic activity of the present study. Further, the influence of nearby Warna reservoir water load has been computed and found that the fault stability (ΔS) was reaching a maximum value of 1.4kPa during this new block activity whereas ΔS tend to low with decreased seismic activity, inferring that the faults which are far from the reservoirs are taking longer time to attain a critically stressed level than the nearby faults which affected with the initial filling of the Koyna and Warna reservoirs in the study region.

COMPARATIVE STUDY ON SEISMIC REFRACTION INTERPRETATION TECHNIQUES FOR VARIOUS GEOLOGICAL FORMATIONS

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Seismic Refraction Method is the most reliable technique for geotechnical applications in delineating the subsurface layering (velocity model), bedrock depth and associated structural features in the complex geological environment. The multiplicity of refraction techniques are proposed to overcome difficulties like a mapping of karstic structure, highly dipping boundaries. In this critique, comparative study was made on refraction inversion processes; they are Generalized Reciprocal Method (GRM) inversion algorithm, Non-linear travel time Inversion, and Wave path Eikonal Travel Time (WET) Inversion. These methods have their own way of computation. The refraction data were acquired at various geological formations. The velocity models are prepared using the relevant software. We discussed the applicability of these methods for different environmental conditions. The depth

sections are presented for each method and results are discussed. In these models, Non-linear travel time inversion method yields smooth boundaries because of no control on grid size. We concluded that the GRM inversion algorithm technique is most reliable than seismic tomographic inversion results in our comparative study for various geological conditions.

SUBSURFACE GEOELECTRIC SIGNATURES ALONG THE SATLUJ VALLEY, NORTHWEST HIMALAYA, INDIA

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In order to understand the deep crustal structures and geometry of Main Himalayan Thrust (MHT) beneath the Satluj valley, magnetotelluric(MT) investigation have been carried out at 22 MT sites by different field campaigns. The profile along the Satluj valley in North West Himalaya is important, as the southern end of the profile crosses Nahan salient and Northern part of the profile cut across Kaurik Chango Rift, a zone of concentrated seismicity. The MT time seriesdata were robustly processed for an apparent resistivity curves using median as the robust estimators. At few stations, electric field recordings were very noisy perhaps due to ongoing hydro-electricity projects and unbalanced power network of the region reflecting larger error bars in estimated impedance tensors. The apparent resistivity curves were analyzed for dimensionality and decomposition. Swift skew and Bahr's phase sensitive skew indicate the complexity of geoelectrical structure, as none of site response of entire period band can be classified as strictly 2-D. Variation of skew parameters therefore suggest that dimensionality of the subsurface geoelectrical structure is band limited and varying depth wise. Modeling of the rotated impedances in the tectonic framework of the region is attempted and a shallow dipping mid crustal conductor is observed at an approximate depth of 5-10km. The poster will present the subsurface resistivity variation along the profile obtained after rotating impedances in the tectonic framework of region and will briefly discuss the tectonic significance of major thrusts along the Satluj profile.

INTERPRETATION OF MAGNETIC DATA OVER NORTH CAMBAY RIFT BASIN, NW INDIA, USING DERIVATIVE TECHNIQUES

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The Cambay rift basin (CRB) in Gujarat is one of the major onshore oil bearing intracratonic failed rift basins of India. Rifting of the basin started after the breakup of the Indian plate from the Gondwana land in early Jurassic and continues till Tertiary. The Cambay basin is bounded by two marginal faults, eastern and western Cambay faults. Keeping the view of oil exploration, structural interpretation of the region is carried out using high resolution magnetic survey.

Interpretation of magnetic data plays an important role in identifying and imaging potential subsurface structures. To understand the structural architecture of the northern CRB, magnetic survey is carried out using a Proton Precession Magnetometer of resolution 0.1nT. A total of ~ 600 magnetic points are collected at 0.5-1.5 km station spacing along the possible roads and tracks. Total magnetic anomaly values of the study area are calculated after being corrected for diurnal variation and International Geomagnetic Reference Field which shows the variation from -900 to -300 nT. To remove the asymmetric nature from the anomaly, Reduction to pole operator is applied. There are several magnetic highs present along the central part of the rift and anomalies decreases towards the marginal faults. Thick Deccan trap may be a possible explanation for the high magnetic anomalies along the central part of the rift. Thickness of the Deccan trap tapers towards the marginal faults which is reflected as a low anomaly value over the both flanks of the basin. On integration with past geophysical studies, NE-SW trending magnetic high in the northern part of the study area can be interpreted as the Unhawa ridge where Deccan trap is located at shallow depths. To image the subsurface extension of regional tectonic features upward continuation of the magnetic anomaly is done. Various derivative techniques like, Total horizontal derivative, Tilt derivative, Analytical signal and vertical derivative are applied to study the major lineaments and it is found that majority of the lineaments have NW-SE trend supported by the tectonic features of the rift.

TECTONIC EVOLUTION OF VIGODI FAULT, KACHCHH RIFT BASIN; WESTERN INDIA

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In present study, we analyzed geomorphic landform and drainage pattern within the NW-SE oriented, Vigodi Fault (VF) to assess neotectonic deformation. The VF zone is located in the western part of Kachchh Basin, that shows a typical wrench geometry, where several compressional and extensional fault segments generating Vigodi-Gugriana-Khirasra fault complex between the Katrol Hill Fault (KHF) and the Kachchh Mainland Fault (KMF). The NW-SE oriented Vigodi Fault (VF) shows a complex morphology of several subsidiary, shear fault segments developed clockwise to the Katrol Hill Fault (KHF). The VF originates near Meghpar to the north and east of the Walka Mota within the outcrop of Jhuran Formation and extends towards the southeast affecting the rocks of Bhuj Formation. Near Walka Nana locality, a NNE-SSW striking normal fault meets the VF at an acute angle forming a wedge. However, the reverse nature of fault has been observed near the Meghpar. The southern up thrust part of the fault has produced a series of domes between Walka Nana and Vigodi brachy-anticline, which is the biggest structure in the area. The throw of the Vigodi up thrust is estimated to be 40-60m. Towards the west, the fault is bifurcated into several branches and generating a significant amount of compressive force for the formation of domes and brachy-anticline parallel to the fault. In Vigodi- Khirsara-Gugriana area, a system of step faults has produced a zone of local uplifts. In this paper, we presented geomorphic evidences along the surface traces of neotectonically active VF zone. The fault zone is encompassed by several neotectonic landforms such as the development of strath terrace towards the upthrown block and, valley fill terrace in the downthrown block of the VF, youthful nature of fault scarps, warping in Quaternary sediments, the formation of slit canyon within Quaternary sediments, knick-points, slickensides, and river offset. Presence of strike and dip parallel slickensides indicates oblique slip motion within the VF zone. We used conventional geomorphic parameters of active tectonics such as stream length-gradient index (SL), steepness index (Ks) to determine neotectonic variability across the fault zone. Further, we tested a novel method called gradient length anomaly (GLA) to identify surface deformation pattern within the VF zone. The observed negative and positive

values of GLA correspond to the long-term uplift and subsidence associated with the VF. The results of geomorphic, geological and morphometric analyses together show that the area is neotectonically active. The combined observations made from the present investigation can be used to estimate seismic hazard assessment of the study area.

INTERPRETATION OF GRAVITY PROFILE DUE TO A HORIZONTAL CYLINDER USING LINEAR AND NON-LINEAR METHODS

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The gravity method is one of the geophysical methods that may be used for the detection of subsurface anomalies of different shapes including spherical, cylindrical etc. This method is also useful for estimation of excess mass, mapping of thickness of sedimentary basins and dipping contacts like faults. It has applications from the hydrological as well as oil exploration point of view. The gravity method provides the useful information rapidly and economically for a region where little or no geological information is available.

The interpretation of gravity anomaly profile includes the estimation of depth and amplitude coefficients of geological structures. The amplitude coefficient is related to the radius and density contrast of the buried structure. A number of techniques including linear as well as non-linear have been reported in the geophysical literature for estimating the depth and amplitude coefficients of geological structure of simple shapes.

The present study shows the application of a linear and non-linear method to interpret the gravity anomaly profile to estimate the depth and amplitude coefficient of a horizontal cylinder ore body. The linear method of least square and non-linear method of Gauss-Newton have been used for this purpose. A comparative study of the results obtained using these two methods have been done and discussed. For this purpose, the methods have been applied on a synthetically generated gravity profile with and without noise. An attempt has been made to apply these methods on published field data for the estimation of depth and amplitude coefficient.

SPATIO-TEMPORAL CHANGES OF SEISMIC AMBIENT NOISE IN THE KOYNA-WARNA REGION, WESTERN INDIA

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We present the power spectral density (PSD) probability density functions (PDF) of seismic ambient noise experienced around the Koyna-Warna seismicity zone to understand the impact of reservoir loading and unloading on ambient vertical motion of the upper crust. We have computed monthly PSD-PDF from continuous ambient noise recorded by four seismic stations situated north, south, east and west directions of seismicity zone for the time period 2015. The monthly ambient noise levels within the frequency band 0.01Hz to 3Hz for each station are compared with the global noise models. We observed significant variations in power and probability of microseisms energies between periods 2 to 15s. Our preliminary analysis suggests the following key features

(i) The noise levels at secondary microseism (~5Sec) and anthropogenic activities (short period up to 0.2Sec) north to the seismicity zone, which is close to Koyna Dam, are high compared to all other directions.

(ii) Randomness in the noise increased for entire range of frequencies (0.01Hz to 3Hz) as evidenced by the reduced power spectral probabilities prior to the monsoon i.e. during the month of June.

(iii) There is a reduction in the noise spectral energies towards north during post monsoon which may be associated with increased loading of the Koyna reservoir.

(iv) Significant changes in spectral energies and probabilities are only present in high frequency associated with anthropogenic processes and secondary microseism.

(v) The high frequency noise energies are above the global mean level and microseism band levels are close to the global low noise model.

Results suggest that the decreased and increased reservoir water levels during pre and post monsoon seasons cause proportional change in the vertical loading and thereby respective increase and decrease in randomness of ambient noise in Koyna-Warna.

DEEP SEISMIC REFLECTION PROFILING EXPERIMENT IN KUTCH BASIN, GUJARAT- PRELIMINARY OBSERVATIONS FROM SEISMOGRAMS

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The Kutch basin in western India has complex geological structure which is significant till date due to the frequent occurrence of major earthquakes. The extensions of the major causative and hidden faults responsible for the earthquakes in the region have never been explored using deep seismic reflection profiling. To address these issues, high-quality multifold seismic data have been collected using the Common Mid-Point method, with suitable asymmetric split spread configuration along two seismic lines, each of ~80 km length traversing almost orthogonally to the major geologically mapped faults. Preliminary observations from the recorded seismograms reveal coherent reflections bands at different depths over a wide range. This was made possible with suitable experiments designed to preserve high S/N with 50 kg explosive for each shot. We noticed back-scattered reflections with negative move-out in various raw shot gathers at different locations. We interpret these reflections are from the near-vertical faults. Diffracted events are also prominent in several seismograms, which were likely due to diffraction caused by the sharp edges of faults. A high amplitude reflective band at about 12.5 s two-way time is observed in the raw shot gathers, which could be reflections from the Moho.

CONDUCTIVITY VARIATIONS, ANISOTROPY AND 3D STRUCTURES IN THE DHARWAR CRATON

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Sub-continental lithospheric mantle beneath the Archean Dharwar craton is imaged. The study consists 124 magnetotelluric stations distributed along three parallel west-east oriented profiles and one long profile starting from Deccan Trap covered region to Madurai block in the Southern Granulite Terrain. Inter-station spacing is approximately 15 km. The measurements are within the period range of approximately 0.01 to 10,000 s. Conductivity variations are observed near the Chitradurga and the Palghat-Cauvery suture/shear zones. In addition, the present study also reports anisotropy in the Dharwar Craton. The other results are: two separate conductors are present in the lithospheric upper mantle in western Dharwar craton; eastern Dharwar cratonis devoid of any conductors; Charnockiticmassifs in the southern side can be interpreted as CO_2 flushed terranes.

HEAT FLOW AND THERMAL STRUCTURE OF INDIA WITH SPECIAL REFERENCE TO CRATONS

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India is mosaic of cratons and mobile belts. The major cratons are the Bundelkhand craton, the Baster craton, the Singhbhum craton, the Western Dharwar craton and the Eastern Dharwar craton. Cratons are the oldest geological unit ranging between Mesoarchaean to Neoarchean and collided along rift zones or fold belts. Later activity, e.g., sedimentary deposition and/or metamorphism took place in the rift zones or fold belts or intra cratonic regions during Meso to Neo-Proterozoic, Upper Carboniferous to Lower Cretaceous and Cenozoic era toform the Vindhyan basins, the Gondwana basins, the Cambay basin, respectively. These regions are main sources for minerals and coal depositions.

Thermal structure of the individual geological units is a vital parameter for knowing geodynamic processes and the occurrence of mineral/coal deposition. Heat flow and heat production studies have been carried out systematically in the many geological provinces of the Indian shield to arrive their thermal structure. Heat flow values show a distinct variation between cratons, mobile belts and Gondwana basins. Cratons have lowest heat flow (25 to 60 mW/m^2), with a maximum in Baster craton and minimum in Western Dharwar craton. Gondwana basins have a high, variable and wide range (50 to 110 mW/m^2). Other geological units, such as the Southern Granulite Province, the Aravalli fold belt, the Vindhyan basin and the Cambay basin have intermediate values (25 to 79 mW/m^2), between the above two extreme ranges. Heat production shows inter and intra variations between the geological province as well as between the same rock formation. The observed variations in surface heat flow could be explained by the variation in the crustal component as well as the mantle component and thus would be helpful in explaining geodynamic processes of the Indian shield.

SEA FLOOR SPREADING AND GEOPHYSICAL SIGNATURES IN INDIAN OCEAN

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Marine satellite altimetry (Free-Air Gravity & Bathymetry), Emag-2 datasets coupled with other available data resources acts as powerful tools in mapping tectonic structures of ocean-floor. In this context, an attempt has been made in preparing high resolution free-air gravity, magnetic, bathymetry maps to observe the geophysical anomaly signatures associated with various seafloor features present in the Indian ocean. These maps are useful in identifying various seafloor morphological features such as constructive (Ridges), destructive (Trenches) as well as their associated (Transform Faults) present in the Indian ocean. The seafloor spreading rate over the past in addition to earthquake distribution maps were also prepared for the Indian ocean region. These studies helped in understanding the complex tectono-magmatic processes involved in the opening and evolution of the Indian ocean along with its morphological features.

MAPPING OF QUARTZ REEF FOR GOLD MINERALIZATION IN BABAIKUNDI, NORTH SINGHBHUM MOBILE BELT, JHARKHAND, USING SELF POTENTIAL AND RESISTIVITY METHODS

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The mineral prospecting around the world depends on the structural characteristics of rocks. Folds, faults, and shear zones are some structural characteristics which describe the mineralization zone according to change in physical properties of the rock. North Singhbhum mobile belt exist within the Eastern Indian shield (EIS) and present high degree crustal deformation and structural variation along the axis. Gold mineralization of moderate concentration is reported from different parts of NSMB along shear /fracture zones within the volcano-sedimentary and meta-sedimentary rocks sequence. The primary gold deposit allied in quartz reef of the Babaikundi area is inferred by the result of geological evidence as outcrop and structural setup of the area.Gold occurs in association with sulfides like pyrite, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, etc. This work is done to identify the conducting anomaly contained by the quartz reefin auriferous shear/fracture zone along the Babaikundi-Birgaon axis, using Self-Potential (SP) and Electrical Resistivity Tomography (ERT) method. The prospect zone is spatially associated in Babaikundi area (23° 02'45" N, 85° 45' 31"E), Tamar block of Ranchi district. The existence of a sheared fractured contact across the Babaikundi-Birgaon axis put forwarded by Gravity and Magnetic signature. Total field SP data have been collected using a fixed base with data point increment of 10m for 480m profile length. Negative SP anomaly zones were identified from drift corrected SP anomaly map for possible mapping of gold mineralization within quartz reef. Excel plot of SP data also shows the well define negative anomaly value of SP. The ERTdata was carried out by Syscal Junior 48 resistivity meter with Schlumberger configuration within the area. The data is taken in a profile line with 10 m electrode spacing having 480 m profile length. The recorded data is processed with help of RED2INV software. The inverted 2D resistivity section indicates very low resistivity value in shallow zone inferring highly conducting material in the area. Total resolved depth by the resistivity method is 100 m in which low resistivity is confined within the depth of 22m. Negative SP anomaly is well correlated with low resistivity value showing the gold mineralization within the quartz reef.

INVESTIGATING THE LITHOSPHERIC STRUCTURE BENEATH ARCHEAN CRATONS OF GONDWANA LAND- INSIGHTS FROM SOUTH INDIA AND WESTERN AUSTRALIA

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In order to understand the formation and evolution of cratons, investigation of the lithospheric structure is highly essential. The cratons of the Archean age have survived the cycles of merging and rifting of continents over geologic time, making them unique. During the Gondwana period, the landmasses of South Africa, Antarctica, Australia and the Indian subcontinent were all joined near the South pole, making the Gondwana an accretion of several cratons. The break up of Gondwana land during the Mesozoic led to the gradual rifting of these different cratons over geologic time. But the most significant movement was that of the Indian plate and the Australian plate. The Indian Plate has migrated to a large extent compared to the other plates,while the Australian plate has been moving at a rapid rate, making it critical to understand the geophysical parameters for insights into their lithospheric structure. Sri Lanka, a part of Southern Granulite Terrain, also rifted along with Dharwar craton. This study focuses on investigating the structure of the lithosphere beneath the Pilbara craton in North Western Australia and the Dharwar craton in the Indian Subcontinent, along with Sri Lanka using Receiver Function and body wave tomography. Teleseismic earthquakes within epicentral distance of 30^{o} and 95^{o} of magnitude greater than 5.5 recorded between 2014 and 2017 in 13 stations of Pilbara craton, 2009-2011 in 33 stations of Dharwar craton and mid 2011 to mid 2018 for 3 stations in Sri Lanka area, were used to image the lithospheric structure. The crustal architecture of Sri Lanka was calculated using Receiver Function. For body wave tomography, teleseisms with good signal to noise ratio were selected and applied for moveout correction and adaptive stacking, to produce arrival time residuals. These arrival time residuals are mapped as 3D perturbations in P-wave velocity with respect to the ak135 global reference model using teleseismic body wave tomography. The tomographic images reveals variations in P wave velocity anomalies in the mantle. Negative arrival time residuals indicate the presence of relatively fast lithosphere, while positive arrival time residuals indicate the presence of slower lithosphere. The lithosphere asthenosphere boundary was observed at around 200 km in the Pilbara craton, compared to around 150 km for the Dharwar craton. Evidence for the presence of mid lithospheric discontinuity in the mantle was also observed in the Archean cratons, which could be attributed to change in radial anisotropy ,low velocity minerals and change in water content of the lithosphere.

ANOMALOUS GEOMAGNETIC VARIATIONS ASSOCIATED WITH THE 2016 NEW ZEALAND EARTHQUAKE (M7.8)

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The present study focuses on the spatial and temporal variations of the geomagnetic components recorded at three Intermagnet stations within the preparatory zone of the New Zealand earthquake that occurred on 13^{th} November 2016 (M7.8, Depth~15.7 km). The stations are selected in such a way that at least one station is close to the epicenter of the event (EYR ~90 km). The other two stations (GUA and SBA) are located ~4000km away from the epicenter. The GPS data of

these three stations during January 2012 to December 2017 (Fs 1Hz) have been extracted from the Intermagnet website. We found presence of long term anomalous variations in EYR station compared with other two stations (GUA and SBA). The Z component of the geomagnetic data of the EYR station shows a rise of 40 nT four months prior to the event. We observed different annual rates for GUA station (near to the equator)and other two stations EYR and SBA (away from the equator). The annual rate at GUA site is found to be 0.06nT/Year whereas the annual rates of EYR and SBA are -0.048nT/year and -0.018nT/year, respectively. The anomalous polarization ratio (Z/H) is found to be greater thanone at EYR station few days before the occurrence of New Zealand earthquake. We also observed the anomalous secular variations of the Z component in EYR station on the day of the New Zealand earthquake. Moreover, we also observed geomagnetic pulsation of 0.4 Hz in EYR station few minutes after this earthquake. We did not notice such pulsation in the other two stations. We speculate that this geomagnetic pulsation might have been generated because of New Zealand earthquake.

