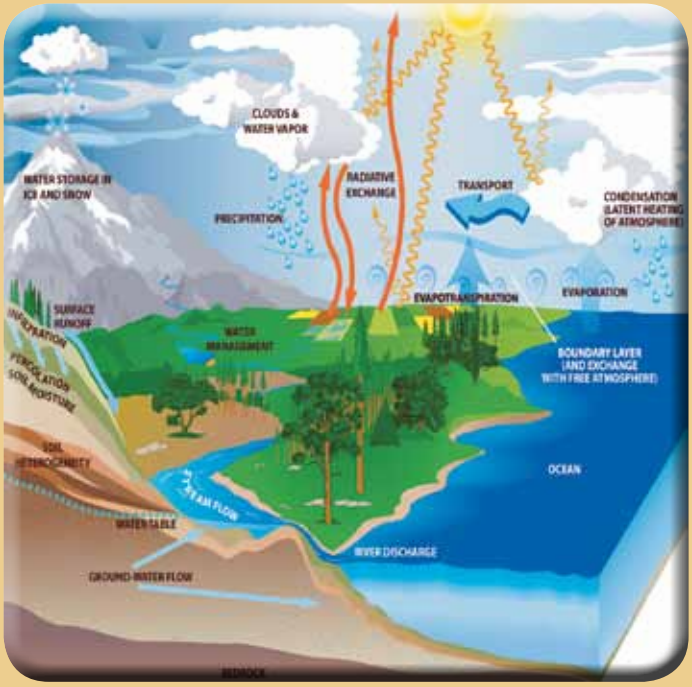
INDIAN GEOPHYSICAL UNION

52ND ANNUAL CONVENTION

AND MEETING ON

'NEAR SURFACE EARTH SYSTEM SCIENCES'



Venue: National Centre for Antarctic and Ocean Research
Ministry of Earth Sciences, Government of India
Headland Sada, Vasco-da-Gama, Goa 403 804

3-5 November 2015

Organized Jointly By

Indian Geophysical Union

&

National Centre for Antarctic and Ocean Research (NCAOR)

Abstracts

CSIR-NATIONAL GEOPHYSICAL RESEARCH INSTITUTE
(Council of Scientific and Industrial Research)
HYDERABAD

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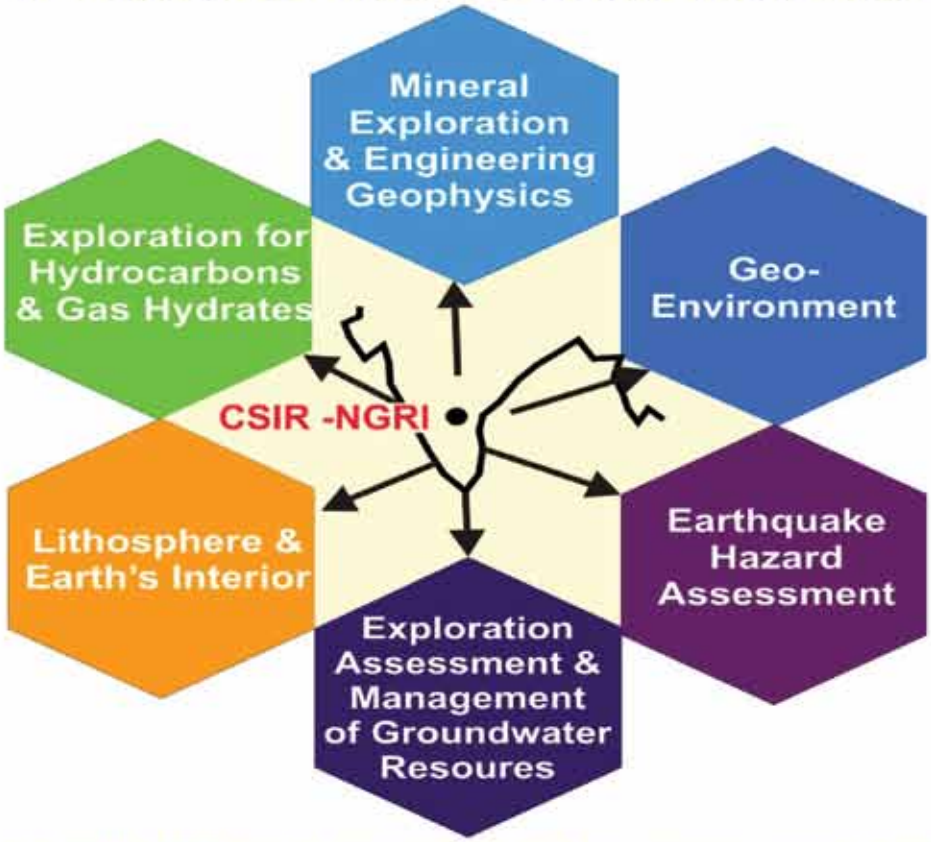