LINEAMENTS AND FAULTS STUDY IN DADRA AND NAGAR HAVELI, WESTERN INDIA: IMPLICATION TO SEISMOTECTONIC OF THE STUDY AREA

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The lineaments and faults study has been carried out in an area of ~8000 km^2in Dadra and Nagar Haveli (Latitudes 19.83°N-20.52°N and Longitudes 72.68°E- 73.67°E), Western India using photo geological interpretations followed by field investigations on 1:50,000 scale. The structural features are recognized using the false color composite and SRTM-DEM based products like slope aspect, shaded relief, drainage network and the drainage profiles. The Seismotectonic map has been prepared identifying the linear features and seismicity of the area since 1856. The area shows highest density of linear features in NNE-SSW, NNW-SSE and EEN-WWS directions, predominantly in NNE-SSW direction. The trend of the NNE-SSW linear structures are sympathetic to the major tectonic feature (Panvel flexure) present in the area. The seismicity has also been observed in the vicinity of NNE-SSW trending lineaments and Panvel flexure. The Deccan basalt along with Rhyolite and Trachyte are the main rock types exposed in the study area. These rocks are intruded by dykes of dolerite, which are found to be stretched, sheared and shifted along the strike of NNE-SSW trending linear features. The presence of seismicity and deformed dykes along the NNE-SSW trending linear features suggests the presence of N-S directed, strike parallel stress in the area. The study can be useful for seismic hazard assessment in Dadra and Nagar Haveli.

THERMAL CONDUCTIVITY VARIATIONS IN GRANITIC ROCKS FROM DIFFERENT CRATONS OF THE INDIAN SHIELD: IMPLICATION IN THERMAL STRUCTURE

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Thermal conductivity (TC) is a key parameter in modeling the thermal structure of the subsurface. Here, TC variations between different cratons of the Indian shield, i.e.,Singhbhum,Bundelkhand, Baster, Dharwar cratons, are discussed.

The Singhbhumcraton (3.5-3.1Ga) in the eastern Indian shield consists of Paleo-Archaean gneisses (OMTG), three phases of Paleo-Meso-Archaeangranitoids (SBG I,SBG II, SBG III)and Early-Neoarchaean granitoid (YG).The Bundelkhandcraton (3.5-2.5 Ga) in central India consist of Meso-Neoarchaean TTG gneisses and Neoarchaeanto Paleo-Proterozoicgranitoids. These granitoidscan be sub-divided into three categories based on the mineralogical, geochemical and textural composition: potassicgranitoid (PG), sodicgranitoid (GG) and biotitegranitoid (BG).The Baster craton (3.5-2.5 Ga) in central India consist of Paleo-Archaean granite-gneiss. The Dharwar craton (3.3-2.5Ga) in southern Indian shield consists of a variety of gneisses, granites, and supracrustal rocks. On basis of age and lithology, it is divided into Neoarchaean Eastern Dharwar craton(EDC) and Mesoarchaean Western Dharwar craton(WDC). The Archean Closepet granite batholith is a long North-South extending granite body between these two.

TC is measured for major rocks from the above cratonsin the laboratory at dry and saturated conditions, using the steady-state divided-bar method.

Results show that the TC for three phases of Singhbhum granite and gneisses show slightly different ranges. The TC, for SBG I varies from 2.1-3.6 $Wm^{-1}K^{-1}$, SBG II varies from 2.1-3.8 $Wm^{-1}K^{-1}$, SBG III varies from 2.0-3.6 $Wm^{-1}K^{-1}$ and OMTG varies from 2.0-3.7 $Wm^{-1}K^{-1}$. The three types of granitoids and gneisses from BC show various ranges. For PG varies from 2.0-4.0 $Wm^{-1}K^{-1}$, for GG varies from 2.3-3.4 $Wm^{-1}K^{-1}$, for BG varies from 2.5-3.3 $Wm^{-1}K^{-1}$and for TTG gneiss varies from 2.4-3.7 $Wm^{-1}K^{-1}$. The TC, from the twogeochronological different regions of the Baster cratonvaries from3.35-4.08 and 3.03-3.80 $Wm^{-1}K^{-1}$. The TC of the granitic rocks in the EDC varies from 3.22-3.74 $Wm^{-1}K^{-1}$ and in WDC varies from 2.1-3.5 $Wm^{-1}K^{-1}$.The TC forporphyritic monzogranite formation in two different levels of Closepet granite varies from 2.5-3.6 $Wm^{-1}K^{-1}$and2.3-2.9$Wm^{-1}K^{-1}$.

Mean TC for granitoids in Baster craton shows the highest compared to other cratons with following pattern.

Baster>Dharwar>Bundelkhand>Singhbhum.

Thus, TC variations for the basement rocks in the four cratons of the Indian shield, show intra and inter cratonic variations and could be due to the effect of one or more factors, e.g., variation ofparent magma composition, mineralogical texture,the age of formations, etc. The above variations have great implication in thermal structure of the cratons.

IMAGING OF SUBSURFACE FAULTS FROM THE DEEP SEISMIC REFLECTION STUDY IN THE KUTCH REGION, WESTERN INDIA

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Earthquake occurrences in intraplate regions are lesser in the world. Long aftershock activity and occurrence of repeated deadly earthquakes in an intraplate region like Kutch rift region, located in western end of India are still poorly understood. Many geophysical investigations are carried out to understand the mechanism of these earthquakes. However, deep seismic reflection study which provides the highest subsurface tectonic information was somehow lacking. We present here images delineating subsurface causative faults from the first deep seismic reflection experiment in this region.

Surface extension of Gedi, North Wagad and South Wagad faults are well detected from shallow seismic reflection images. Preliminary observations show that the geologically mapped Kutch Mainland Fault strike extends further 10-15 km towards east. The present study suggests that South Wagad fault is most seismologically active in the shallow region. Basement configuration is well demarcated at 1.0 s two way time with a subhorizontal reflection band corresponding to a depth of 1.5 km. The Mesozoic sediments with velocity of 2.9 km/s directly lay just above the crystalline basement with a velocity of 5.8 km/s.

INTERANNUAL VARIABILITY OF TROPICAL CYCLONES ACTIVITY IN THE BAY OF BENGAL: ROLE OF LARGE-SCALE ENVIRONMENT

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The interannual variability of tropical cyclones (TCs) activity in the Bay of Bengal (BoB) is not well documented in comparison to the other ocean basins, such as North Atlantic, north-west Pacific and Australian region. Therefore, the present paper investigates the interannual variability of tropical cyclones (TCs) activity particularly in the post-monsoon season over BoB during the 44-years long period (1972-2015). The analysis exhibits a large interannual variability in the frequency of TCs formation. On the basis of number of TCs, 9 active (≥4 TCs per year) and 18 inactive (≤1 TCs per year) TC years have been identified. To identify the causes of active and inactive TC years, the pattern of large-scale environmental conditions has also been examined in this study. The analysis shows that the sea surface temperature does not significantly affects the BoB TCs activity, as it remains greater than the threshold value (26.5°C) for cyclogenesis throughout the year. However, the existence of more relative humidity, strong convective activities, reduced vertical wind shear (VWS), upper level easterly winds and high low level cyclonic vorticity have provided the favourable conditions for the TCs genesis during the active TC years. Conversely, less relative humidity, reduced convective activities, enhanced VWS, upper level westerly winds and lack of low level cyclonic vorticity have provided the unfavourable conditions for the TCs genesis during the inactive TC years.

GEOTECHNICAL CHARACTERISTICS OF SOILS TO IDENTIFY LIQUEFACTION POTENTIAL OF COASTAL AREA OF THE BHAVNAGAR, GUJARAT, WESTERN INDIA

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The Bhavnagar district falls in zone III where magnitude of 6 and an intensity of VII or VIII can be expected due to regional or local large earthquakes; can damage single to multistory buildings. The district is located in the south eastern part of the Saurashtra peninsula of Gujarat with a coastline of almost 145 kms. The Bhavnagar, Ghogha, Talaja and Mahuva are the important sea ports of the district. Major parts of the district are occupied by basalt while loamy mixed, calcareous, fine and montmorillonite soils occur in the different geomorphological terrains of the district near coastal area. The region has experience most interesting being an event of February 1705, with an intensity nearly as high as XI (MMI) near Ghogha. During 2000, the region has experienced almost 132 earthquakes (3 earthquakes of >3.8 magnitude) in the span of almost 4 months (9th August to 15th December-2000). Among them almost 43 events were defined to the area of 6km x 4km located in the south eastern

part of the town near coast. The damages were reported inexplicably high considering the magnitudes of the events due to the presence of loose alluvium/poorly consolidated alluvium. Recently, in 2015 the tremor of 3.1 magnitude was also reported by Institute of seismological research (ISR) at palitana, Ghogha and Talaja talukas of Bhavnagar district. In context to this, we have selected some coastal area and performed geotechnical investigation of soil in domain of liquefaction hazard mitigation. The boreholes of minimum 18m and maximum 50m depth were considered for estimation of index properties of soil in the study area. With the help of density, plasticity index, ground water level, Peak Ground Acceleration (PGA), fine content and SPT N value, liquefaction hazard has been estimated by standard methodologies. The results of sub-surface investigations suggest that near the coastal area the soil layer of the 8m to 18m is present. The study shows the coastal area is having moderate to high probability of the liquefaction.

PRESENCE OF FLUID IN LOWER CRUST AS INFERRED FROM MAGNETOTELLURICS SURVEY: A CASE STUDY FROM EASTERN KACHCHH, GUJARAT, INDIA

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The presence of fluid plays an important role in the seismicity and earthquake rupture process, especially in seismically active zones. The Magnetotellurics can be used to map the subsurface structures/presence of fluid based on resistivity contrast. In the present study, the Magnetotellurics (MT) survey has been carried out in the least explored easternmost part (across Little Rann area) of Kachchh region. The zone lies at the trijunction of Kachchh basin, Cambay basin, and Saurashtra horst. The present MT traverse runs in an almost N-S direction having a length of ~52 km with a station spacing of 3-4 km. The MT data acquired in the broadband range (0.001-1000 s) with recording period of 3-4 days. From 2D inversion of MT data, four major conductive zones are identified. The first conductive zone (~50-100 Ohm.m) found at a distance of ~3 km in the south of Adesar and is inferred as Kanmer Fault (KF) (the eastern extension of South Wagad Fault (SWF)). The second conductive zone (~300-500 Ohm.m) found at a distance of ~42 km in the south of Adesar and ~13 km north of Enjar village and is located at the contact zone of Kachchh and Saurashtra peninsula at the location of North Kathiawar Fault (NKF). It is inferred as NKF. Third conductive zone (~300-500 Ohm.m) is found between the first and second conductor. This is interpreted as a step fault, formed during the rifting process of Kachchh. The fourth conductive zone is found in lower crust (below 20 km) having resistivity ~120 Ohm.m. This comparatively low resistive/conductive zone in the lower crust can be explained by the presence of interconnected carbon films, graphite, partial melt, and aqueous fluids. The regional gravity surveys suggested a gravity low in this zone. A similar pattern of gravity low and elevated conductivity was also observed in the lower crust of Central India Tectonic Zone (CITZ). Based on this pattern and observation, the presence of fluid is inferred as a cause of low resistivity/ conductivity in the lower crust.

MAGNETOTELLURIC IMPEDANCE TENSOR ESTIMATION USING AN ADAPTIVE TECHNIQUE EMPIRICAL WAVELET TRANSFORM

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In magnetotelluric (MT) data processing, estimation of impedance tensor from acquired time-varying electric and magnetic fields is a major step. Conventional signal processing techniques such as short Time Fourier Transform (STFT) is used in MT processing for estimation of impedance tensor as function of frequency which assumes that the signals are stationary over the particular duration. Recently, anon-stationary processing adaptive technique i.e. Empirical Mode Decomposition (EMD) is developed to process the MT signals. EMD gained popularity in signal analysis because the technique has the ability tosplitstationary and non-stationary components from a practical non-stationary signal. However, the problem of EMD algorithmic approach is its lack of mathematical theory. And also, it is difficult to model because of its non-linearity. Based on these issues analternate approach Empirical Wavelet Transform (EWT) is used to process the magnetotelluric data to determine the impedance tensor and compare the results with the conventional data processing methods.

DISPARITY ALONG HIMALAYAN AND ANDMAN ARC USING INVERSION OF FAULT PLANE SOLUTION AND B-VALUE

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In the continental crust and subduction zones b values decrease linearly with the differential stresses. Here we report a regression-derived relation between earthquake b-values and crustal stresses using the Anderson fault parameter (Aφ) in Himalayan and Andman arc. This regression relation is well established by using a large and complete earthquake catalogue for Himalayan and Andman arc. The data set consists of b-values and Aφ values derived from relocated earthquakes and focal mechanisms, respectively. Thus, b-values could be used as stress indicators for subduction zone. However, the state of stress is relatively well correlated with the surface geological setting with respect to earthquake b-values in Himalayan and Andman arc. Temporal variations in the b-value could constitute one of the main reasons for the spatial heterogeneity of b-values. We therefore suggest that b-values could be highly sensitive to temporal stress variations.

The earthquake size distribution in the Earth's crust commonly follows the Gutenberg-Richter power law $\log_{10}N = a-bM$, where a is the total number of earthquakes, b is the relative earthquake size distribution, and N is the number of earthquakes with a magnitude equal to or greater than M. Here the b-value governs the slope of the power law, and it is used to describe the frequencyof the earthquake size distribution. These studies indicate that normal and thrust faulting regions have higher and lower b-values, respectively, while strike-slip faulting regions have intermediate b-values. The Anderson fault parameter (Aφ) is very useful for the stress indicator calculated from the focal mechanism inversion and in their simple forms, Aφ varies from 0 to 1 for normal, 1 to 2 for strike-slip, and 2 to 3 for reverse faulting. In our work we find b-values and the Aφ values in the same grid size and find out a relationship between these parameters. These parameters are very important which indicates that b-value and Aφ values indicate the disparity from one region to another region.

GEOELECTRICAL INVESTIGATIONS IN KURUKSHETRA UNIVERSITY AND SURROUNDINGS, HARYANA

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The resistivity method is the technique to understand the resistivity distribution in the subsurface. Geoelectrical investigations help in understanding the subsurface lithology. It is carried out by applying an electrical current between two electrodes implanted in the ground and then by measuring the potential difference between two additional electrodes used for the purpose. The current used is either direct current or low frequency AC. The resistance so measured is converted into the resistivity and thickness of subsurface layers. The geoelectrical survey helps in understanding the subsurface moisture condition, groundwater availability and contamination.

The present survey deals with the electrical resistivity survey at 12 observation sites lying in Kurukshetra University campus and adjacent Brahma Sarovar area having latitude and longitudinal bounds from 29°57′47.0″N to 29°57′53.9″Nand 76°49′14.4″E to 76°49′19.2″E. the survey was conducted with Syscal kid -24 and data was interpreted by using RES2DINV software. Vertical Electrical Sounding (VES) survey was carried out using Wenner configuration with electrical spacing of 2 meters with expected depth of penetration in the range of 10-12meters. The present paper will describe the results pertaining to subsurface resistivity distribution at the selected sites so as to understand the subsurface lithology from geotechnical perspective.

WASTE WATER AS A SIGNIFICANT RESOURCE OF HYDROLOGICAL CYCLE IN THE CHANGING CLIMATE

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Domestic wastewater generated (303 km3/yr) on global scale has become a significant component of hydrological cycle in the changing climate. The combined use of treated wastewater and rainwater for various applications including agriculture, industrial, domestic, etc will certainly reduce the burden on freshwater resources (i.e. groundwater and surface waters). However, the complexities associated with wastewater treatment in resource poor, low and middle income countries, can be inadequate funds for financing the wastewater treatment infrastructure resulting in low quality water being discharged into the environment. With the inadequate infrastructure to treat the wastewater in the developing world, the natural wetlands offer a promising alternative for treating wastewater more sustainably. Natural wetlands are characterized as energy efficient, they use natural energy and require low maintenance costs, which are also easy for management, and can function well in various climatic conditions and geological settings. The structure and function of the wetland which defines the treatment efficiency are highly varied which necessitates that each wetland has to be characterized against the anticipated treatment potential, and this study shows a novel way to address it. We attempt to characterize the

natural wetlands around the Musi River, Hyderabad city (India) by utilizing a number of methods, of which the ERT method is a key component. Further, the hydraulic properties including flow velocity and flow through cross section area of subsurface wetlands were characterized using hydrogeological tests to evaluate the function of several naturally occurring wetlands.

The geophysical scans of the wetlands indicate that the wetlands studied were geologically stable with deep bedrock, isolated hydrogeological systems and devoid of any geological lineaments such as fractures. They catalyze the bio-chemical interactions that enhance the wastewater treatment. Further, the pollutant removal processes were determined as bioremediation, sedimentation, adsorption, redox reactions and ion exchange reactions with removal efficiencies for nutrients up to 97.00 %, organic content up to 80.00 % and microbes up to 99.99 % in the deep-seated wetland (Wt-1). The shallow wetland (Wt-2) had relatively reduced efficiency for pollutant removal owing to its shorter longitudinal section and lower hydraulic retention time. The hydro-geophysical parameters, determined in the natural wetlands, can be used to design constructed wetlands to enhance pollutant removal capacity.

ATTENUATION TOMOGRAPHY OF THE KOYNA-WARNA REGION, INDIA

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Attenuation of seismic waves provides additional constraints on the Earth's an-elastic properties, which affected by temperature and fluid content. The strength of attenuation represented by inversion of dimensional less quantity-quality factor (Q-1) in terms of fractional of energy loss per unit cycle. Although, Quality factor (Q) is probably frequency dependent in high Q region. In the low Q, region dominate the absorption of seismic wave, these regions have a Q that is roughly dependent on frequency or frequency independent. In this study, frequency-independent 3-D Qp attenuation model is proposed as an alternative to the existing velocity model for understanding the structural heterogeneity and fluid saturation of rocks in the study area. Here, we have utilized the seismological data recorded from 6th January 2010 to 28th May 2010 with a dense network of 97 temporaries 4.5 Hz Geophones. The estimates of attenuation are computed from non-linear least square fits Fourier amplitude velocity spectrum of P-wave arrivals. We apply the simul2000 tomographic algorithm to the attenuation operator t* values for the inversion of Qp perturbations through the 3D velocity model derived previously in the non-linear velocity inversion. Our results show a low Q near the fault zone and Qp generally increases with depth. In the vicinity of the source zone reduced Qp (high attenuation) observed than the surrounding crust. The highest attenuation anomalies coincide with the seismogenic zone of previously reported high Vp low Vs, and High Vp/Vs ratio (Dixit et al., 2014; Kumar and Dixit, 2017) which interpreted as a fluid-filled fractures zone to the Southwest of Warna Reservoir and extended up to Koyna reservoir.

MEASURING THE SEISMICITY ANOMALIES IN KOPILI FAULT REGION: A CASE STUDY BEFORE AND AFTER THE 11TH MAY, 2012 EARTHQUAKE OF ML 5.5 USING SEISMOTECTONIC PARAMETERS

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The past two large earthquakes in the Kopili fault region of magnitude M7.5 (1869 Cachar Earthquake) and M7.2 (1943 Assam earthquake) indicates the possibility of occurrence of future large earthquake in this seismically active strike-slip fault zone. This northwest-southeast trending fault of nearly 400 km long separates the Shillong plateau and Mikir Hill. The region is bounded by Himalayan arc to the north, Dauki fault to the south and Indo-Burmese arc to the east of the fault makes the area more tectonically complex region leading to high and clustered seismicity. We are trying to understand the mechanism of evolution of earthquakes using seismic b-value and correlation fractal dimension based on the microseismicity (ML ≥1.5) of seven years. We observed anomalous behaviour of seismic b value prior to the mainshock of ML5.5 and drastic change after the event. On the other hand fractal correlation dimension value indicates gradually decrease and then increase before the event. Similar nature of variation of b value and correlation dimension after the event is observed. The monthly frequency of occurrence of earthquakes show a trend of gradual increase before the main event which indicates the possible increase in the stress. The region is now experiencing low frequency of earthquakes after the event of ML5.5. The continuous monitoring of these parameters may provide us some crucial information regarding the stress build-up in the region.

PRE-STACK SEISMIC INVERSION BASED ON SIMULATE ANNEALING ALGORITHM: A CASE FROM THE NOVA SCOTIA FIELD, CANADA

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Simulate Annealing is a global optimization algorithm used to find global optima in the presence of large numbers of local optima. Pre-stack seismic inversion is performed based on simulate annealing for the data from the Penobscot field; Nova Scotia, Canada in this study and a verity of attributes are estimated. These attributes are P-wave velocity, S-wave velocity, density and ratio. These attributes are more meaning to the seismic data interpretation which is crucial step of any exploration project. Initially, the algorithm is tested on synthetically generated data over 7 layer earth model. The inverted and expected results points out good performance of the algorithm with very high correlation value (0.99). Thereafter, the algorithm is applied to the real pre-stack seismic data in two steps. First, the algorithm is applied to the composite trace near to well location and inverted for attributes. After getting satisfactory results from the composite trace, in the next step entire seismic section is inverted and a verity of attribute cubes are estimated. The inverted results shows very high resolution images of the subsurface compared with the seismic section. The correlation is estimated to be 0.82 and RMS error is 0.354m/s*g/cc. The impedance variation is estimated to be 4000-10000m/s*g/cc of the region. The inverted section shows smooth variation of the attributes from top to bottom and hence concluded that the area does not have any major prospective zone. Thereafter, these attributes are transformed

into the lame parameters which include lambda-rho and mu-rho parameters. These lame parameters are more sensitive towards fluids and rock properties. The analysis of these section also confirm to non-availability of prospective zone. These analysis is performed for one inline and 100 cross-lines and hence this can be not deny that the other part of the area have some other interpretation.

FLUID INCLUSION PETROGRAPHY AND RAMAN SPECTROSCOPY OF OLIVINE XENOCRYSTS WITHIN THE SUNG VALLEY CARBONATITE, MEGHALAYA PROVIDE DIRECT EVIDENCES OF MANTLE METASOMATISM OF ULTRAMAFICS BY CARBONATITE MAGMA DURING KARGUELEN PLUME ACTIVITY

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The Shillong Plateau of Meghalaya, hosts four ultramafic-alkaline-carbonatite complexes (UACC), associated with the Kerguelen plume igneous activity(Gupta & Sen, 1988). Sung valley complex, East-Khasi hills is one of those four UACCs. Itcomprisesof ultramafics, alkalines and carbonatites. The emplacement age of this UACC varies between 106±11 Ma (Rb–Sr), 107.2±0.8 Ma ($^{40}Ar/^{39}Ar$)(Ray et al., 1999, 2000) and 115.1±5.1 Ma (U–Pb) (Srivastava et al., 2004).

We carried outpetrography and Micro-Raman Spectroscopy of representative carbonatites from the Sung Valley UACC to understand mantle metasomatism caused by carbonatite melt. The carbonatites have sovitic appearance with dominantly subhedral minerals. Calcite is the major constituent mineral (65-75 %) along with Dolomite (10-20 %)andapatite, phlogopite and some opaques as accessory minerals. These carbonatites contain subhedral xenocrysts of olivine (Forsterite) (Sai & Sengupta, 2017), which are fractured and serpentinized along the fractures. One of the studiedolivine xenocrysts, hosts a pseudo-secondary, intragranular fluid inclusion trail.We interpret this as a result of trapping along preferred crystallographic orientation at the time of deformation and recrystallization/reprecipitation of olivine. These inclusions, in the form of saccharoidal grains with euhedral to subhedral morphology, are identified as Magnesite(1096.12 cm^{-1}), along with H_2O and some unidentified volatilesby Micro-Raman Spectroscopy. Fluid inclusions in apatite are mostly $H_2O$with dissolved CO_2. However, magnesite inclusions are restricted only to the pseudo-secondary trails of olivine xenocrysts. Stable isotopes, $\delta^{18}O$ composition (7.88 to 9.22 ‰) and $\delta^{13}C$ composition (-3.79 to -4.46‰) of these carbonatites indicate primitive mantle lineage with no crustal contamination.

Presence of magnesite only as intracrystalline pseudo-secondary trail in olivine and pristine mantle signature of oxygen and carbon isotopic ratios confirm that this resorption of olivine and subsequent development of magnesite is not caused by any secondary hydrothermal or crustally derived fluid. We infer that this whole phenomenon of trapping fluid inclusions was controlled by recrystallization of olivine, i.e., forsterite reprecipitation in the carbonatite reservoir by chemical exchange between melt and mantle rocks, (say dunite), during percolation of carbonatitic magma. We envisage a dissolution-precipitation mechanism of deformation/recrystallization of olivine by carbonatitic magma at grain edges(Hammouda & Laporte, 1999) and forsterite reprecipitation in the carbonatite reservoir. Olivinexenocrysts may have incorporated in the carbonatitic magma, either from the lithospheric mantle during plume-lithosphere interaction or from the plume itself.

ESTIMATION OF SITE AMPLIFICATION FUNCTIONS USING HVSR TECHNIQUE AT SITES IN THE KURUKSHETRA UNIVERSITY CAMPUS

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It is well known that the surface geology is one of the dominant factors that affect the amplitude, duration and frequency content of strong ground motion as significantly observed in the case of Bhuj earthquake. The site-specific studies are important for seismic hazard analysis for representing realistic ground motion scenario. The study area of Kurukshetra University campus lies in the Indo Gangetic plain, which represents almost flat alluvial plain without any conspicuous topographical features. The estimation of site amplification can be done using different techniques namely HVSR, SSR and Generalized Inverse technique. In present study, the site amplification and predominant frequency are estimated using HVSR technique at five sites in Kurukshetra University campus. The site amplification function obtained at these sites is found to be in the range 2-3 which is may be due to the loose sediment cover over the region. The predominant frequencies are very low for the region and lying in the range of 0.60-0.90 Hz. The spatial distribution of site amplification and the predominant frequency has been prepared. The output of the study will be helpful for micro zonation, simulation and for the preparation of scenario hazard maps of the region.

ON A GRAVIMETRIC–ISOSTATIC MODEL FOR CRUSTAL DEPTH ESTIMATION OVER THE INDIAN LITHOSPHERIC PLATE USING GEOID/GRAVITY DATA

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Moho depth or simply, Moho, in general, describes the boundary between the earth's crust and the mantle and is a very important geophysical parameter. It is also related to the earth's crustal thickness at any point. However, satellite gravity technique is not working over land/continent. So, we need to develop technique like the VMM model which is equally working over land. In addition of generating crustal thickness, it also saves energy to generate Bouguer anomaly over land and ocean. A revised gravity anomaly map, generated from the EIGEN6C4 high resolution global gravity model, has been utilized for understanding structure and tectonics over the regions of interest and surroundings. EIGEN6C4 data have been analysed using different derivatives and Analytical Signal techniques for delineation of structural features and comparative analysis with the published results, which shows good correlation. The Bouguer anomaly map of India has also been digitized and the values interpolated at 10 km interval to prepare a composite gravity map of India. The Vening Meinesz–Moritz (VMM) model, as generated by Bagherbandi (2012), determines the Moho depth such that the compensating attraction totally compensates the Bouguer gravity anomaly on the Earth's surface, implying that the isostatic anomaly vanishes on the Earth's surface. With the advent of more and more altimetry missions with increasing accuracies and varying orbital configurations, it has been possible to generate large-scale altimeter-derived residual/prospecting geoid and gravity anomaly maps over the oceans. It can be used to infer subsurface geological structures analogous to gravity anomaly maps generated through ship-borne survey. However, the situation is much more complex over the landmass; more so, over the Indian Landmasses including the Himalayan tectonic region, The NASA Goddard Space Flight Center (GSFC), the National Imagery and Mapping Agency (NIMA), and the Ohio State University (OSU) have collaborated to develop an improved spherical harmonic model of the earth's gravitational potential to degree 360. Earth Gravitational Model 1996 (EGM96), incorporates improved surface gravity data,

altimeter-derived gravity anomalies from ERS-1 and from Geosat Geodetic Mission (GM), extensive satellite tracking data as well as direct altimeter ranges from TOPEX/POSEIDON, ERS-1 and Geosat. Here a practical method to recover the Moho depth from the gravity data is used based on the Vening Meinesz–Moritz method.. Bouguer gravity over the Indian plate could be estimated using terrestrial and satellite geoid/gravity data. In this case, the Bouguer gravity anomaly ranges over the Indian plate as estimated using the VMM model and terrestrial data utilization matches satisfactorily. Further, The Moho/crustal depths as generated by VMM model across the profile vary within expected ranges.

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THE X-DISCONTINUITY IN THE INDIAN SHIELD

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The X-Discontinuity is a weak 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 not a ubiquitous global discontinuity and could probably associated with the mineralogical phase changes in the mantle. To find out its presence in the Indian shield, seismological data from 43 stations have been processed and P receiver functions are estimated. These stations are deployed and operated by the CSIR- National Geophysical Research Institute, National Center for Seismology and GEOSCOPE. The existing limitations in mapping this interface, imposed by the interference of direct P-to-s conversion from the X-discontinuity and multiples from the shallow interfaces have been overcome by exploiting their different moveouts and subsequently applying the Radon transformation. The moveout correction is more for multiples than primaries and increases with depth. However, the identifications of primaries and multiples in observed data are sometime challenging in the traces or in migrated section. We utilize both the Forward and Inverse Radon transformations for the separation and reconstruction of the data. We clearly observe the upper mantle global discontinuities (e.g . 410 and 660 km) and an additional discontinuity termed as X-Discontinuity below most of the stations in the Indian shield. A number of mineralogical explanations have put forth globally for the occurrences of the X-discontinuity. However, most of the theories proposed that either the coesite to stishovite phase transition or exsolution of stishovite from clinopyroxenes containing excess silica may cause for this X-Discontinuity. Here a detail explanations and interpretations will be presented for the evolution of the deep mantle in the Indian shield.

DEDUCING GROUNDWATER POTENTIAL ZONES IN A PART OF CHANDRABHAGA RIVER BASIN, NAGPUR DISTRICT, MAHARASHTRA USING RS, GIS AND AHP TECHNIQUES

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Groundwater is a vital natural resource for drinking, domestic and irrigation purposes. Several factors are being controlled its potentiality. Nowadays Remote Sensing (RS) and Geographic Information System (GIS) help in assessing, monitoring and conserving groundwater resources by the manipulation

and analysis of individual layer of the spatial data for identifying groundwater potential map. Thus the RS and GIS techniques had been used in a part of Chandrabhaga river basin, Nagpur district, Maharashtra covered by an area of ~360 km2. We had collected available geology, geomorphology and soil maps of the study area. Land Use & Land Cover (LULC) and Lineament maps had been prepared using the LANDSAT-8 Satellite Image. The SRTM DEM (resolution:30 m) data had been utilized for the preparation of Slope and Drainage maps. These maps were converted into the raster format. Analytic Hierarchy Process (AHP) was applied to weightage, ranking, and reclassify these maps individually in the ArcGIS ver.10.4 environment and the groundwater prospect map was prepared by overlying these maps. This prospect map has been categorized into five groundwater potential zones such as very poor (11.8%), poor (21.7%), moderate (30.1%), good (25.3%) and very good (11.1%). Further, the yield data collected from the 11 existing wells had been utilized to validate. It shows that the yield values vary from 5.94 to 14.88 lps with an average of 8.63 lps in good to very good groundwater potential zones, whereas 0.38 to 1.37 lps with an average of 0.84 lps in the poor to very poor groundwater potential zones. The work will help to construct artificial recharge structures and planning of sustainable groundwater management.

SEASONAL VARIATION OF SEISMIC AMBIENT NOISE IN INDIAN SUBCONTINENT

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Background noise experienced by the seismic stations known as ambient noise influences the threshold detection of micro earthquakes and is gaining interest as robust data for understanding crustal velocity structure, temporal velocity changes, volcanic activity etc. Therefore, we analyze the continuous ambient noise data recorded for one year (2012) to compute probability density functions (PDF) of power spectral density (PSD) from Southern, Northern, Eastern, Western and Central parts of India using ten broad band stations to provide average background noise levels. The seasonal ambient noise levels at each region are calculated and compared with the global noise model in the frequency band 0.01Hz to 3Hz. In general, the seasonal variations in ambient noise levels due to oceanic climate system appear at longer periods >5s. In addition, high frequency content of background seismic noise/cultural noise is associated with anthropogenic activities. We have noticed statistically significant power in the microseisms band between 2 to 15s in the PSD-PDF of the five regions. The noise at primary and secondary microseism bands from most of the Indian regions is close to the lower limit of the global noise model during summer and winter season and is above the mean global levels during monsoon and post monsoon. The high frequency noise (> 0.5 Hz) is close to/ above the global maximum suggesting a high cultural noise surround the seismic stations used in the present study. The PSD-PDFs of North East India are slightly deviating from other regions with different spectral distribution which may be associated with its distinct geo dynamics. The seasonal and spatial variations presented in this work help to plan better sites for seismic networks.

NATURAL AND ANTHROPOGENIC VARIATIONS IN OF TOTAL WATER STORAGE (TWS) AT VISAKHAPATNAM, ANDHRA PRADESH, INDIA

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Understanding the role of natural and anthropogenic influences on groundwater variability is of upmost importance in the present scenario of climate change, especially to develop strategies to preserve/save groundwater resources. We analyse the monthly Total Groundwater Storage (TWS) at Visakhapatnam, Andhra Pradesh, India for the past 14 years (2002 to 2016) using Gravity Recovery and Climate Experiment (GRACE) data. We employ Singular Spectrum Analysis (SSA) to decompose the data into cyclic components associated with well-known climate processes as well random components associated with anthropogenic as well as catastrophic activities. The first principal component reconstructed from first and second Eigen modes of the data contributes 12.72% of total TWS with annual periodicity. The second principal component reconstructed from Eigen modes 3 to 8 depicts the seasonal cycles, lower order ENSO cycles of periodic to chaotic dynamic with 18.43% of total TWS. The 9th Eigen mode shows very high depletion in TWS between 2002 and 2005 and periodic oscillations with decreasing trend afterwards. The 10th Eigen mode depicts the impact ENSO signatures on TWS with periodicities 1.3 to 5.2 years. The residual signal reconstructed from Eigen modes 11 to 75 contributes nearly 65% to the total TWS with stochastic/random behaviour. These stochastic/random signatures may be associated with the loadings from anthropogenic activities, catastrophes and natural disasters. Overall the study suggests the dominance of random anthropogenic and catastrophic processes on TWS variations at Visakhapatnam, Andhra Pradesh, India compared to cyclic and quasi cyclic changes associated with climate processes.

REGION-SPECIFIC VELOCITY MODELS FOR GUJARAT REGION, WESTERN INDIA

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Gujarat region, located in the western part of India is an active intraplate region. It comprises of geologically three distinct regions: Kachchh, Saurashtra and mainland. The Kachchh regions is seismically most active whereas Saurashtra and few pockets of mainland are moderately active. After 2001 Bhuj earthquake of Mw7.6, Government of Gujarat has set up Institute of Seismological Research (ISR) and installed a dense network of seismic station spread all over Gujarat in 2006. For the past 12 years, a large number of earthquakes are recorded in these stations. In this study, these datasets are used to obtain 1D velocity models for Kachchh and Saurashtra regions. A total of 570 and 114 well recorded earthquakes with azimuth gap $<180°$ that have occurred in Kachchh and Saurashtra regions, respectively, are used in the analysis. A seven-layer model is proposed for Kachchh region up to depth of 34 km where the *P*- and *S*-wave velocities varies from 3.01 to 7.88 km/s, and 1.74 to 4.55 km/s. For Saurashtra, a four-layer model is proposed, up to the depth 18 km, where *P*- and *S*-wave velocities varies from 4.61 to 6.73 km/s and 2.66 to 3.89 km/s, respectively. The obtained optimum 1D velocity models in this study are further used to relocate all the earthquakes recorded during 2006 and 2015. The relocation provided us better constrain on depths though horizontal difference in earthquake locations is small. Another important observation is that in the Kachchh rift, both the upper and lower crust are seismically active with earthquakes occurring up to Moho. In Saurashtra, the upper crust is seismically active, whereas lower crust is a seismic. These region-specific 1D velocity models can also be used as reliable starting models for seismic tomography studies to obtain 3D velocity structure of these regions.

SUSPENDED SEDIMENT FLUXES FROM AN AGRICULTURAL CATCHMENT IN LOWER HIMACHAL HIMALAYA, INDIA

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Data describing sediment yield rates on sub-tropical highland agricultural catchments in Himalayan region are relatively rare. Therefore, the aim of this study is to analyse suspended sediment transport in a lower Himachal Himalayan agricultural catchment. Since a major part of the discharge and suspended sediments from Himalayan catchments drains out during the rainy season (July-October), therefore assessments were made only for this period. Data regarding rainfall, discharge and suspended sediment concentration was collected from Bhakra Beas Management Board (BBMB), Sundernagar, Himachal Pradesh during four rainy seasons for the period 2012-2015. The analyses were undertaken to assess the suspended sediment load, sediment yield, denudation rates, particle size distribution and interpretation of sediment delivery processes using suspended sediment-discharge hysteresis patterns. Also, the results of this study were compared with other agricultural catchments in the Himalayan region. The mean monthly suspended sediment concentrations for July, August and September were observed to be 3298.6, 3764.1 and 1912.4 mg^{-1}, respectively with a mean daily value of 3003.4±2265.3 mg^{-1} (CV= 75 per cent). Similar observations were recorded for suspended sediment load and about 50 per cent of the load was transported in the month of August. The catchment yielded 4413 t sediments km^{-2} $year^{-1}$, higher than that of the mean annual erosion rates in India. Various hysteretic loops obtained for the catchment revealed channel erosion and transfer of eroded, deposited and loose particles as the major source of sediments. The average percentages of coarse, medium and fine size particles were found to the tune of 10.77, 18.84 and 70.38 per cent, respectively, suggesting towards low flow volumes which may not have enough energy to transport the coarse and medium size particles.

SPECTRAL DIRECTIONALOGRAM: AN ELECTROMAGNETIC DIRECTION MAPPING TOOL

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In many applications, it is important to ascertain the location of the source emitting electromagnetic (EM) signals from the time series data recorded at a single receiver. This can be done by utilizing the property of directionality of the EM signal. The arithmetic of this calculation requires both electric and magnetic data-sets. However, often the availability (of both data sets) is limited and thus restricting the directional illustration. We are underlying therefore a new approach mapping the directions. Rather than time, the approach actually works in the frequency domain. However, some fixed time steps of short term Fourier Transform help in gaining the time information. The treatment is new and we named it as spectral-directionalogram (SD-gram). It maps a spectral line direction of a vector. The SD-gram and its efficacies are demonstrated with an example. We have sketched theory and physics behind and will detail. Moreover, it is interesting to observe and comment on the current standard practice of signal characterization. Strictly, it may go inaccurate only with amplitude (i.e. in the absence of directions). Artificial data based simulations are also conducted for evaluating the limitations and advantages of the SD-gram.