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ABSTRACTS

INDIAN GEOPHYSICAL UNION

52nd Annual Convention

"Near Surface Earth System Sciences"

November- 3-5, 2015

Venue:
National Centre for Antarctic and Ocean Research, Goa

Sponsored by

NATIONAL CENTRE FOR ANTARCTIC AND OCEAN RESEARCH, GOA
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PREFACE

Time runs when we are on the right track and achieve good results. It stagnates when things do not culminate into successful outcomes. The Indian Geophysical Union (IGU) has witnessed both these phases over the 52 years of its existence. Now, we are happy to see IGU healthy and growing. We wish it to remain in this positive stride in future also. The growth and sustainable development has been possible due to significant contribution made by the past and present Executive Committee (EC) members. We salute them for their unequivocal involvement and support. The new EC that came into office on 1st April, 2014 has been working assiduously for sustainable growth; an initiative set by the predecessors. IGU is developing further in terms of visibility by associating with other geo-scientific associations like the AGU and AOGS. Continuous efforts are also made to make it an internationally reputed scientific society by organizing annual conventions on topics of region specific, current interest and relevance to societal welfare. IGU is publishing quality research details through its journal. As a part of continuous up gradation of quality, efforts are made in disseminating knowledge through oral and poster presentations during annual conventions and focused workshops. It is our endeavor to create IGU Chapters throughout the country and provide platform for close interaction between young and experienced geoscientists. We are also organizing special talks on frontier areas of research. In addition, we are encouraging P.G. students and young women researchers by providing grants for their participation in annual convention. To strengthen the HRD in Geosciences we are separately awarding students and young researchers for their R&D initiatives/achievements. Since seniors have contributed significantly by laying a strong foundation to build long lasting structures of quality we have been honoring senior earth scientists with National awards/ medals/ prizes and memorial/endowment lectures.

We are fully aware that IGU can serve the best and achieve better results only with the support of all those associated with it. The main objective of this annual convention, being held at the ESSO National Centre for Antarctic & Ocean Research (NCOAR) at Goa, is motivating young researchers in enriching their knowledge on diversified fields of Earth Sciences and enhancing their research capabilities through presentation, interaction and discussion with the experienced scientists. As in the past, we have assiduously planned to provide a proper forum for presentation of latest results/ discoveries covering various topics of Solid Earth, Marine, and Atmospheric, Space & Planetary Sciences. The special theme of this convention is chosen as the "Near Surface Earth System Sciences" that assumes importance as our day-to-day activities are directly linked to earth system processes in one form or the other. We need to understand the basics associated with the earth system and appreciate scientific initiatives to make it the focal point for sustainable development of society and enhancing the quality of Life on Earth.

All the fundamental needs of the society - air, water, food, energy, shelter are directly related to the optimal use of natural resources and knowledge of Earth System dynamics. Even though the space scientists advocate that there are millions of exoplanets

that flourish with life, akin to Earth, there is no direct evidence to prove such statements. Till such time it is proved unequivocally, we can state that Earth is the only planet in the Universe that has life in the form of human-beings, flora and fauna. Unfortunately, due to combination of natural phenomena and man-induced environmental degradation, mainly by the greed for excessive urban development, we have been witnessing series of negative impacts on the Earth during the past few decades. This trend, if continues, will lead to obliteration of life on Earth. It is the responsibility of all human beings to save our Planet Earth from different negative activities like the environmental degradation caused by over-exploitation of its natural resources and destroying the eco-system. For effective positive changes that can lead to overall betterment of life saving resources, namely, air, water and food we have to first understand the dynamics of Earth System processes that are unique in many ways. To ensure our scientific endeavors are better focused with a view to change the existing dismal scenario, we have selected "Near Surface Earth System Sciences" as the special theme for its 52nd annual convention. This topic is important in view of conflicting interests of developed and developing nations, in reducing various pollutants that are affecting different segments of earth system - solid earth (or lithosphere), watery (hydrosphere) and gaseous (atmosphere) envelopes, and the life (biosphere). Each of which has evolved and interacted continuously throughout the geologic time. This interaction takes place at or near the Earth`s surface, and the energy required is a combination of Earth`s internal heat and radiant energy from the Sun. During the annual convention, we expect researchers to present their studies covering the factors that impact on the earth system and suggest needed impetus to ensure its safety from natural and man-induced aberrations. The deep understanding of different branches of Earth System Sciences can help us in taking up apt measures to resolve many of the setbacks witnessed on a regular basis.