DELINEATING GAS HYDRATE USING NEURAL NETWORK LEARNING IN KG OFFSHORE BASIN

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We use a combined unsupervised and supervised neural network learning scheme to delineate gas hydrate in different litho-units in Krishna-Godavari (KG) offshore basin. The increase in sonic velocity and resistivity responses in presence of gas hydrate can be used to know the distribution of gas hydrate in sediments. In the present study, we have done neural network based analysis of well log data for mapping of lithology with depth and also interpret the effect of gas hydrate on lithology identification. In the present study, we use density, neutron porosity, gamma ray, resistivity and sonic velocity of Logging while drilling (LWD) logs of hole 10A, which were acquired in 2006 under the first Indian National Gas Hydrate Program (NGHP-01). We apply the neural network scheme on the data with (i.e. observed) and without gas hydrate (i.e. water saturated sediments) to know the effects of gas hydrate in identifying lithology using neural network. At first, we apply two unsupervised methods (e.g. elbow method, 3D clustering) to obtain the number of clusters/litho-units present in the data. The elbow method explains the initial guess about existing clusters present in data by taking trade-off between optimum cluster centre and sum of intra cluster distances. The minimum value of sum of intra cluster distances at a particular cluster centre considers as an optimum number of cluster unit, which has been taken as input in 3D clustering. Then Bayesian neural network aided with Hybrid Monte Carlo searching technique in supervised learning has been applied to the data to revise each defined cluster unit of training samples and map them with depth. We find that the hole 10A is dominated by clay with some amount of clay, silty-clay, silt and sand, where gas hydrate is distributed mainly in clay, silty-clay and silt, not in sand. Our results demonstrate that, if we do not consider gas hydrate as a separate class, gas hydrate is distributed as lithology in its host classes (i.e. clay, silty-clay and silt).

SIMULTANEOUS PRE-STACK INVERSION OF DENSITY, P- AND S-IMPEDANCES: A CASE STUDY FROM MAHANADI OFFSHORE BASIN, EASTERN MARGIN OF INDIA

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Depletion of fossil fuels and increasing demand for hydrocarbon energy resources have necessitated to look for unconventional energy resources such as the gas hydrates, which are found in abundance in the outer continental margins and permafrost regions. Parameters like bathymetry, sediment thickness, rate of sedimentation, TOC content, seafloor temperature indicate that shallow sediments along the Indian margin are good host for gas hydrates. The presence of gas hydrates is identified by an anomalous reflector, known as the bottom simulating reflector or BSR, on seismic section. The BSR is a physical boundary between gas hydrate-bearing sediments above and free gas saturated sediments below. In the present study, simultaneous inversion on 2-D pre-stack seismic reflection dataset of Mahanadi basin has been applied to obtain P-impedance, S-impedance and density. The approach is based on Modified Fatti equation, which uses the ratio of P-wave and S- wave velocities

as constraints. The Modified Fatti equation provides a relation between P-impedance &density and S-impedance &density. In order to increase the signal-to-noise ratio of the data,NMO corrected CDP gathers, obtained after initial processing of the seismic data, are pre-conditioned to form super gathers. Random conjugate-gradient algorithm is used for the inversion process as it produces global solutions. The whole exercise clearly demarcates gas hydrates distribution in the study area,as the impedance sections act as attributes towards confirming the presence of BSR. The inverted density section can be further used for pre-drill pore pressure prediction in the area. As gas hydrates are untapped till date, information on the pre – drill pore pressure will help in future for drilling purposes. The obtained P-impedance, S-impedance and density sections can be used to compute V_P and V_S sections, which in turn can be used for rock physics modelling.

SELECTION OF PROPER MOTHER WAVELET AND OPTIMUM LEVEL OF DECOMPOSITION: EXAMPLES FROM WIRE-LINE LOG DATA IN THE KG BASIN

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Wavelet transform, a popular time-frequency analysis tool, has been applied to analyse a wide range of signals covering science, engineering, medical sciences etc. Though the wavelet transform (WT) overcomes the limitations of Fourier transform, still the challenge lies in selecting a proper mother wavelet and choosing optimum level of decomposition for extracting required information from the signals. To address these issues, we have used the maximum energy to Shannon entropy ratio (MEER) and average error (E_r) methods to find out the proper mother wavelet and optimum level of decomposition using geophysical wire line log (non-stationary signal) for accurate geological interpretation. The feasibility of this study has been tested over the wire line logs like the Gamma ray log (GR), Resistivity log (R_T), Bulk density log (RHOB), Sonic velocity (V_p) log data, collected during the Expedition-02 of the Indian National Gas Hydrates Program at holes NGHP-02-17C, NGHP-02-19-C and NGHP-02-22-C in the KG basin India. The results show that the GR, RHOB, V_p logs are optimally de-noised by Daubechies wavelet (db4) at level three decomposition, whereas, R_T log is optimally de-noised at level one decomposition using the Haar (db1) wavelet.

PORE PRESSURE PREDICTION FROM POST STACK SEISMIC DATA IN DEEP OFFSHORE OF MAHANADI BASIN, INDIA

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Pore pressure prediction is vital for ensuring safe drilling operation, selection of mud, and designing of well, particularly in the deep offshore to avoid well control problems such as the blowout. It is also important to understand the geomechanical behaviour of gas hydrate stability zone. We have predicted pore pressure from post stack seismic data in the Mahanadi basin, located at the northern side of eastern continental margin of India, where gas hydrates have been established in clay/silt sediments by drilling and coring of Indian National Gas Hydrates Program. Gas hydrates, ice-like crystalline substances of methane and water, are formed in shallow sediments of deep waters at low temperature and high-pressure conditions. The magnitude of pore pressure is mapped on 2D-multi channel seismic data with bathymetry ranging from 1433m to 1935m by utilizing the well

information. Initially, Bower's parameters (A and B) from plot of effective stress versus P-wave velocity have been computed from log data in individual wells. The vertical stress section has been computed from inverted density in time section and log data in depth domain. Thereafter, the pore pressure is predicted by subtraction of effective stress section from vertical stress section. The pore pressure distributions have been mapped within the gas hydrate stability zone (GHSZ) and sediments below the bottom simulating reflector (BSR) or the BGHS zone. The pore pressure gradient of 10.11 MPa/km is observed in the study area. The predicted pore pressure from seismic data matched closely with the measured pressure at the drilling location with excellent goodness of fit (R^2) varying from 0.82 to 0.95. Normal pressure is observed in the gas hydrate bearing sediments but slightly high pressures are found below the BSR in enhanced reflective regions. The pore pressure, obtained from seismic data, will guide for selecting mud weight selection during drilling and casing optimizing in other part of deep offshore in the study area.

ASSESSMENT OF GAS HYDRATES IN AREA-B OF KRISHNA-GODAVARI BASIN, OFFSHORE EASTERN CONTINENTAL MARGIN OF INDIA, NGHP EXPEDITION-02

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Various Holes were drilled and logged and core samples were acquired at 25 sites in the Krishna-Godavari (KG) and Mahanadi Basins along the eastern margin of India during the Expedition-02 of Indian National Gas Hydrate Program (NGHP Exp-02) for establishing gas hydrates in sand reservoirs. In our study we have used the wireline log data from NGHP Exp-02 to characterize the gas hydrate bearing sand, clay-rich sedimentary sections and estimate the saturation at two sites in Area B of the KG Basin: Sites NGHP Exp-02-22 and NGHP Exp-02-23. Since elevated resistivity and elastic velocity are the most notable changes in physical properties of gas hydrate bearing sediments, so we have analysed the resistivity log data using Archie's empirical equation based on isotropic reservoir properties. Further,the saturation of gas hydrate has been computed by using a simplified version of three phase Biot equation (TPBE)that models the P-wave velocity by considering gas hydrate as a part of homogenous load bearing sediment. The downhole log data exhibit the base of gas hydrate bearing sediments (BGHBS) at the depths of 284 mbsf and 290 mbsfin Holes NGHP Exp-02-22 and NGHP Exp-02-23, respectively. The maximum gas hydrate saturations,as estimated from the resistivity log data, are 65% in Hole NGHP Exp-02-22 and 70% in Hole NGHP Exp-02-23, whereas the maximum hydrate saturation obtained from P-wave velocity modelling are 55% and 85% in Holes NGHP Exp-02-22 and NGHP Exp-02-23, respectively.

COMPARATIVE STUDY OF PORE PRESSURE PREDICTION USING FOUR DIFFERENT INTELLIGENT MODELS

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Normal pressure is the pore-fluid pressure and itequals to the hydrostatic pressure and overpressure is the excess of pore pressure. This over pressure plays a significant role in understanding geological processes. There are different causes for generation of overpressures in sedimentary basin. Overpressure in young sedimentary basins is mostly generated by rapid sedimentation of low permeable

material. Presently, well log data is being used invariably to estimate pore pressure in oceanic setting of rapid sedimentation rate environment. Yet, prediction of pore pressure from well log data is difficult due to the non-linear/complex relationship between well log data and/or over-burden pressure with pore pressure Here,we implement four intelligent models to predict pore pressure from well log data. The calculated pore pressure using Eaton's method at depths has been used to build a model akin to time-series forecasting and four intelligent models namely, Adaptive Neuro-Fuzzy Inference System (ANFIS), Automatic Relevance Determination-based Bayesian Neural Networks (ARD-BNN),Gaussian Process Regression Networks (GPRN), and Support Vector Machine (SVM),are developed to solve a regression problem. Prior to actual data prediction in unknown/test interval, each model is calibrated using cross-validation datasets and optimal model parameters are evaluated for final prediction. To make a fair comparison, and to examine the accuracy of these models, four statistical performance measure indicators are adopted such as mean square error (MSE), reduction of error (RE), index of agreement (IA), correlation coefficient (R). Based on correlation coefficient (R), GPRN model outperforms rest of the models considered in the present study.

POREWATER GEOCHEMISTRY AND SOLID PHASE SPECIATION OF PHOSPHORUS IN EASTERN ARABIAN SEA SEDIMENTS THROUGH TWO TRANSECTS ACROSS THE OXYGEN MINIMUM ZONE

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In order to study the effect of varying bottom water oxygen concentration on the benthic regeneration of phosphorus (P), sediments along two transects across the oxygen minimum zone (OMZ) in the eastern Arabian Sea were studied. Porewater phosphate concentration gradually increased with the decreasing dissolved oxygen concentration of the bottom water. The magnitude of calculated diffusive phosphate fluxes at the sediment-water interface ranged between 0.017 and 1.17 μmol cm^{-2} yr^{-1}. The fluxes were highest on continental slope sediments overlain by oxygen-depleted water and were low at deeper depths overlain by oxic bottom water. Preferential release of P from organic matter and dissolution of fish debris are main processes that seem to have controlled the release of P to the porewater leading to an increase in porewater phosphate concentration with increasing sediment depth. The decrease in porewater phosphate with sediment depth is attributed to their consumption for formation of calcium fluorapatite. The solid phase speciation studies of surface sediments in these two transects show that the P enrichment is in the order of biogenic (P_{bio})> iron bound (P_{Fe})> organic (P_{org}) P > authigenic (P_{auth})> detrital (P_{det}). The high C_{org} and P_{org} content in the continental slope indicates enhanced OM preservation under oxygen-depleted condition. Relatively high percentage of P_{Fe} content in the transect off Gujarat reflects the re-adsorption of phosphate released from organic matter or reduction of iron oxyhydroxides at deeper depths, whereas the decreasing P_{Fe} concentration with decreasing bottom water oxygen concentration in the transect off Karwar indicates the release of P to the porewater on reductive dissolution of iron oxyhydroxides.

ESTIMATION OF CRUSTAL THICKNESS FROM OBS DATA USING TRANSFER FUNCTION: A CASE STUDY FROM THE ANDAMAN SEA REGION

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The teleseismic receiver function is widely used to estimate the crustal thickness and the Vp/Vs ratio beneath the seismological stations. The success of teleseismic receiver function depends on the P to S conversion at the Moho and its reverberations. However, the receiver functions are complicated in a marine environment due to strong reverberations from the shallow sediments and water column. Using synthetic data, we show that the receiver functions cannot distinguish between P to S conversion from Moho and other sediment reverberations. Therefore,the receiver functions cannot be used to estimate the crustal thickness and Vp/Vs ratio in a marine environment. We propose an alternative approach to this problem using the transfer function which is defined as the ratio of the radial Green's function to the vertical Green's function. The vertical and radial Green's functions are computed for a variety of model with varying properties of crust, sediments and water column, and the transfer function is estimated for each of the models. The transfer function is used to calculate the radial component from the observed vertical component. Next, we calculate themisfit between the computed and observed radial component and the subsurface model which best predict the observed radial component represents the correct subsurface model. We tested the proposed algorithm using the synthetic data, and observed that the methodology can be used to estimate the Moho depth in the presence of sediment and water column. We applied the methodology to the data recorded by the OBS located on the Alcock seamountin the Andaman Sea. We selected local earthquake with high signal-to-noise ratio occurring on the subducting Indian plate at an epicentral distance of less than 100 km and hypocentral depth of more than 40 km. The velocity structure reveals the presence of soft sediments of thickness of 300 to 400 m which is also confirmed by a nearby seismic profile. We can successfully model the waveform from the sediment-basement interface for all the events. Apart from the sediment reverberation, we also observe two major crustal phases with strong P-to-S conversion; the shallow interface (H1) is approximately located at a depth of ~ 7 km while the deeper interface (H2) is located at a depth of ~ 12 km from the seabed assuming an average velocity of 6.3 km/s for the crust. We are attempting to derive the crustal velocity based on the amplitudes of the crustal phases.

DECODING THE NORTH EAST MONSOON SIGNALS IN THE NORTHEAST INDIAN OCEAN DURING THE SOUTH WEST MONSOON DOMINATED HOLOCENE

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Investigating the past variations in the Indian Ocean monsoon (IOM) from sedimentary archives of Indian Ocean provides a unique opportunity to understand the response of earth processes to the prevailed climatic conditions. While the origin, dynamics and impact of southwest monsoon (SW) in IOM is well established, the precise role of northeast (NE) monsoonal influence especially during the Holocene is poorly understood due to SW monsoon domination. Here we attempt to interpret the IOM variability of last 21ka from a chemical weathering record from a sediment core from the western Andaman Sea, reconstructed using various geochemical weathering indices (CIA, CIW, PIA and WIP) and elemental ratios (Al/K,Rb/Sr and Y/Ho) indicative of provenance and weathering. Although,

the study area known to have signatures of local vocanics and islands, the Myanmar watersheds are considered as major sediment contributors. Geochemical discriminants (Al/K, Rb/Sr and Y/Ho) indicate increased chemical weathering between ~15 and 5ka which is a manifestation of SW monsoonal intensification,which is similar to the chemical weathering records in the central Andaman Basin(CAB). But in contrast to CAB record,the weathering indices displayed three extremely low chemical weathering events (8.9-7.9ka, 6-5ka and 2.8-1.8ka) during Holocene in this western Andaman Sea record. Absence of such events in central Andaman basin, the main depo-centre of Myanmar watersheds, suggests the influence of sediment input from a different provenance, possibly from local islandic sources. The timing of these three low weathering events are matching with dry events identified in northern Atlantic climate like increased terrestrial dust in Greenland ice record and reduced NADW (north Atlantic deep water) contribution to the AMOC (Atlantic meridional overturning circulations) mixing recorded in benthic $\delta^{13}C$ together suggests an atmospheric teleconnection linking northern hemispheric dynamics with Indian monsoon system. The present-day high monsoonal precipitation during NE monsoon months OND (October, November and December) shows the NE monsoon would have strengthened during those periods/events as the winter intertropical convergence zone expands south of Nicobar Islands. Further, the increased dust input recorded in a southern Tibetan lake and wet intervals in the SW monsoon shadow region of the Sri Lanka during same time periods broadly suggests the increased NE monsoon precipitation during SW monsoon dominated Holocene.

INVERSION AND ATTRIBUTE ANALYSIS FOR THE DELINEATION OF GAS HYDRATE DEPOSITS IN KRISHNA-GODAVARI OFFSHORE, INDIA

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The study of model based inversion(MBI)and seismic attribute analyzing techniques are extensively used for characterizing hydrocarbon reservoirs. Here we use multi-channel seismic (MCS) and well log data, which were acquired in the Krishna-Godavari (KG) offshore basin of India, for the investigation ofgas-hydrates. We have estimated acoustic impedance using MBIof MCS data, calibrated with log data, delineated the bottom simulating reflector (BSR), main marker for gas hydrates. The study shows the high impedance gas hydrate reservoirs above the BSR low-impedance free gas zone underneath. The analysis of seismic attributes such as the instantaneous phase, amplitude, sweetness, reflection strength and instantaneous frequency characterize the gas hydrates and free gas across the BSR. The high frequency, low amplitudes, low reflection strength and low sweetness are observed in the hydrate-bearing sediments above and opposite characteristics below the BSR ascertain the presence of gas hydrates and free gas across the BSR in KG basin.

MAPPING OF SEA FLOOR AND SUB-SEA FLOOR SEDIMENTATION USING MARINE GEOPHYSICAL TECHNIQUES –A CASE STUDY

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Near shore surface and sub-surface sedimentation study is one of the useful tool to identify suitable zone for coastal based infrastructure developmental activities. The seabed and sub-seabed mapping were performed in the north coast of Andhra Pradesh in order to understand the sediment

distribution and sub seabed formation where river Vamsadhara meets Bay of Bengal. The surface seabed sediment distribution was examined through high resolution Edge-tech side scan sonar system (4125) and sub-surface sedimentary formations were studied using Edge-tech sub-bottom profiler (216S) operated at 2-10 kHz. In addition to this, current measurements and sediment samplings were carried out for these studies.

Side Scan Sonar records and sub-bottom profiles acquired in the study area were processed by CODA software using various geophysical signals processing tool available in the software. The surface seabed sediment samples were collected at four locations using grab sampler and analyzed for sediment grain size distribution for various sizes. The results interpreted from side scan sonar records were validated with results derived from sieve analysis. Near-shore bottom currents were measured at one location to understand the stability/mobility of seabed sediments.

The interpreted results show that the seabed is generally spread by sedimentary layers such as sandy clay, clayey sand and sand. It is also observed that the presence of a few manmade objects on seafloor. The sub-seabed is composed by various sediment layers at various thickness and depth. The current measurements carried out for one tidal cycle shows a slow speed of current and scattered along all directions which indicates the moderate energy environment. Further oceanographic measurements and numerical models would be essential to understand the quantity and frequency of sedimentation.

DELINEATION OF BASEMENT CONFIGURATION AND CRUSTAL STRUCTURE IN KERALA KONKAN OFFSHORE BASIN FROM MODELLING OF GRAVITY AND MAGNETIC DATA

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The Kerala-Konkan offshore basin witnessed the impact of Deccan volcanism that might have masked sediments underneath. This western continental margin of India has evolved through breakup of India and Madagascar-Seychelles during the Cretaceous period. The margin is characterized by strong inland topography indicative of rift-flank uplifts caused due to rifting mechanism. We intend to delineate the basement configuration overlying tertiary sediments, Deccan basalts, probable sediments below basalts and crustal structure of the basin. We tried to find out the subsurface information from combined modeling of satellite borne bathymetric, free air gravity and magnetic (G/M) data. The seismic constrains have taken from the previous study in the basin. One of the objective of this study also is to confirm whether the seismically derived structures can be explained by other geophysical data such as the G/M data. Two profiles (one is E-W and other is N-S trend) have extracted from the larger grids to perform combined G/M modelling.

The spectral analysis has been done for regional and residual gravity anomaly separation and contour maps are prepared to find out deeper and shallow source depth information. The average depths of subsurface geologic bodies, as estimated from spectral analysis of gravity data are 11.0 km, 2.5 km and 0.2 km. These are found to be at 10.46 km, 1.12 km and 0.15 km depths respectively from the analysis of magnetic data. The average depth of basement from G/M modellingvaries between 9 to 12 km, which coincide with the results from seismic data. The gravity varies from -65 to -15 mGal with bathymetry variation from -2347 to -246 meter in E-W profile and in N-S profile gravity varies from

-70 to-52 mGal with bathymetry variation from -2148 to -1532 meter. The Moho depths are found out from 22 to 27 km in E-W profile and from 18 to 24 km in N-S profile. The G/M results also satisfy the presence of sedimentary formation, sandwiched between two layers of Deccan Basalts, which have been delineated by seismic experiments. Regional gravity anomalies derived from satellite gravity data indicates thickening of crust towards the continent and thinning of crust towards the ocean.

A 21 KYR RECORD OF SOURCE AREA WEATHERING RESPONSE TO INDIAN SUMMER MONSOON VARIATIONS FROM THE ANDAMAN SEA

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The paleomonsoonal variations and their impact on the weathering patterns in the source regions of sediments of the Andaman Sea were investigated from a 21 kyr sedimentary record using environmental magnetic, clay mineralogical and geochemical techniques. The results illustrate a strong Indian Summer Monsoon (ISM) during the late glacial (16 – 13 kyr), early (10.5 – 8.5 kyr) and middle Holocene (5 – 3.5 kyr) and a weak ISM during the Younger Dryas (12.9 – 11.7 kyr) and late Holocene (3.5 – 0 kyr) periods. The mineral magnetic grain size parameters (c_{ARM}/SIRM, SIRM/c_{LF}, c_{ARM}/ c_{LF}) shows finer grain sizes during the strong ISM periods indicating the increased chemical weathering while cold and dry periods are marked with an increase in magnetic grain size indicating the shift from chemical to physical weathering in the source regions. The mineral magnetic record of GC 3A suggests that the deglacial intensification of the ISM in the Myanmar region started at 16 ka and continued through B/A period. This is also evident from the increase in $d^{18}O$ records from this region and the decrease in SSS record from the nearby Bay of Bengal indicating the increased fresh water input. This warming trend and the ISM intensification were disrupted during the Younger Dryas (YD) period. A gradual weakening in the ISM strength since the mid–Holocene (~4.5 ka) is seen which corresponds well with the lowered solar insolation and moisture record during this interval. The results from our study are in agreement with the global and local records of paleoclimate and weathering and exhibit a close correlation with the solar insolation data suggesting the major role played by the solar forcing on the ISM variability.

DYNAMIC GAS HYDRATE SYSTEM IN ANDAMAN OFFSHORE BASIN

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One of the deepest bottom simulating reflector (BSRs) among worldwide BSR observed on seismic section is imaged on available high resolution 2D multi-channel seismic data off Andaman. The depth of the BSR is observed in the range of ~430 m to ~639 m along the seismic lines. To understand the unusual depth of the BSR geothermal modeling of BSR performed and heat flow estimated from the BSR depth. BSR-derived heat flow values ranges from ~12 to ~42 mW/m^2 from the study area and follow the bathymetry trend of dominant North-South ridges and can be explained with the east-ward trending increase in heat-flow toward the current seafloor spreading center. The base of gas hydrate stability zone (BGHSZ) modeled to analyze the linkage between gas hydrate occurrences in the Andaman Sea and its relation to the tectonic activity. Our analysis suggests an extensively variable

BGHSZ in the Andaman Sea controlled mainly by overall low geothermal gradients. Consistent local minor variations were observed with lower heat flow values over prominent topographic highs and higher values in valleys/troughs due to focusing and defocusing effects of the topography.

MAGNETIC FINGERPRINTING OF SEDIMENT DYNAMICS OF MUD BANKS OFF SOUTHWEST COAST OF INDIA

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Magnetic minerals are ubiquitous and indicative sediment constituents in estuarine, coastal and shelf systems. We integrate environmental magnetic, sedimentological and hydrodynamic data to delineate the formation mechanism of mudbanks along southwest coast of India. Magnetic susceptibility measurements on bedload and suspended sediments shows distinct association between enrichment of silt-sized magnetic particles and mudbank formations. The rockmagnetic and sediment grain size data from mudbank (M2, M3) and non-mudbank (M1) station provided clues on sediment fractionation and transport conditions controlling the mudbank formation. Coarsening in magnetic grain size and increase in magnetite concentration is seen at mudbank stations, whereas the non-mudbank stations showed a reverse trend. A close correlation between magnetic and physical grain sizes is noticed. Two key mechanisms responsible for mudbank formation are identified. First, calmer wave climate enable accumulation of silt-sized magnetic and non magnetic fractions leading to formation of magnetically depleted sediment bed. As monsoon commences, the entire sediment bedload are brought into suspension resulting in formation of fluid mud. Mineral-density based selective fractionation favours settling of magnetic particles (coarse silt-sized), while the finer magnetic particles gets enriched and forms thick fluid-mud as a suspended load leading to mudbank formation. We have developed a conceptual model which can be applied to decipher the sediment dynamics of mudbanks in other sedimentary (coastal and shelf) systems.

SPATIAL DISTRIBUTION OF GAS HYDRATE DEPOSITS IN KG OFFSHORE BASIN FROM THE ANALYSIS OF 3D SEISMIC DATA

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Methane hydrate is a non-stoichiometric compound containing methane molecule bounded with weak Van der Waals force within the cages of water molecule. In marine sediments, methane hydrate is formed at high pressure and moderate temperature in the presence of gas and water molecules. Due to the high volume of methane gas trapped by hydrate, it is considered as a potential future energy source. Conventionally, the occurrence of gas hydrate is established by the presence of Bottom Simulating Reflector (BSR) in seismic reflection data. Alternatively, the high-resolution velocity model is an important proxy for the occurrence of gas hydrate deposits as well as free gas deposits. The presence of methane hydrate within marine sediments increases the velocity whereas free gas decreases the velocity. In the present study, we have developed a robust methodology for automatic estimation of velocity model using migration moveout analysis and applied it to build a high-density velocity model using 3D multi-channel seismic (MCS) data from KG-offshore basin. The proposed method can handle mild heterogeneity of the subsurface as well as the dip of the reflector. The estimated velocity matches well with the observed velocity at three sites NGHP-01-02, NGHP-01-03 and NGHP01-10. The Site NGHP-01-10 shows an increase in velocity above BSR due to hydrate and a significant drop in velocity observed below BSR due to free gas, and drilling confirmed this observation. The other two locations do not show any velocity anomaly, and methane hydrate is not observed during drilling. We prepared an interval velocity map above the BSR and identified four different zones of possible gas hydrate deposits. Zone I is close to the Site NGHP-01-10 where high velocity trend is observed along the faults. Zone II is the extended gas hydrate deposits with low fracture density. Zone III deposit is similar to Zone 1, and also represents fracture filled gas hydrate deposit. Zone IV represents high velocities anomaly in the vicinity of toe-thrust region. We also prepared an averaged interval velocity map below the BSR to understand deep-seated gas sources in KG basin. The map show region of low velocity oriented in NW-SE direction in zones I-III indicating the presence of deeper free gas-bearing sediments. We propose that the gas hydrate deposit in the vicinity of site NGHP-01-10 is linked to the deep-rooted gas reservoir and shallow fault system.

GEOMAGNETIC DATA CHARACTERISATION AND ANALYSIS OF SEASONAL TREND OF SOLAR QUITE TIME CURRENT AT LOW LATITUDE SITES OF INDIAN SECTOR DURING DIFFERENT PHASE OF SOLAR CYCLE-24

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One second sampled geomagnetic three component (H, D and Z) variations recorded using Digital Fluxgate Magnetometer at Desaplar (DSP), Kutch region have been analysed for 2009 and 2012 to obtain seasonal trends of solar quite time current. The spikes in the DSP data are identified by first difference methods and are removed from all components. The calculated total field (F) at DSP have been compared with nearby INTERMAGNET site (ABG-Alibag, HYB-Hyderabad, JAI-Jaipur) in order to verify the trend of diurnal pattern at the site. The verified data have been used to obtain diurnal variation of H component and its seasonal pattern, the observations are compared with ABG, HYB and JAI sites which provide latitudinal variations of Sq current with seasons. It has been observed that Sq current shows clear variations in its amplitude with season, higher in E and J season and lowest in D. The observed seasonal trend is enhanced during the peak phase of solar cycle-24 (2012) compared to initial phase (2009). The difference in the amplitude of H components between the low latitude sites DSP, HYB, JAI and ABG with seasons is an implication of Sq focus shift with season.

PLANKTIC FOR A MINIFERAL RESPONSE TO OCEANOGRAPHIC CHANGES AT IODP SITE U1385, WESTERN IBERIAN MARGIN FROM 117 KYR TO 166 KYR

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The Iberian margin has been an area of paramount importance concerning global climate change. This region is characterised by a complex current system including the North Atlantic Current, Gulf Stream and their extensions, and are globally the major contributors to polar heat transport. The Iberian margin is an ideal region for investigating the changes in North Atlantic circulation during glacial and interglacial periods because of its rapid sedimentation rate.

High-resolution marine sediment cores retrieved from the Integrated Ocean Drilling Program (IODP) Site U1385 (37°34′ N, 10°7′ W, 2578 m below sea level) in the Iberian Margin, north-east Atlantic Ocean were used to better understand the paleoclimatic and hydrographic conditions. Even though numerous studies have been produced using various climatic and hydrographic proxy records from the Iberian margin to understand the surface ocean conditions on centennial to millennial time scales, the outcome of climate change on these surface currents and vice versa still needs evaluation in detail. This makes the eastern North Atlantic region very promising for further investigation.

Here we present a 49 kyr record of planktic foraminiferal assemblages from the Iberian margin to reconstruct changes in surface hydrography, dynamics of past upwelling intensity changes on centennial to millenial scales, and to investigate probable links of these changes with climatic oscillations in low and high latitudes during the time period 117 kyr to 166 kyr. Relative abundances of ecologically sensitive species are used to infer past changes in the latitudinal position of the polar water, influence of the transitional subpolar and subtropical water mass, and paleo-productivity pattern related with seasonal trade wind strength.

YOUNG RESEARCHER PROGRAM

PERFORMANCE EVALUATION OF MAGNETIC PHASE ANGLE INTERPRETATION TECHNIQUE

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Performance of Magnetic phase angle interpretation technique over 2D bodies has been studied for performance analysis. This technique interprets magnetic anomalies over two dimensional tabular bodies for source parameter (via origin, depth, width and magnetization angle). Synthetic magnetic anomalies over 2D- Tabular bodies, dyke with inclined top surface and arbitrary shaped have been computed. Different dimensions for geometry of the bodies and different magnetization angles have also been considered for generating synthetic anomalies. All these anomalies over different geometric shapes were subjected to the interpretation by the magnetic phase angle technique. The interpreted parameters by this technique have been compared with the theoretical parameters. Errors and percent errors in source parameters via origin, depths, and magnetization angle were computed. The percent errors plots in these parameters have been analyzed. It is observed that percent errors in origin is very less (<0.5%) in all the cases. When the technique is applied on regular 2D-bodies via, sheet, dyke and fault, the percent errors are within reasonable limits for depth, width and magnetization angle for cases of the right choice of model.. However, when the wrong choice of the model is given, the percent error in origin is less ($<\pm 0.5\%$), where as the percent errors in depth and magnetization angle are relatively high and particularly when the body is shallow. In the case of inclined the top surface of dyke, the percent error in origin is less and within reasonable limits. The widths are considerable limit and is constant (<2%). In the case of arbitrary shaped bodies also, location of the body by this method is reasonable, but depth of the body yields considerable errors. All the cases of geometries have been analyzed for the performance of this technique.

IMAGING THE ELECTRICAL CONDUCTIVITY STRUCTURE BENEATH THE DHARWAR CRATON, INDIA

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The Dharwar craton covers the major part of the southern Indian shield. The craton is surrounded by eastern Ghat mobile belt (EGMB) in the east and Arabian Sea in the west. Northern part is covered by Deccan flood basalts and the Godavari rift characterizes the north-east margin. Southern granulite terrain (SGT) consists of spectacular charnockites bound the south region of the Dharwar craton. The vertical extension and structure of sub-continental lithospheric mantle beneath the Archean Dharwar craton is the main attraction of the work presented here. The study consist 280 km long, west-east oriented profile of 22 magnetotelluric stations. The inter-station spacing is approximately 15 km. This magnetotelluric study is initiated from Dandeli (in the west) to Sindhanur (in the east side) of the Dharwar craton. The preferable geoelectric strike directions for the crust and lithospheric mantle are N3°E and N16°E respectively. MT impedance tensors were estimated using robust processing code. The data were modelled using non-linear conjugate gradient (NLCG) scheme taking both apparent resistivity and phase into account to obtain 2-D models to image lithospheric electrical conductivity structure.A 2-dimensional (2-D) resistivity model derived using the crustal and lithospheric mantle

strike azimuths are identifying conductive features in the stable continental Dharwar craton. In the crust prominent conductors are present in eastern and western part of the profile. Dharwar cratoncontains the thick lithosphere. Conductive anomalies are present in the uppermost mantle beneath the western part of the profile. The model contains two separate conductors at the depth range of 110-250 km. This study shows the possibility of kimberlite melt in the western Dharwar craton in the depth range of 110-150 km.Detailed 3-D modellingis in the process.

CARBON BASED NANOPARTICLE: A REVOLUTION IN GROUNDWATER TRACER STUDIES

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Tracers are the potential tool in providing information on groundwater flow characteristics such as groundwater flow velocity and flow direction. Conventional chemicals namely chloride, bromide, iodide, dye tracers (Rhodamine-WT) and radioactive chemicals (tritium) was normally used as the injected tracers in hydrogeological applications. However, use of chemical tracers have a limited scope due to high diffusion rates and difficult to estimate for very low water flow velocities of the order 0.00001 to 0.001 m/s. The radioactive elements as tracers has potential hazardous effects on the environment and human health. There have been a lot of progress made in the area of biological tracers/markers based on nanomaterials in India, but no effort has been made for geo-tracers. Nanoparticles, due to their unique properties, have been used for various applications in the chemical and biological studies. Carbon based nanoparticles have been widely used due to their small size and unique physical and chemical properties. It acquires fluorescence characteristics at nanoparticle size. In the present study, an attempt is being made to use fluorescence emitting carbon nanoparticle tracer as an alternate tracer in fluid movement in the pore spaces of un-saturated and saturated zones for characterizing the hydro-dynamic conditions of polluted areas in various geo-environments. In this paper we report the experimental work carried out using laboratory columns (PVC tube fitted in angle steel frame) to study performance of three different tracers such as chloride, tritium and carbon particle tracers (CQD), which is fluorescent under simulated condition. The study was initiated for identifying alternate tracer, which has less diffusion coefficient for studying water movement in unsaturated or saturated zones of the geological formation. The porous media used in the present column experiment is medium to fine sand and red soils. The column studies indicated that nano-tracers arrived together with the conventional tracers with almost same velocity. The experimental study indicated that nanoparticle tracer could be a substitute for existing chemical and radiotracer for the groundwater and environmental studies. The column study provides and emphasize the scope to analyze the performance of different tracers and to select the suitable and the better tracer for water movement through different type of geological formations in order to estimate the reliable hydraulic parameters of the aquifers.

ATTENUATION CHARACTERISTICS OF CODA WAVE OF LOCAL EARTHQUAKES IN KINNAUR REGION OF NORTH-WEST HIMALAYA, INDIA

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The attenuation characteristics of seismically and tectonically active Kinnaur region of North-west Himalaya are investigated. The attenuation of coda wave is evaluated using the analysis of local earthquakes occurred in this region. The broadbandseismic data of ten stations with interspacing distance of ~45 km installed in the highly remote mountainous terrain of Kinnaur region is utilized for this work. A total of seventy earthquakes of magnitude 1.6 - 3.4 (M_L) with epicentral distance of 2 - 80 km, occurred in Kinnaur region during 2008 to 2010 is considered for this work. The Single Backscattering method (Akii 1975) adopted for estimation of coda wave quality factor at different central frequencies i.e. 1.5, 3.0, 6.0, 12.0, 20.0 and 28.0 Hz through three lapse time window length of 10, 20 and 30 starting from twice the S-wave time.

The obtained Q_c values varies from 75 at 1.5 Hz to 1411 at 28 Hz, 273 at 1.5 Hz to 5097 at 28 Hz and 390 at 1.5 Hz to 7402 at 28 Hz for 10, 20 and 30 sec lapse time window, respectively. The average frequency dependent relation of form $Q = Q_o f^n$ for lapse time window 10, 20 and 30sec are computed as $(50\pm23)f^{(1.00\pm0.008)}$, $(182\pm60)f^{(1.00\pm0.001)}$ and $(259\pm52)f^{(0.99\pm0.05)}$, respectively. An average $Q_c(f)$ relation is developed for the Kinnaur region as $(162\pm28)f^{(1.00\pm0.01)}$. In general coda attenuation provides Q_o, which represents heterogeneities and 'n' represents level of tectonic activity of the region and present result of low Q_o (<200) and high n (>0.8) values corresponds to tectonically and seismically active regions (Kumar et al., 2004).

The South Tibetan Detachment (STD) is the main tectonic feature of the present study region. The $Q_c(f)$ relations are determined at different stations situated on both sides of STD. The stations lies on the southern side of the STD have high Q_c values as compared to northern side stations. The higher Q_c values are due to the presence of high grade metamorphic rocks towards the southern side of STD, whereas northern side have low grade sedimentary rock due to which low values of Q_c (high attenuation) are observed in this part of study area. Comparison of the present relation with other available relations for the vicinity of present study area revealed that it falls within the range of values that are typically found in the tectonically active part of the Himalaya.

A COMPARATIVE STUDY ON HYBRID OPTIMIZATION METHODS FOR INVERSION OF VERTICAL ELECTRICAL SOUNDING DATA

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The vertical electrical sounding (VES) is popularized based on a stratified homogeneous and isotropic layered earth model. Different local and global optimization methods have been invariably used in the inversion of VES data. The major drawbacks of local and global optimization methods are finding *a priori* information and computational cost respectively. A good starting model is essential to obtain optimal solution via local optimization method. In global optimization, obtaining a fast

convergence with global minimum is a cause of concern. A common problem in global optimization methods is the frequent occurrence of premature convergence when the exact position of the global minimum in complex geophysical error surface is unknown. The drawbacks of local and global optimization methods have been effectively circumvented by different hybridization techniques. Here we implement various global optimization methods (e.g., particle swarm optimization(PSO), genetic algorithm(GA), simulated annealing(SA)) and local optimization methods (e.g., damped least square inversion(DLSI), steepest descent(SD), conjugate gradient (CG)) and hybridization methods combining with local and global optimization in an optimal way to invert the VESdata acquired over various geological complex settings of India. The comparative study suggests that the PSO in combination with DLSI-based hybrid optimization outperforms the rest of the competitive hybrid inversion scheme in the present study.

A NEW APPROACH FOR ADVANCED INTERPRETATION OF 3D SEISMIC DATA USING META-ATTRIBUTES: EXAMPLES FROM TARANAKI BASIN, OFFSHORE NEW ZEALAND

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We have computed meta-attributes from a set of known attributes,by designing work flows based on artificial neural networks (ANN), which have been used for advanced interpretation of seismic data in four prospects of Taranaki basin off New Zealand. Application of this new approach to the time migrated 3D seismic data in Maari prospect of highly structured and deformed Taranaki basin has distinctly imaged gas clouds, originating from the Late Cretaceous source rocks (Pakawau Group) and migrated into the Eocene (Kapuni Group) and Miocene (Mahakatini Group) formations. The study also shows that the gas has seeped through the overlying Pliocene to recent formations, the imprints of which are observed as pockmarks on the seabed. The findings match with the results in Moki-1 well available nearby. Several fault intersection zones (weak zones) within the reservoirs exhibit high probability of gas chimneys.

We have extracted a set of seismic attributes by conditioning the 3D time migrated seismic data in Waitara prospect and amalgamated them with the interpreter's acquaintances based on ANN. This has resulted into a meta-attribute, defined as the thinned fault cube (TFC), that shows augmented interpretation of geological discontinuities from seismic data. The attributes are trained over example locations selected from the data volume through a fully connected multi-layer perceptron (MLP).

The Kora volcano, a submarine Miocene andesitic stratovolcano, is buried below ~1700m sedimentary strata in the northern Taranaki basin. This buried volcano and enclosing older sedimentary strata have modulated subsurface architecture leading to structural and stratigraphic traps for hydrocarbon accumulation. We have computed seismic attributes that are optimally amalgamated into a meta attribute, defined as the intrusion cube (IC), and trained them over the interpreter's acquaintances to image this complex geological system from 3D seismic data based on ANN scheme. The result shows clear image of volcanic edifice along with other structural elements such as the Mass transport deposits, folding of beds, drag folds, intrusion, dyke swarms, saucer sillsetc. in the host sedimentary successions to understand the geo-tectonics of the region.

For the interpretation of magmatic sills, we have computed a meta-attribute, defined as the sill cube (SC), by combining several other seismic attributes from 3D seismic data in Kora prospect and training over interpreter's knowledge on sill network through a supervised scheme of neural learning. The novel approach shows its efficacy in producing enhanced images of magmatic sills. The SC meta-attribute shows saucer-shaped geometry of most of the sills along with different structural elements such as the limbs, bridges, junctions, fingers and overlying forced folds, and helps in understanding the tectonic architecture of the region.