To encourage scientific measures in addressing various policy requirements, IGU wishes to be associated with different research organizations and academic centers. It encourages positive initiatives through close interaction between the students/young researchers and the experienced scientists. Presently, to ensure a viable strategy to help the society in ensuring better quality of life, IGU has taken up an initiative to jointly organize its 52nd annual convention at NCAOR, Goa, which has achieved significant success in recent times in addressing deteriorating environment in polar regions and on top of high mountains that are home to thick ice columns and glaciers respectively.

During the convention, IGU would provide a platform to the Indian Geo-scientific community to focus on the most relevant problems that are affecting quality of life on the earth due to presently witnessed global change that is directly or indirectly linked to Earth System processes. Additionally, the convention has aimed to bring into light the recent developments in Solid Earth, Ocean and Atmospheric Sciences that are useful in solving problems related to energy, minerals, ground water and environmental hazards. We appreciate the efforts of researchers in presenting the area-specific results intended at lessening damages. We also wish to hear from researchers in understanding the genetic mechanisms associated with the natural hazards like the Earthquakes, Avalanches, Tsunamis, Landslides, Soil degradation, Subsidence and Coastal Ecosystem dynamics. Since a better understanding of the origin and development of various natural processes associated

with our enigmatic subcontinent and adjoining oceans and the 16-km thick atmospheric structure is needed, we have provided specific slots to present the area-specific results.

Besides 9 IGU award and memorial lectures, 6 invited talks and 3 special talks, we have 63 oral and 188 poster presentations spread over the three-days annual convention. We have tried to provide reasonably good amount of time for presentation and fruitful discussion. Even though there is a two-hour slot for the poster presentations on 4th November, 2015, we encourage continued display of posters to enable better projection of results and healthy interaction between the presenters and the delegates. For motivation we have created a four-member Jury that will select two students and two researchers who will be recognized with the IGU Best Poster Awards. Besides, two more Special Awards will be given to them keeping in mind the big number of poster presenters. We are also organizing a special session for the Young Researchers with a view to project their scientific caliber and to honor them through the Best Presenter Award along with a Runner-up.

As a member of the Federation of Indian Geosciences Association (FIGA), IGU extends its support in successfully conducting a half-day (4th November, 2015) afternoon session of FIGA, where key topics will be deliberated. All the delegates are requested to participate in this special session.

On behalf of IGU, I request the delegates and awardees to send full papers of their presentations for publishing in the Journal of IGU.

Every year, IGU recognizes both the young and senior geoscientists during its annual convention through several national awards/ medals/ prizes and memorial/endowment lectures: Dr. Hari Narain Lifetime Achievement Award, Krishnan Medal, Decennial Award, Annie Talwani Memorial Prize, Prof. D. Lal Best Paper Award, Dr. H.N. Siddique Memorial Lecture, Prof. K.R. Ramanathan Memorial Lecture, Prince Mukarram Jah Endowment Lecture, L.N. Kailasam Endowment Lecture and Elektrotek & Geometrics Endowment Lecture etc. IGU also encourages the first and second rank holders of the M.Sc./M.Sc.(Tech) final year students of Geophysics/Applied Geophysics from recognized university by providing them with Prof. Jagdeo Singh and Dr. S. Balakrishna Memorial Grant for their participation to the annual convention. Recently, IGU has introduced Anni Talwani Memorial Grant to encourage 4 Young Women Researchers to participate in its annual convention.

It is not possible to organize a convention without financial support. We acknowledge the Ministry of Earth Sciences (MoES), ESSO Indian National Centre for Ocean information Services (INCOIS), Oil and Natural Gas Corporation (ONGC) Limited, Oil India Limited (OIL), CSIR-National Geophysical Research Institute (NGRI), Indian Institute of Geomagnetism (IIG), CSIR-National Institute of Oceanography (NIO), ESSO-National Centre for Earth Science Studies (NCESS) and ESSO-NCAOR for providing IGU with the financial support.

We also thank various organizations like the Electrotek International Inc., Omni Infoword (P) Limited, Horizon Survey Company (IPL), Aimil Limited, JCS Instruments Pvt. Limited for their financial support to IGU and demonstrating the state-of-the-art

services or products related to acquisition, processing/modeling and interpretation of Geo-scientific data.