PRODUCTIVITY VARIATIONS FROM THE EASTERN EQUATORIAL INDIAN OCEAN SINCE THE MID-PLEISTOCENE

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The eastern equatorial Indian Ocean is relatively remote area in terms of direct fluvial discharge from Indian land mass to the deep sea. The two possible sources of sedimentation to this region are turbidity currents and authigenic sedimentation. The surface hydrography of the regionis influenced byopen ocean conditions. Here we present the Total Inorganic Carbon (TIC) and Total Organic Carbon (TOC) variation in a sediment core, SSD-044GC-05R located at the western flank of Ninety-East Ridge with a geographical location of 6.5° S and 88.60° E, to reconstruct millennial scale changes in productivity sincethe mid Pleistocene. The 4.40m long gravity core was collected from a water depth of 4080m.The TIC and TOC were analysed by coulometer and NC Soil analyser respectively, using sediment sample at an interval of 5cm. The Ninety East ridge is known for pelagic carbonates and the sedimentation rate is very low ~4mm/kyr (*Dickens et. al., 1994*). The carbonate compensation depth (CCD) in this region is ~4500m (*Cullen and Prell, 1984*)and the core depth (4080m) is just above the CCD. The $CaCO_3$% ranges from 50%-90% throughout the core with large fluctuations observed in the upper half of the core. On the other hand, organic carbon ranges from almost negligible to 1.5 % throughout the entire coreand displays an increasing trend downcore. Since dilution by terrigenous material and dissolution is negligible, the high $CaCO_3$% throughout the core suggests that productivity was high through the time period. The downcore variability in $CaCO_3$% could be the result of fluctuating sedimentation rate due to the bottom topography or under water current activity.

3D-REGIONALIZATION OF SPECIFIC YIELD AT WATERSHED SCALE AND GROUNDWATER STORAGE MAPPING IN CRYSTALLINE ROCK OF SOUTHERN INDIA.

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Approach for regionalizing the specific yield in 3-dimension has been taken from earlier researcher and applied on the deep weathered crystalline rock of Maheshwaram watershed (53 km^2). A method is based on water table fluctuation method and groundwater budget components with up-scaling and regionalization of parameters. Satellite based land use data has been used for the estimation of

groundwater abstraction at spatial scale. At watershed scale, the specific yield of the aquifer ranges from 0.2% to 5%. For the regionalization of specific yield in 3-dimension, saprolite layer has considered as one layer and fractured aquifer is divided into four layers of equal thickness. Result shows that vertical variation of specific yield at watershed scale is decreasing with depth and lateral variation of specific yield is larger than vertical ones. These variations are suggesting that degree of weathering in fractured rock may vary within the same weathering profile. This method provides the specific yield value at 3-dimensions that can be used in groundwater modelling and it may helpful to improve the groundwater flow model outputs. Groundwater storage mapping is also discussed which may help in groundwater resource management and strategies.

ANNI TALWANI MEMORIAL GRANT FOR WOMEN RESEARCHERS

ESTIMATION OF GAS HYDRATES FROM VELOCITY MODELING AT THE SITE NGHP-02-19, KRISHNA GODAVARI BASIN, EASTERN INDIAN MARGIN.

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The estimation of gas hydrate saturation is carried out at the Site NGHP-02-19 of Krishna Godavari Basin, eastern margin of India using velocity modeling by considering both isotropic and anisotropic nature of gas hydrate bearing sediments (GHBS). When gas hydrates occur in the secondary porosity, the sediments show anisotropic character. For accurate estimation of gas hydrates, anisotropy needs to be incorporated. We have utilized both the P-wave and S-wave velocities. The simplified three phase Biot equation (STPBE) has employed for isotropic study and the transverse isotropic theory for laminated media for anisotropic study. The purpose of this work is to investigate whether the gas hydrate saturation at this site is best predicted by isotropic or anisotropic modeling. The result shows that a combination of both isotropic and anisotropic character with vertical/sub vertical fractures is required at the lower part. The anisotropic character is much more pronounced by S-wave velocity than the P-wave velocity.

INFLUENCE OF THE HOOGHLY ESTUARY ON THE COASTAL ACIDIFICATION IN THE NORTHERN BAY OF BENGAL.

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The increased emission of anthropogenic carbon dioxide to the atmosphere have effects on both the coastal ocean and the open ocean but the variability and the extent of the effect is different on both. Dissolved Inorganic Carbon (DIC), Total Alkalinity (TAlk), Dissolved Oxygen (DO), Water Temperature, Salinity and pH were measured in four different stations of the Hooghly estuary during three seasons of monsoon, pre-monsoon and post-monsoon to understand the carbonate chemistry and to examine the associated impact on coastal acidification. The predominant carbonate species of inorganic carbonate system is bicarbonate and its concentration decreases from inner to outer estuary during all the seasons. The net annual residual flux out of the estuary is 1123.79×10^{9} $mmolday^{-1}$ for DIC and 1211.92×10^{9} $mmolday^{-1}$ for TAlk. The distinct difference has been observed in pH of the coastal Bay of Bengal which is in the range of 8.1 to 8.3 compared to normal sea-water pH of 8.1 to 8.2. There is an increase of 3.7 % of the pH which can be mainly attributed to the river discharge which brings in large amount of alkaline waters to the coastalwaters.

Introduction:

The riverine export of Dissolved inorganic carbon (DIC) and total alkalinity (TAlk) plays an important role in the response of adjacent estuarine and coastal ecosystem to ocean acidification. The features which are predicted for the open ocean acidification in most of the cases is not applicable to the coastal ecosystem (Hendriks et al.,2010 a,b ; Kelly and Hofmann et al., 2012) as coastal ecosystem is affected by many factors like freshwater discharge , agricultural runoff and groundwater discharge .Our study mainly focusses on the study of carbonate chemistry of Hooghly estuary , fluvial and estuarine flux of inorganic carbon from river to estuary and estuary to ocean using modelling and estimate the pH change due to flux from Hooghly estuary.

Data Analysis:

The samples were collected from the Hooghly estuary ,Sundarban area ,north-east coast of Bay of Bengal . The estuary was divided into four zones and samples were collected in the mid of each month from the stations Diamond Harbour, Haldia, Tip of the Sagar Island and Hugli River mouth (bottom of the Sagar Island).Surface salinity and temperature were measured using a Multikit (WTW Multi 340 i Set; Merck, Germany) fitted with the probe WTW Tetracon 325. The precision of salinity and temperature was 0.1 and 0.1 ^{o}C respectively. DO was measured by using a probe (Mettler Toledo Five Go DO Meter) and verified by Winkler's titrimetric method (analytical precision 0.07%). pH was measured using the Orion PerpHecT ROSS Combination pH Micro Electrode fitted with a pH meter (data logger) [Thermo Scientific, U.S.A.] having a precision of 0.001. TAlk was determined by using an automated titrator (905 Titrando, Metrohm, Switzerland). DIC were computed from TAlk and pH using the software CO_2SYS.EXE (Lewis and Wallace et al., 1998). The dissociation constants K_1 and K_2 are used according to (Peng et al., 1987) on the NBS scale.

Methodology:

LOICZ- Biogeochemical Modelling (Gordon et al.,1996), was applied to the estuary according to the guidelines and the surface area and volume of the three boxes were taken from (Mukhopadhyay et al., 2006). The estuary was divided into three boxes based on the salinity of the sample collected from different stations (H1, H2, H3 and H4). The amount of rainfall in each boxes was calculated using gridded rainfall data from , New High Spatial Resolution (0.25×0.25) Long Period (1901-2015) Daily Gridded Rainfall Data Set Over India (Pai et al.,2014). The amount of water lost due to evaporation from the water surface was calculated using rate of evaporation multiplied by surface area of water body. The rate of evaporation data was taken from a report of Central Water Commission (Evaporation Control in Reservoirs,2006, Central Water Commission, Government of India).

Results and Discussions:

The percentage of saturation of DO is 91%, 78 % and 87% respectively for the pre-monsoon, monsoon and post-monsoon respectively. The coastal sea is almost saturated with DO during pre-monsoon and post – monsoon. The DIC/TAlk ratio in the freshwater zone is greater than saline zone which suggest a more dissolved CO_2 concentration from soil organic matter respiration. The non-conservative flux of TAlk within the estuary is -371.67×10^9 mmol/day, -243.17×10^9 mmol/day and -150×10^9 mmol/day during monsoon, pre-monsoon and post-monsoon respectively. The non-conservative flux of DIC within the estuary is -420.50×10^9 mmolday^{-1}, -225.10×10^9 mmolday^{-1} and -157.12×10^9 mmolday^{-1} during monsoon, pre-monsoon and post-monsoon respectively. The percent

of removal of DIC is 44%, 41% and 33% during the monsoon, pre-monsoon and post-monsoon and for TAlk is 40% ,43% and 32 % during the monsoon, pre-monsoon and post-monsoon season.

Conclusions:

The pH of the estuary remains almost alkaline throughout the mixing zone to the oceanic end-member in all the seasons but in the monsoon the pH slightly decreases from the normal sea-water and estuarine pH. This may be due to the decrease in concentration of DIC and TAlk. The mid estuary acts as source of DIC and TAlk for all the seasons but the inner and outer estuary acts as a sink. The DIC /TAlk ratio is more than 1 during low salinity and low pH at the inner end of the estuary and decreases to 0.95 at the estuary mouth. the increased carbonate concentration during pre-monsoon and post-monsoon suggests that the estuary have a good buffering capacity due to increased DIC and TAlk which help in counteracting the decrease of pH in the coastal sea and maintaining the standard pH during the pre-monsoon and post-monsoon .

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POROELASTIC MODELLING OF STRESS MAGNITUDE IN TECTONICALLY ACTIVE UPPER ASSAM BASIN

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Introduction

The Upper Assam basin is a young tectonically active belt, rich in hydrocarbon resources where wellbore stability is a major issue in regards to exploration and production. Of its various tectonic regions, the Assam Shelf lies between the main boundary thrust (MBT) and Naga Thrust area and is comparatively free from thrust tectonics depicting normal faulting reaching down to basement. One of the wells, M1 is located at here while the second well J1 is located in the thrust faulted region in the Naga-Schuppen belt. Figure 1(a) marks out the well locations along with the major thrust systems at work.

Here, pore pressure (PP), vertical stress magnitude (Sv) and minimum and maximum horizontal stress magnitudes (S_h and $S_H$respectively) have been estimated from these two wells taking into consideration the effect of strain that comes into play. M1 penetrates geological formations from top Alluvial through Dhekiajuli, Girujan, Tipam, Barail, Kopili, Sylhet and Langpur to the granitic basement while J1 in thrusted zone crosses through GirujanSuprathrust, TipamSuprathrust, BarailSuprathrust to reach Naga Thrust.

Theory

Pore pressure is calculated using Eaton's sonic equation which takes into account vertical stress (S_v), hydrostatic stress (P_h) and normalized transit time (Δtn) derived from normal compaction trend through shale points.

The formula given by Eaton (1972)

$$PP = S_v - (S_v - P_h) * (\Delta tn / \Delta t)^x \quad (1)$$

where $S_V = \int_0^z \rho(z) g dz$

ρ=density

z=depth

g=gravity

P_h =10MPa/km

Δt = sonic transit time

x = Eaton's exponent

Estimated PP is noticed to match closely with Eaton's exponent 1 when calibrated with Modular Dynamic Tester (MDT) data.

Linear poroelastic model considers horizontal strain in two Cartesian directions which is then incorporated to determine the maximum and minimum horizontal stress is obtained by solving the following linear poroelastic equations simultaneously for Upper Assam basin (Al-Qahtani et al. 2001):

$$S_h' = \frac{\nu_s}{1-\nu_s}(S_V - PP) + PP + \frac{\nu_s Y_s}{1-\nu_s^2}\varepsilon_x + \frac{Y_s}{1-\nu_s^2}\varepsilon_y \quad (2)$$

$$S_H' = \frac{\nu_s}{1-\nu_s}(S_V - PP) + PP + \frac{\nu_s Y_s}{1-\nu_s^2}\varepsilon_y + \frac{Y_s}{1-\nu_s^2}\varepsilon_x \quad (3)$$

Where, ε_x and ε_y are the horizontal strain in x and y directions. S_h' and S_H' are the measured minimum and maximum horizontal stress obtained from LOT and breakout (BO) data. Y_S is the static Young's modulus and υ_S is the Poisson's ratio calculated from core reports and conventional well data. Table 1 gives the strain values on solving the above equations simultaneously. These strain values are further incorporated in the equations 2 and 3 to determine the horizontal stress values for the whole wells. The resultant stress magnitude profiles have been plotted in figure 1(b and c) along with pore pressure with an Eaton's exponent of 1, hydrostatic pressure, vertical stress for comparative study and mud weight, leak off test and break out derive maximum horizontal stress for calibration. As observed, calculated stress values match well with the known hydrofrac data (LOT and BO derived maximum horizontal stress.)

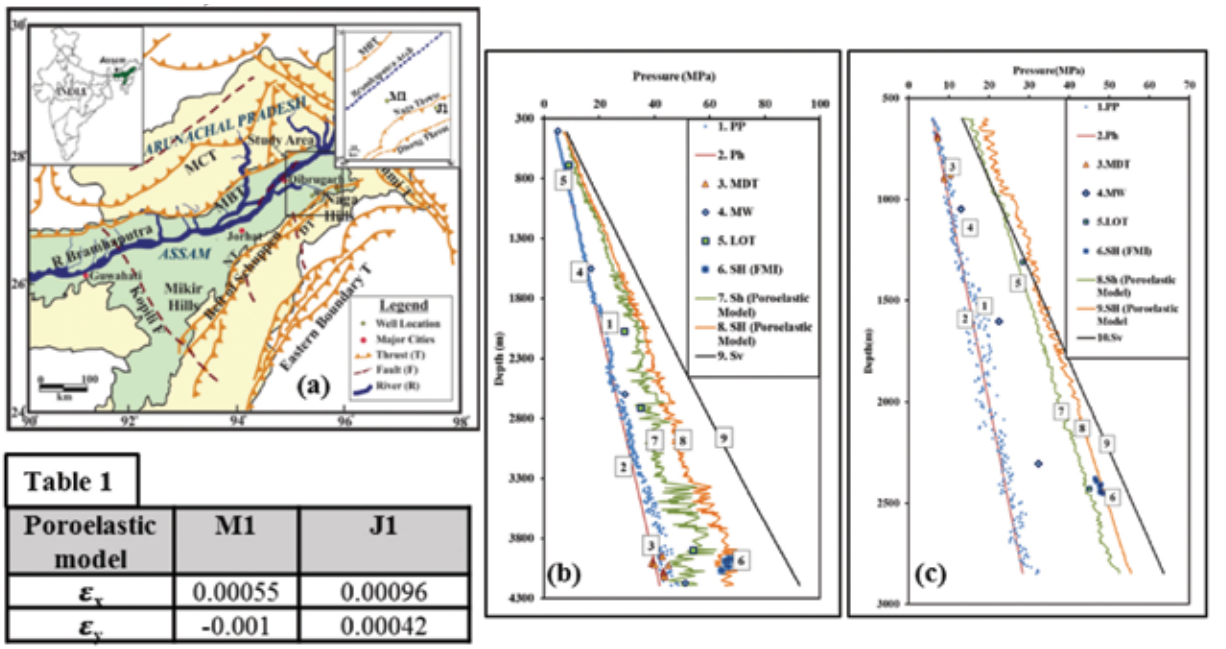

Table 1

Poroelastic model	M1	J1
ε_x	0.00055	0.00096
ε_y	-0.001	0.00042

Figure 1: (a)*Tectonic setting of North-East India along with inset of well locations; Comparativeprofiles of hydrostatic pressure (P_h), Pore pressure(PP), Modular Dynamic Tester (MDT) data, mud weight(MW), leak-off test (LOT), break out derived maximum horizontal stress (S_H(FMI)), minimum and maximum stress from poroelastic model (S_h and S_H) and vertical stress (S_v) in* ***(b)*** *M1 and* ***(c)*** *J1.*

Table 1*: Biaxial strain values for both wells*

Results

From the poroelastic model we observe the average S_h/S_V varies from 0.84 to 0.98 and from 0.68 to 0.78 in J1 and M1 region respectively. And average S_H/S_V varies from 0.92 to 1.09 and from 0.76 to

0.84 in thrust and normal faulted region respectively. As it is known from Anderson's faulting theory (1951) that normal faulting region shows $S_v \geq S_H \geq S_h$ while a thrust faulting region shows $S_H \geq S_v \geq S_h$ and the estimated horizontal stress magnitude follows this trend. The north-eastern part of India is one of the oldest producing basins of India. Its complicated tectonic setting calls for a deeper understanding of the stress regimes for better designing of exploration and production techniques. From this study we can conclude that the poroelastic model is a good tool to for study of the stress profiles in the Upper Assam basin.

Acknowledgment

Oil India Limited, Duliajan is acknowledged for providing with data. Ministry of Earth Science is acknowledged for funding the project (MoES(11)/2015-16/456/AGP).

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STRUCTURAL AFFILIATION BETWEEN BASEMENT ROCKS AND KALADGI BASIN SEDIMENTS, INDIA: INFERENCES FROM THE GRAVITY ANOMALIES

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Multiple phases of magmatic activity gave rise to the complex tectonic set ups, granitic intrusions and sedimentary basins in the Indian Peninsular region during pre-Cambrian era. Several intra-cratonic Proterozoic sedimentary basins viz., Kaladgi, Bhima, Cuddappah, Vindhyan basins have also formed in the Indian Peninsular region during its tectonic evolution beginning from the Archean era. Kaladgi basin is an almost E-W trending intra-cratonic Proterozoic basin located at the southern fringe of the Deccan volcanic province (DVP) over the northern margin of the Archean Western Dharwar Craton (WDC). The Closepet granite intrusion of palaeo-Proterozoic age is regarded as one of the pre Cambrian suite of rock assemblage in the Dharwar Craton along with Peninsular Gneiss, Greenstone schists etc. The geology of the Kaladgi basin is very complex with exposures of Deccan traps, different phases of Peninsular Gneiss, Greenstones, Closepet Granite and proterozoic sediments. Detailed knowledge about the structural set up of sediments in these basins with their basement and granitic intrusions is of great importance in understanding the magmatic and sedimentation processes in cratonic regions. Knowledge about subsurface extensions of sediments beneath the Deccan traps and variations in the thickness is of another valuable geological importance. Very few geophysical studies are available to understand the structural control, magmatic relations and sedimentation processes in this Kaldgi basin. Hence an attempt has been made to interpret quantitatively the gravity anomalies over the Kaladgi basin for deciphering the structure and configuration of its basement, thickness and extension of sediments and possible subsurface granitic intrusion contacts. The interpretation reveals extension

of Proterozoic sediments beneath the Deccan traps towards north and west. This study also brought out a huge thickness of Closepet granite intrusion beneath the Proterozoic Kaladgi sediments. The gravity low anomaly observed over the Kaladgi basin now attributed to the combined effect of both Proterozoic sediments and Closepet granite intrusive rocks.

CHARACTERIZING THE NULL ANISOTROPY BENEATH TEZPUR, NORTHEAST INDIA

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Introduction

The north-eastern part of India possesses a very complex geodynamic history since late Cretaceous followed by two major tectonic events viz. northward movement and subsequent frontal collision of Indian plate with Eurasian plate that gave rise to Himalayan mountain belt and eastward oblique convergence with Burmese Silver which produced Indo-Burmese wedge (IBW). In between these two major mountain chains, seismically active intraplate rigid blocks namely Shillong plateau and Mikir Hills, separated by Kopili lineament, were originally a part of peninsular India but later moved eastward along E-W trending Dauki Fault (Evans, 1964). Northern boundary of these blocks is demarcated by Assam valley where the Archean crystalline basement is covered by Tertiary to recent sedimentation (Nandy, 2001). To unravel the deformation processes that ultimately gave rise to such complex tectonic network, Shear Wave Splitting (SWS) is so far the most popular method. It quantifies the seismic anisotropy of the mantle, developed mainly due to the lattice preferred orientation (LPO) of Olivine. Whenever the shear waves from local or teleseismic earthquake (beyond 20^{o}epicentral distance) encounter an anisotropic layer in its ray path, it undergo splitting into two originally polarized components (fast and slow) that are separated by a delay time (δt)(Savage, 1999). The vibration direction of fast component (Φ) is orientated along the direction of olivine a- axis. These two splitting parameters contain wealth of information in terms of orientation and strength of anisotropy (Silver and Chan, 1988).Recent studies of Singh et al., 2007; Mandal, 2011, Roy et al. 2012a, b based on SKS/SKKS phase and documented complex anisotropic structure in the north-east Himalaya. The present study aims to characterize the null measurements in splitting analysis beneath Tezpur station (TZR), northeast India, on the basis of ray paths of core refracted PKS phases from a particular cluster of events pertaining to a particular back azimuthal range and deciphers the possible causes of these null measurements contrary to the published good anisotropic measurements using SKS/SKKS phases.

Data Analysis

The data used in the present study are obtained from a broadband seismic station, Tezpur (TZR) (26.37^{o}N, 92.46^{o}E) (Figure 1), situated in the low-lying basement ridge of Brahmaputra valley in Assam. The mean elevation of the station is 77 m.It is instituted by CSIR-NEIST Jorhat and is equipped with instrument RT-151-120B and digitizer REF TEK 130. The raw data with sample rate of 100 Hz is preprocessed by resampling it into 30 Hz to reduce the aliasing effect.

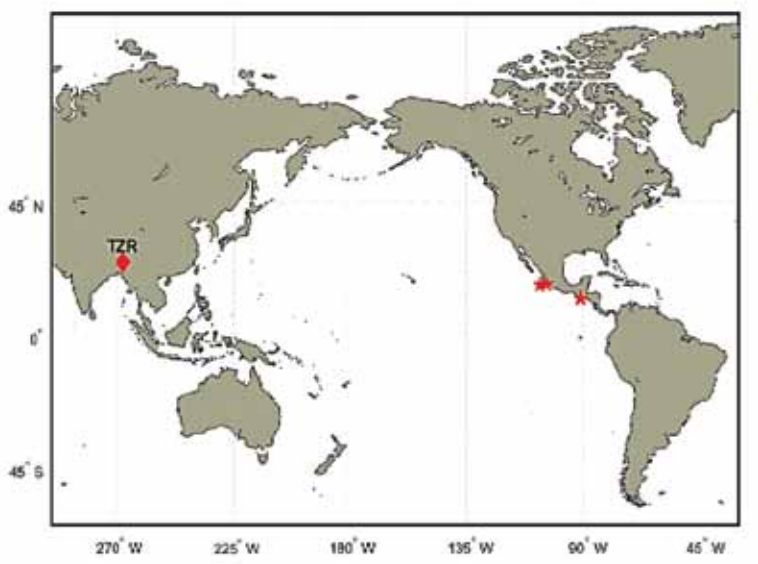

Figure 1. *The broadband seismic station (TZR) is marked by red cross and the epicenters of earthquakes are marked by red dots.*

Methodology

For the shear wave splitting analysis, we have chosen core-refracted PKS phase only. The cut-off magnitude for earthquakes from epicentral distance 120-180° is greater than 5.5. All the seismograms were band-pass filtered in the frequency range of 0.04–0.2 Hz to improve the SNR. The minimum SNR (Signal-to-noise ratio) considered here is 3. The best pair of splitting parameters- delay time (δt) and polarization angle (φ) are searched by using rotation correlation method (RC) (Bowman and Ando, 1987) and transverse component minimization method (SC) (Silver and Chan, 1991). The RC method maximize the cross-correlation between the corrected horizontal components; this is equivalent to the maximization of determinant of time-domain covariance matrix.On the other hand, the SC method is based on the principal that in absence of anisotropy, the particle motion of the shear wave would be linear. Hence, the method rotates and time-shifts the horizontal components appropriately so that the energy in the transverse component of seismogram becomes nullified and the initially elliptical particle motion corrected to linear one. Both these techniques use grid search parameters of Φ and δt with an increment of 1° and 1s respectively with half of the sampling rate to remove splitting effect. In grid search method, the seismogram is titled in Q-T plane to search the best pair of splitting parameters for which radial and transverse component have similar pattern and then calculate the minimized energy.The error with confidence level of 2σ is estimated for Φ and δt. Results havingan error of more than 0.6s in delay times or error larger than half of the original delay time along with ~25° polarization angle are discarded. For null measurement, the ratio of delay times obtained from RC and SC method ($\rho = \delta t_{RC}/\delta t_{SC}$) is $0 < \rho < 0.3$ (good null) and $0 < \rho < 0.5$ (fair null). The difference between fast axis of these two methods is $\Delta\varphi = (\Phi_{SC}-\Phi_{RC}) \sim n^{\star}\ 45^{o}$, where n is a positive or negative integer, $36^{o} < \varphi < 52^{o}$ (good null) and $32^{o} < \varphi < 58^{o}$ (fair null) (Wüstefeld and Bokelmann, 2007). Even the null events can be interpreted visually from the small energy present in the original transverse component of seismogram, elongation of energy contour in the direction of δt and φ within a range of 10-15° with initial polarization (Savage, 1999).

Results

During the shear wave splitting analysis, total 48 events were matched with the data and significant PKS phases were only produced for 21 events.Only those seismograms are retained where the PKS phases are prone and the picks are distinguishable. On the basis of SNR, good phases and results for anisotropic parameters, many seismograms are discarded and only a few qualified our objectives. Most of these results are Good Null. Total 3 Good Null and 1 Fair Null events are presented in the analyzed data (*Table 1*). The epicentral distance range for these events is 131-139° and backazimuth distribution is clustered into a single group ranging 5-25°. (*Figure 2*).

EQ Date	EQ Time	ED	BAZ	Intial pol.	Depth (km)	SNR	Φ_{RC}	Φ_{SC}	δt_{RC}	δt_{SC}	Q
21.01.2003 (021)	02:46	139.88°	4.9°	6.5°	24	13	37°±8	85°± 2	0.20± 0.05s	1.97± 0.50s	Good
22.01.2003	02:06	132.08°	21.3°	22.7°	24	23.7	43°±12	79°± 2	0.47± 0.16s	1.77± 0.24s	Good
09.11.2003	00:14	139.73°	5.5°	6.7°	33	7.2	44°± 9	4°± 3	0.03± 0.09s	1.67± 0.33s	Good
25.08.2003	23:24	131.39°	24.5°	24.4°	10	16.3	41°±13	80°± 4	0.20± 0.12s	1.03± 0.32s	Fair

Table 1: *Null measurement of shear wave splitting. EQ=Earthquake; ED=Epicentral Distance; BAZ= Backazimuth; Initial pol. = Initial Polarization; SNR= Signal-to-noise ratio; Q=Quality of the null results (i.e. Good/Fair).*

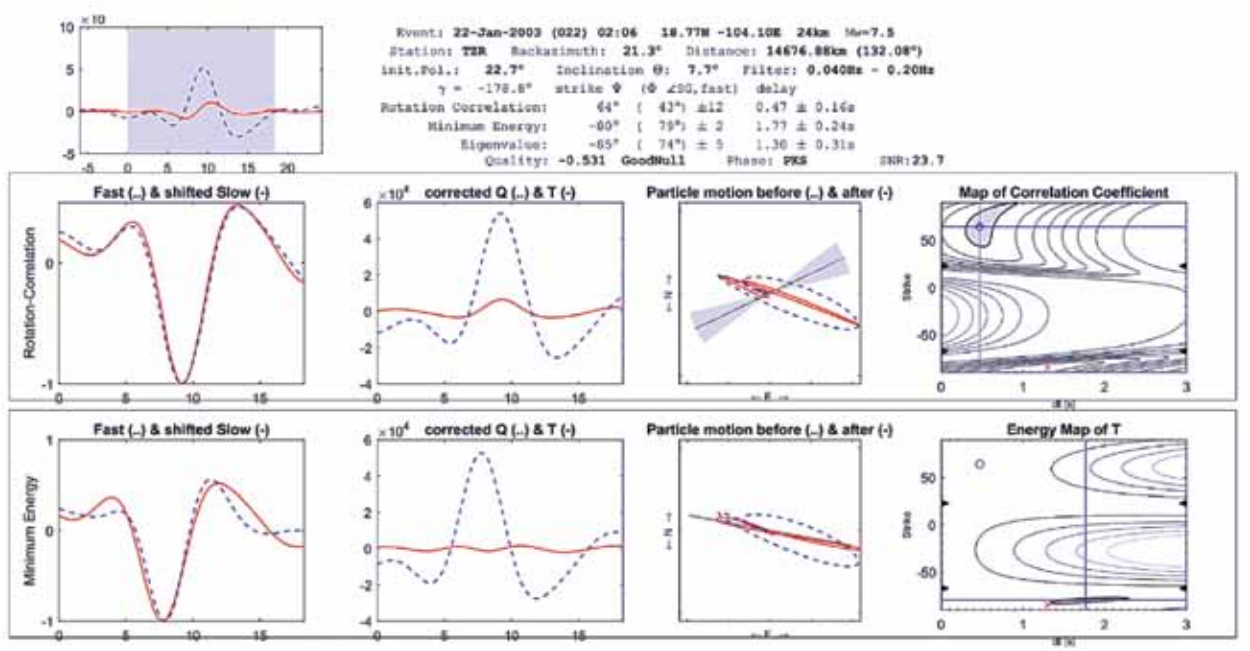

Figure 2*: Null result of TZR station for PKS phase, corresponding to the event on Jan 22, 2003. The top left panel shows radial (dashed blue line) and transverse (solid red line) components of the seismogram. Panels of middle row are indicative of Cross-correlation method (RC) results. Corrected fast and slow components (left), corrected radial and transverse component (middle) and initially elliptical part motion and corrected linearized particle motion (right) are shown in middle row. The same thing is done for Transverse component minimization method (SC) in the lower panel. Contour plots with 95% confidence are calculated to find out the best splitting parameters and are mentioned at the top.*

Discussion

In general Null results are recorded in three situations, (a) If the mantle beneath the station is isotropic in nature, (b) presence of vertically oriented lineation in the mantle or (c) due to the multi-layer anisotropic structure having mutually perpendicular symmetry axes and similar delay times in each layer. Already published results using SKS/SKKS phase (Singh et al., 2006) indicates that the mantle beneath the Tezpur station is anisotropic ($\varphi = 95^{o} \pm 8.0$; $\delta t = 0.9 \pm 0.3$s). So, the first possibility of isotropic mantle obtaining Null result holds no longer. Moreover if a media is devoid of any kind of anisotropy, it will produce Null results regardless of backazimuth. On the other hand, region containing strong anisotropy will show Nulls only for a small and distinct range of backazimuth(Wüstefeld and Bokelmann, 2007). In our case, Nulls correspond to earthquake events having backzimuth5-25^{o}. These null results may be attributed towards the presence of multiple layers of anisotropy which in deed nullifies the effects of each layer, suggesting a very heterogeneous or complex mantle beneath the station. As the nulls can be attributed towards an event azimuthal range of 5-25^{o}, the more over similarity in the initial polarization range of seismograms, can be attributed for this cause which doesn't allow to split the ray path coinciding with the same angle. Moreover, all the results from the same corner of backazimuth (5-25^{o}) produce the null anisotropic parameters, suggesting a dependence upon the ray paths from this particular direction of events contrary to good results from other range of backazimuthal distances.

Conclusion

Though the region shows a significant anisotropy in the upper mantle suggested from the previous study with the help of SKS/SKKS splitting, the null measurements at the same place can be attributed towards the possibility of multiple layers beneath the region. An approach towards a particular direction of ray paths from a particular back-azimuthal range of events or coincidence of event and initial polarization directions, cannot be ignored for the same purpose also. Though a straight forward cause for null anisotropy can't be argued beneath Tezpur, the above possibilities answer the so much null measurements beneath a significant anisotropic mantle.

Acknowledgment

The authors are thankful to the Geosciences and Technology Division (GSTD) of CSIR-NEIST Jorhat for the broadband seismic data to undertake the seismic experiment in north-eastern India. The Academy of Scientific and Innovative Research (AcSIR) and GSTD are also acknowledged for the constant support in the research work. Poulommi Mondal is thankful to the Department of Science and Technology for the Inspire Fellowship support.

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CONSTRAINTS ON THE VARIATIONS IN CRUSTAL STRUCTURE, SEGMENTATION AND SPREADING RATE ALONG THE CARLSBERG AND CENTRAL INDIAN RIDGES FROM SATELLITE-DERIVED GEOID AND GRAVITY DATA ANALYSIS

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The Central Indian Ridge (CIR) and the Carlsberg Ridge (CR) together forms one arm of the major spreading ridge system in the Indian Ocean. Seafloor spreading along these ridge systems had played an important role in the evolution of the western Indian Ocean. Both these ridges show considerable variation in the spreading rates and are characterized by diverse morpho-tectonic features and segmentation. Further, along the CIR, the interaction of the Reunion hotspot and the diffuse boundary zone in the Central Indian basin is not very well understood. In this study, satellite derived geoid and gravity data are used to understand the variations in crustal structure, segmentation and spreading rate along these ridges. Geoidslope analysis ofseveral transects across the ridge reveals asymmetry in the trend of residual geoid v/s age on both flanks suggesting thermal sources, possibly from the Reunion plume,causing the differential subsidence of oceanic lithosphere. Geoid-Topography ratio (GTR) analysis carriedout along overlapping blocks suggests shallow level compensation for both the ridges. However, the GTR values of the slow-spreading (12-13 mm/yr)CRare found to be distinctly higher (~1.3-1.6 m/km) compared to the GTR values of CIR (~0.95 m/km)which have intermediate spreading rates of 18-27 mm/yr. Using satellite gravity and topography data Mantle Bouguer Anomaly (MBA) and Residual Mantle Bouguer Anomaly (RMBA) over the area are calculated andanalyzed to understand crustal thickness variations and magmatic sources along the ridge systems. The MBA values on both flanks of the ridge are almost found symmetric about the ridge axis,

whereas this symmetry is almost lost in the case of RMBAdue to the thermal sources other than the ridge spreading affecting the cooling and thermal subsidence of the lithosphere. Further,variations in crustal thickness estimated by downward continuation of RMBA along the ridges and its tectonic implications are also discussed.

SEISMIC VELOCITY MODEL BUILDING IN UPPER ASSAM BASIN, INDIA: AN AID TO RESERVOIR CHARACTERIZATION STUDY

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Introduction

A successful reservoir characterization mainly includes derivation of rock properties from the seismic data and relates them to reservoir properties and mapping their distribution. Model–based seismic inversion has been carried out to understand various rock properties from the 2D post-stack seismic section. Porosity, volume of shale (Vsh) and water saturation (Sw) has been evaluated for reservoirs of Upper Assam basin, located in north-eastern India from well log and seismic data. MLFN modeling is now being used frequently for quantitative analysis of reservoir properties. One of the advantages of using the artificial neural network algorithm is related to its fast speed and small errors in determining the nonlinear relationships between the input data and the target property (Das and Chatterjee, 2018 and Singha et al., 2014). MLFN analysis is carried out to establish a nonlinear relationship between the seismic attributes and reservoir property at well locations provided an improved correlation between the predicted and the actual logs and then implemented for mapping of Vsh and Sw in Upper Assam reservoirs.

For modeling and developing a subsurface reservoir, integration of seismic data measured in time units with well data measured in depth units is the key tool. Therefore, creating a good velocity model that converts seismic data from the time domain to the depth domain provides an effective means to integrate data from the two domains. Also geological and reservoir modeling studies are inherently in depth, so by transforming seismic interpretations from time to depth, it enable the integration of the seismic asset with geologic, petrophysical and production data (Etris et al., 2002). Time-depth relationship is obtained tying two wells with the post-stack seismic section for creation of velocity model.

The main objective of this study is to develop two MLFN models for mapping of Vsh and Sw distribution using acoustic impedance (AI), shear impedance (SI), porosity ($\varnothing$) and density (ρ) as inputs derived from post-stack seismic data. Then these properties are converted to its depth domain using the generated velocity model of Upper Assam.

Methodology

Well log responses namely; gamma ray, resistivity, density and neutron porosity logs are used to delineate shaly sand reservoirs under the study area. Log data from three wells: M1, M2, M3 and the 2D post-stack seismic section (Figure 1a) are used for estimation of petrophysical parameters in TS and BAS reservoirs. The methodology for development of MLFN models involves log derived parameters Vsh and Sw as desired outputs whereas AI, SI, density and porosity sections as input parameters (Gogogi and Chatterjee, 2018).The SI and density sections are generated by mathematical transformation from inverted AI section. Amongst the three wells, M2 and M3 are used as training wells, whereas well M1is kept to validate the model predicted results.

The depth map of the seismic line has been created using well tie with M1 and M2 wells of Upper Assam. An accurate and reliable depth conversion is one that ties the existing wells and accurately predicts depths at new locations (Pandey et al., 2013). The instantaneous velocity as a linear function of depth can be described as: V(z) = V0 + kZ, where V(z) is the instantaneous velocity at depth Z, and V0 and k are the intercept and slope of the line.

As an approach to depth conversion, a velocity model is built here using picked horizons, p-wave velocities, and time-depth relation. Velocity values vary between 2500-4000 m/s (Figure 2). The generated model is well matched with the output interval velocity from well log data at well M1 and M2 (Figure 2c). Having the available formation tops of well M1, the depth matching at each well location was performed as a validation of the method. Validation away from well location is also done by seeing the preservation of pattern of major structures between different well locations in both time and depth maps.The velocity model can be used to convert any elements within its spatial domain from time to depth in the vertical axis. The seismic data and the interpreted elements such as horizons and faults are converted to depth using the velocity model. Seismic inversion results such as AI, porosity, Vsh and Sw previously performed in the time domain are converted to depth domain using the velocity model.

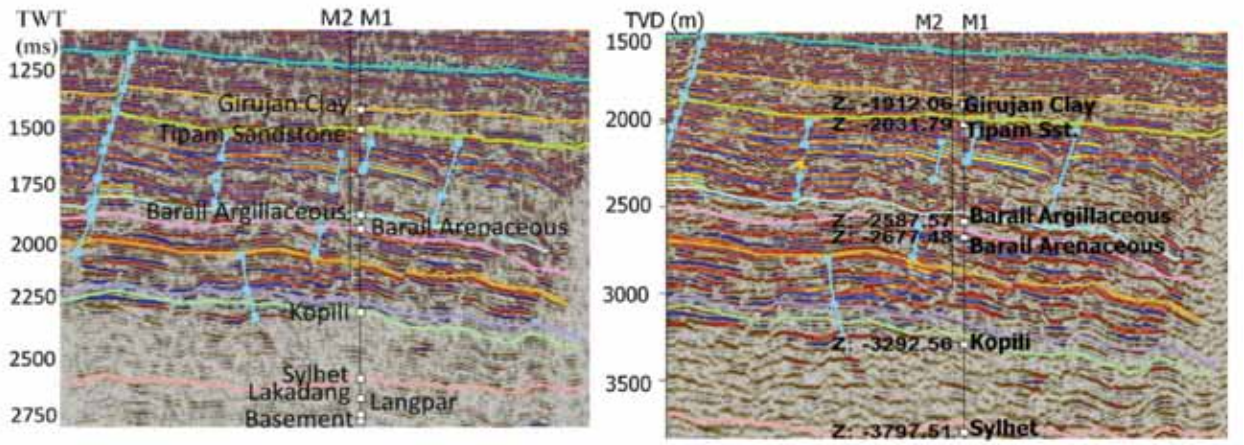

Figure 1: (a) 2D post-stack seismic section of Upper Assam basin in time domain along with the formation tops of well M1 and M2 and (b) Depth converted interpreted Seismic section with the formation tops in depth

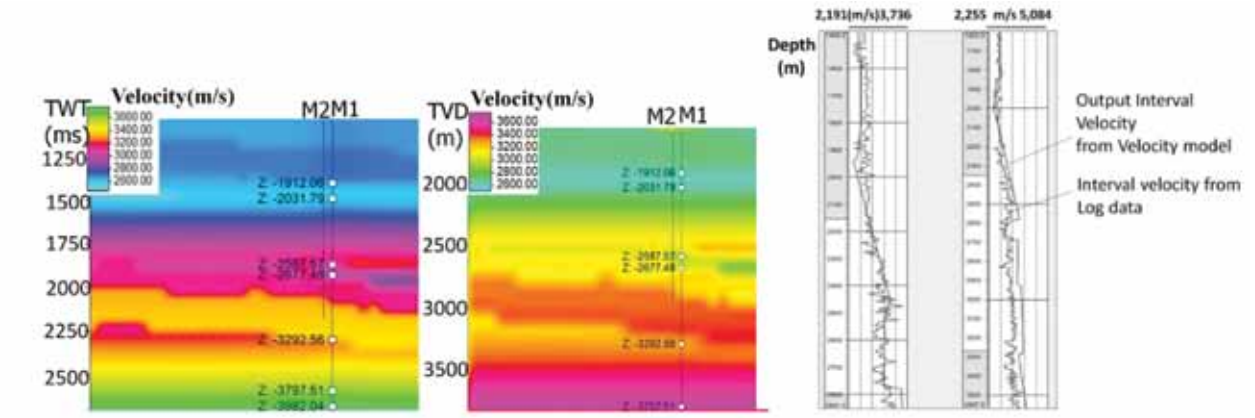

Figure 2: Generated Velocity model in (a) Time domain, (b) Depth domain with the available formation tops displayed in depth and (c) Output of velocity model shows reasonable match with the interval velocity from well data at location of well M1 and M2.

Results and Conclusions

The MLFN predicted Vsh and Sw shows strong correlation with the log derived values, both at training and validation well locations. We are also able to generate porosity, Vsh and Sw variations with depth in the seismic section. TS and BAS reservoirs are identified at depth intervals 2050-2185m and 2695-2740m respectively. The estimated average porosity in TS and BAS reservoir varies from 30% to 36% and 18% to 30% respectively. The Vsh and Sw varies from 10% to 30% and 20% to 60% in TS reservoir and 28% to 30% and 23% to 55% in BAS reservoir respectively. These are the main producing reservoirs in Upper Assam basin. This formation serves as a good shaly sand reservoir in this study area. Seismic images recorded in time are not enough for an exploration or field development interpretation. Good well ties and reliable depth conversion are also required for a better picture. A velocity model is necessary to obtain a depth image of the earth subsurface. It is developed here integrating all the available geological and velocity information from well and seismic data.

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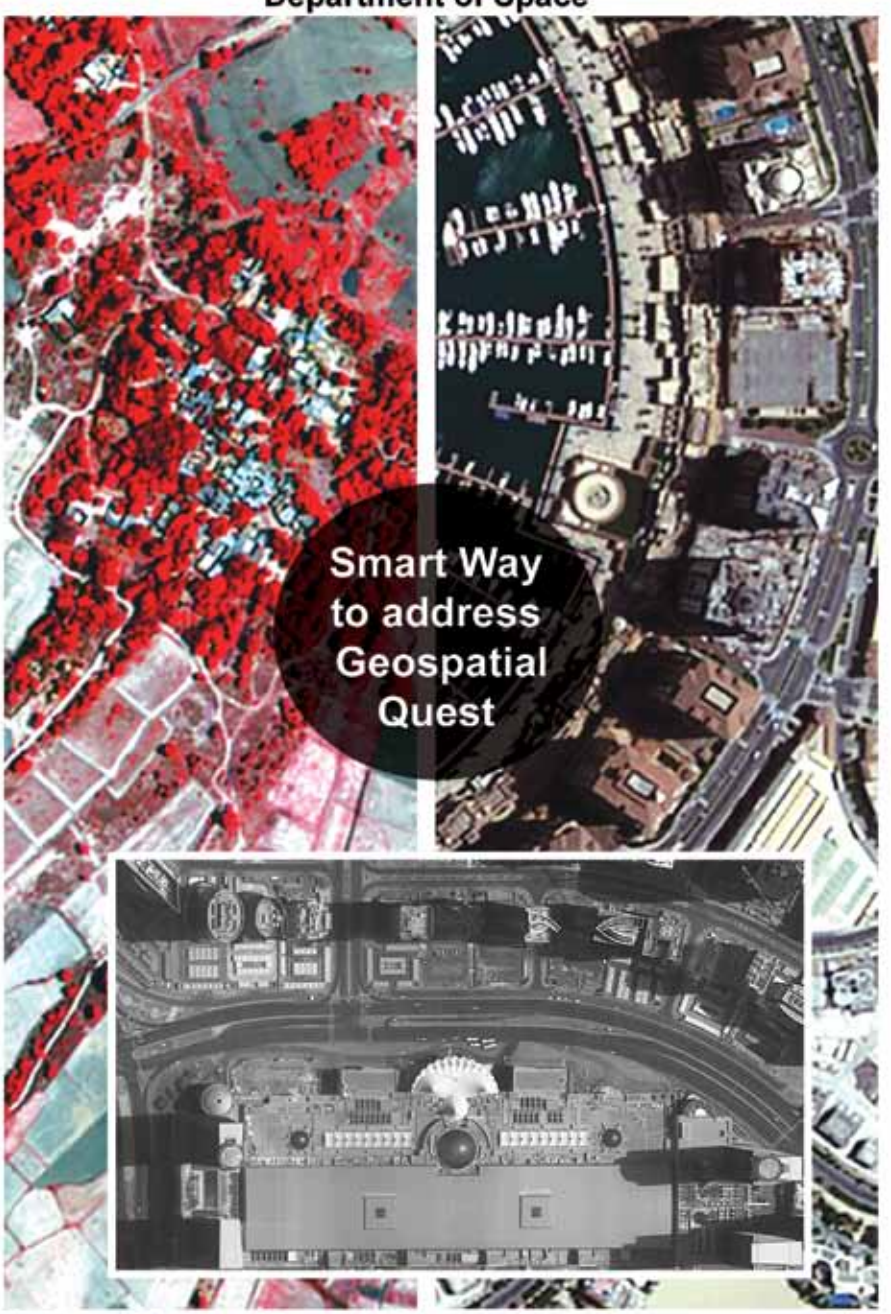

Smart Way to address Geospatial Quest

National Remote Sensing Centre
Hyderabad, India

www.nrsc.gov.in
www.bhuvan.nrsc.gov.in
data@nrsc.gov.in

National level nodal agency for acquiring and distributing satellite data

Supporting specific user demands and disaster management through aerial acquisition

Bhuvan for Open Data & Value Added Products for users

NRSC Outreach Facility

सीएसआईआर - केन्द्रीय खनन एवं ईंधन अनुसंधान संस्थान, धनबाद

(विज्ञान एवं प्रोद्योगिकी मंत्रालय, भारत सरकार, नई दिल्ली के अंतर्गत सीएसआईआर की एक अंगीभूत प्रयोगशाला)

CSIR-CIMFR has been formed after integrating the core competencies of erstwhile Central Mining Research Institute (CMRI) and Central Fuel Research Institute (CFRI) both at Dhanbad with the Vision "to be an internationally acclaimed mining and fuel research organisation

Controlled Demolition of Railway Over Bridge by Rock Excavation Group, CSIR-CIMFR, Dhanbad

Major Contributions of CSIR-CIMFR are:

- Development of Safe Methods and Assessment of stability of Mine Workings
- Design of Stowing Systems for Stabilization of Mine Workings
- Design of Safe Blasting Patterns of Mines
- Assessment of Subsidence and Ground Movement due to Mining
- Design of Environmental Management Plan for Eco-Friendly Mining and Coal Based Industries
- Investigations on Methane Emission due to Mining and GHG Inventories

- Resource Evaluation and Reservoir Modeling
- of Coal bed Methane
- Evolution of Methods to Control Mine Fire
- Design of Support Systems for Mines
- Design & Development of Equipment, Instruments and Components for Safe Mining
- Coal Quality Assessment
- Basic Studies on Coal Science
- Coal Preparation
- Coal Carbonization
- Coal Liquefaction – Direct and Indirect routes
- Coal Gasification
- Coal Combustion
- Non Fuel Uses of Coal/ Value Added Chemicals
- Fly Ash Utilization

Coal-to-Liquid (CTL) Pilot Plant Designed and Developed by CSIR-CIMFR

Controlled Blasting at Navi Mumbai International Airport Project Site

CSIR-CIMFR also extends testing, evaluation, calibration and consultancy services for explosives and accessories, mine ventilation and safety equipment, roof supports, personnel protection equipment, flameproof and intrinsically safe equipment, electrical cables, mining and allied industrial components, wire ropes, cage and suspension gear components, aerial ropeways, etc., for their safe use. All facilities for conventional & instrumental analysis of coal & coke, coal washing pilot plant, pilot coke oven by electrical heating & non-recovery type, XRF, XRD, FTIR, FETR, DTF, TGA, Surface Area Analyser, Porosimeter, coal water emulsion, GTL, PTGA-MS, HPLC, CPT, IPT, etc. EIA & monitoring of Air, water, noise & soil pollution, GC, Particle size analyzer, washability investigations on coals for cleaning potentialities, various laboratory Tests on coal preparation, Coal washing Pilot plant for coarse and Fine Coal Beneficiation.

For Further Information Please Contact:

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Director

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Phone : 91-326-2296023/ 2296006/ 2381111

Fax : 91-326-2296025/2381113

E-mail : director@cimfr.nic.in/ drpksingh@cimfr.nic.in

CSIR - National Institute of Oceanography

(a constituent laboratory of the Council of Scientific & Industrial Research)

Established in 1966, CSIR - National Institute of Oceanography (NIO) is a premier oceanographic research organisation in the Indian Ocean region. This distinction has been gained over almost five decades of experience on the seas - as far south as the Antarctica, east as Australia and west as the Caribbean.

Mission : *"to continuously improve our understanding of the seas around us and to translate this knowledge to benefit all"*

Research Themes

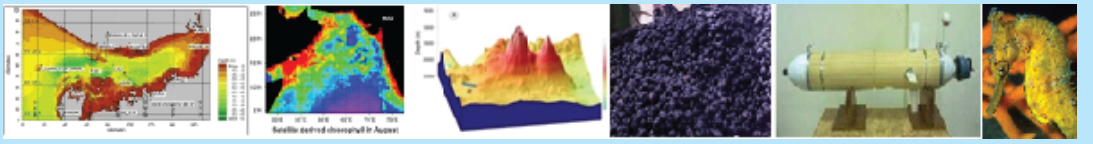
- Ocean processes
- Marine biodiversity
- Marine ecology
- Marine biotechnology
- Human imprint on Aquatic environment
- Marine minerals
- Energy from the ocean
- Seafloor tectonism
- Reconstructing the past
- Marine instrumentation
- Marine archaeology

Services Offered

- Studies related to coastal zone management
- Delineation of Coastal Regulation Zone
- Environmental impact assessment and monitoring
- Numerical modelling of meteorological and oceanographic data
- Oil spill prediction and risk analysis
- Oceanographic design parameters for marine facilities
- Underwater inspection and videography

Infrastructure

- Three Regional Centres
  - Mumbai, Kochi, Visakhapatnam
- 500+ scientific & technical staff
- State of the art analytical facilities
- National Information Centre for Marine Sciences (Library)
- National Oceanographic Data Centre
- AcSIR School of Oceanography
- Research Vessels
  - RV *Sindhu Sankalp*
  - RV *Sindhu Sadhana*



Environment | Processes | Tectonics | Resources | Instrumentation | Biotechnology

CSIR - National Institute of Oceanography

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Phone : 91(0)832-2450 450 Fax : 91(0)832-2450 602/03
e-mail : ocean@nio.org / director@nio.org
URL : http://www.nio.org

CSIR-NIO

Regional centres

- **Mumbai**
  Phones : 022-26359605 (4 lines)
  Fax : 022-26364627
  e-mail : chaubey@nio.org
- **Kochi**
  Phones : 0484-2390814 (7 lines)
  Fax : 0484-2390618
  e-mail : pankaj@nio.org
- **Visakhapatnam**
  Phones : 0891-2784569, 2539180
  Fax : 0891-2543595
  e-mail : vsnmurty@nio.org

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

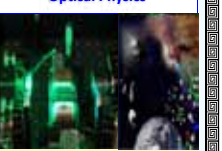
(अंतरिक्ष विभाग, भारत सरकार)

Physical Research Laboratory, Ahmedabad

(Department of Space, Government of India)

Known as the ‘cradle’ of Space Sciences in India, the Physical Research Laboratory (PRL) was founded in 1947 by Dr. Vikram A. Sarabhai.

As a unit of Department of Space, Government of India, PRL carries out fundamental research in selected areas of Theoretical Physics, Space & Atmospheric Sciences, Astronomy, Astrophysics, Solar Physics, Planetary & Geo-Sciences, Atomic, Molecular & Optical Physics and Astrochemistry.

Astronomy & Astrophysics	Solar Physics	Geosciences	Planetary Sciences	Theoretical Physics	Space & Atmospheric Sciences	Atomic, Molecular & Optical Physics
						

National Centre for Earth Science Studies

Ministry of Earth Sciences, Government of India

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 - 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

PB No. 7250, Akkulam, Thiruvananthapuram-695011, India
पि.बि.नं 7250 आक्कुलम, तिरुवनन्तपुरम - 695011, भारत
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फैक्स/FAX +91-471-2442280 ई-मेल/E-MAIL adm.ncess@nic.in
वेबसाइट/WEBSITE www.ncess.gov.in

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

CSIR-National Geophysical Research Institute

(Council of Scientific & Industrial Research Institute)

CSIR

NGRI

Established in the year 1961, the CSIR-National Geophysical Research Institute (CSIR-NGRI), Hyderabad is a premier earth science research institute of the Council of Scientific & Industrial Research (CSIR) under the Ministry of Science & Technology, Government of India. As per its mandate, the institute has been carrying out innovative basic and applied research encompassing the broad disciplines of Geology, Geophysics, Geochemistry & Geochronology. Its multidisciplinary earth science research programs are in tune with the mission of the CSIR and frontier global challenges.

Our Core R&D Strengths:

- Exploration of Hydrocarbons, Minerals and Groundwater
- Seismology, Earthquake Hazard Assessment & Earthquake Processes
- Understanding the Structure, Dynamics & Evolution of the Indian Lithosphere

Our aim is to:

- Develop new and novel technologies for exploration as well as harnessing of natural resources (hydrocarbons, minerals and groundwater), often in complex and challenging geological settings
- Provide a realistic assessment of natural hazards like earthquakes to the Indian society
- Provide comprehensive understanding of shallow and deep earth processes
- Assess the anthropogenic and geogenic pollution, management and control strategies, especially with regard to potable water and environmental safety

Unique Services and Facilities for:

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

Towards Water Security:

- Groundwater Exploration for Potable Water at ~ thousand problematic areas across the country
- Leadership Role in Ground and Heli-borne Geophysical Surveys for Water and Mineral Exploration

Towards Energy Security:

- Delineated thick Mesozoic sediments hidden underneath Deccan Volcanics in Saurashtra and Kutch regions leading to new oil and gas targets
- Quantitative estimate of methane in the form of gas-hydrates and free-gas for Indian offshore regions
- Undertaken R & D program for exploration of coal, coal-bed methane (CBM) and uranium
- Exploration for geothermal energy at Tapoban and Tattapani power generation under NGRI-NTPC collaboration

Earthquake Monitoring and Hazard Assessment:

- Real time monitoring of earthquakes in High Risk Areas through networks of broadband seismological stations leading to lowering the thresholds in detection
- Earthquake hazard assessment of major cities in seismic zone 4 and 5 and for strategic installations such as nuclear power stations and dams
- Active participation in the MoES initiative of Deep Drilling Program (upto 7 km) into the Koyna-Warna Earthquake Hypocentral Zone for understanding basic reservoir triggered seismicity

Understanding the Geodynamics & Evolution of Indian Lithosphere:

- Active and passive seismology for structure of the Indian lithosphere, Simulation of Core & Mantle Dyanmics, Mathematical Modeling
- Ground, Airborne and Satellite based Earth Observations for assessment of tectonic displacements along major deep faults
- Reconstruction of Lithospheric Evolution through Paleomagnetic, Geochronology, Stable and Radiogenic Isotope Geochemistry

For more information please contact:

Director
CSIR-National Geophysical Research Institute
Uppal Road, Hyderabad – 500 007
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e-mail: director@ngri.res.in ; Website: www.ngri.org.in

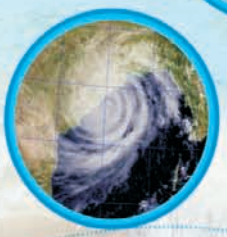
INCOIS ESSO - Indian National Centre for Ocean Information Services

ESSO-Indian National Centre for Ocean Information Services (ESSO-INCOIS) is an autonomous body under the Earth System Sciences Organization (ESSO), Ministry of Earth Sciences, Govt. of India. The Centre provides special advisory services and ocean data products for society, industry, the government and scientific community through sustained ocean observations and modelling, constantly improved with systematic and focused research.

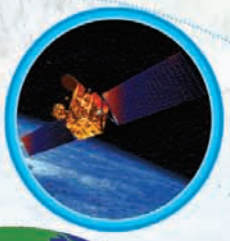
Key Activities

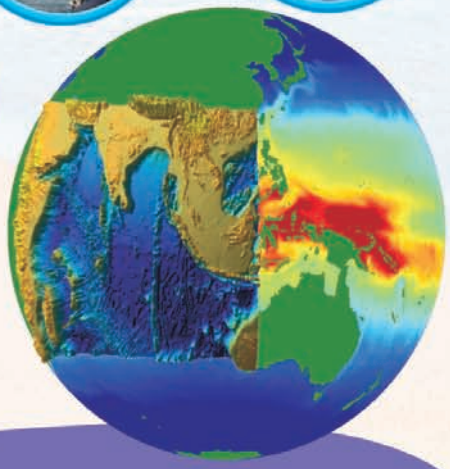
- Early Warning for Tsunamis & Storm Surges
- Potential Fishing Zone Advisories for Fishermen
- Ocean State Forecasts for Fisherfolk, the Navy, Coast Guard, Shipping and Offshore Industries
- Search and Rescue Tool, Oil Spill Advisory
- Mobile Apps and Web-based Ocean Information Services
- Satellite Coastal and Oceanographic Research
- National and Regional Data Centre
- Coastal Geospatial Applications
- Ocean Observation System
- Ocean Modelling
- International Training Centre for Operational Oceanography









ESSO-Indian National Centre for Ocean Information Services
(Earth System Sciences Organisation, Ministry of Earth Sciences)
Ocean Valley, Pragathi Nagar (BO), Nizampet (SO), Hyderabad - 500 090

Phone:91-(040)-23886000, Fax:91-(040)-23895001
Email: director@incois.gov.in
www.incois.gov.in

CSIR-NEERI

The Leader in Environmental Science & Engineering

- Providing solutions to environmental problems through Science & Technology
- Technology transfer in the interest of industry and society

The goals of CSIR-NEERI

- Global scientific impact
- Innovation-driven industry
- Socio-economic development

Current R&D activities

Eco-restoration 

Solid & hazardous waste management 

Water technology & management 

Wastewater technology 

Air pollution control 

Environmental materials 

Environmental impact & Sustainability 

Environmental biotechnology, genomics, virology 

Achievements

Phytorid technology for sewage treatment

Rejuvenation of Harmu River in Jharkhand: CSIR-NEERI provided the design for 8 Sewage Treatment Plants (STPs) to be set up with a total treatment capacity of 10 MLD

'WAYU (Wind Augmentation Purifying Unit)' has been developed which reduces particulate matter and VOCs at traffic junctions. This device has been tested in Mumbai

Electrolytic defluoridation for removal of fluoride from water

Development of green corridor on National Highway

Deployed hand pump attachable iron removal plants in 240 hand pumps in rural areas

CSIR-NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE

Nehru Marg, Nagpur - 440 020. Website: www.neeri.res.in