We place on record our sincere thanks to Dr. P.R. Reddy for extending unequivocal support and guidance in structuring the convention, sparing his valuable time in editing most of the abstracts, and providing needed guidance in bringing out this Preface. Special thanks are due to Dr. O.P. Mishra of MoES and Dr. A.P. Singh of ISR, Gandhinagar for motivating young students and researchers including the women researchers to participate and present their research work in the annual convention.

We profusely thank Dr. M. Ravichandran, Chairman of Local Organizing Committee (LOC), Dr. Dhananjay Kumar Pandey, LOC-Convener and Dr. Ajeet Kumar of NCAOR for their committed and unselfish involvement in organizing the 52nd annual convention at NCAOR, Goa. We sincerely hope that with the full cooperation and support from all delegates, we shall be able to successfully complete all the technical sessions and IGU award/ lecture functions. We are indebted to Prof. Shailesh Nayak, President of IGU, Prof. Harsh Gupta, Chief Patron of IGU, Dr. Y.J. Bhaskar Rao, Dr. Sateesh C Shenoi, Dr. S.W.A. Naqvi, Dr. V.K. Dhahwal, the Vice-Presidents of IGU, Dr. Ch. Mohan Rao, Director, CSIR-NGRI, Prof. V.P. Dimri, INSA Senior Scientist, Dr. P. Sanjeeva Rao of DST, Prof. Manik Talwani of USA, Shri A.K. Dwivedi of ONGC, Dr. R.N. Singh, Emeritus Professor of AcSIR, Prof. S.R. Shetye, Vice Chancellor of Goa University, and Dr. Neloy Khare of MoES for their explicit support and guidance. We are also grateful to all Fellows & Members of IGU, and members of EC for their continued support. We also thank the chair persons for accepting our request to conduct various technical sessions of IGU convention. I owe my personal thanks to Dr. A.S.S.S.R.S. Prasad, Organising Secretary and Mr. Rafique Mohammad Attar, Treasurer for continued support throughout the year. Thanks are also due to Mr. Satender Singh and Shri Krishna for their help to IGU, whenever required. Finally, we wish to thank Mr. T. Suryaprakash and Ms. Revathi, IGU office personnel, for their continued support in executing various works related to this annual convention of IGU.

Kalachand Sain

Hon. Secretary
Indian Geophysical Union

TECHNICAL PROGRAM

NOVEMBER 2 (MONDAY), 2015

16:00 - 18:00 **Registration** **Venue: Near Auditorium**

NOVEMBER 3 (TUESDAY), 2015

08:00 -10:00 Hrs - **Registration** **Venue: Near Auditorium**

10:00-11:30 Hrs - **Inauguration** **Venue: Auditorium**

11:30- 11:35 Hrs - **Inauguration of Exhibition** **Venue: Near Auditorium**

11:35-12:00 Hrs - **High Tea** **Venue: Open Ground**

12:00-13:10 Hrs - **IGU Award Lectures** **Venue: Auditorium**

Chair: Prof. Shailesh Nayak

Theme Talk by Dr. P.R. Reddy, Editor, Jour. of IGU	20 mins
Decennial Award by Prof. S.K. Nath	20 mins
Krishnan Medal -I by Dr. Parthasarathi Chakraborty	15 mins
Krishnan Medal -II by Dr. M.S. Girish Kumar	15 mins

13:10-14:10 Hrs - **Lunch** **Venue: Open Ground**

14:10-15:30 Hrs - **Memorial/Endowment Lectures** **Venue: NCAOR Auditorium**

Chair: Prof. Shailesh Nayak

Sri LN Kailasam Memorial Lecture by Shri A.K. Dwivedi	16 mins
Prince Mukarram Jah Endowment Lecture by Prof. Talat Ahmad	16 mins
Dr. H.N. Siddique Memorial Lecture by Dr. M. Sudhakar	16 mins
Electrotek & Geometric Endowment Lecture by Prof. A.K. Sinha	16 mins
Special Talk by Shri G.C. Katiyar, President, SPG	16 mins

15:30-15:45 Hrs - **Tea Break** **Venue: Open Ground**

15:30- 17:00 Hrs - **EC Meeting** **Venue: Conference Room**

15:45- 17:20 Hrs - **Technical Session 1** **Venue: Auditorium**

YOUNG RESEARCHERS PROGRAM

Chair: Prof. V.P. Dimri
Co-Chair: Dr. O.P. Pandey

7 Oral Presentations - (7x 13.5 mins)	94.5 mins

17:20-18:00 Hrs - **Technical Session 2** **Venue: Auditorium**

Presentation by Exhibitors & Special Talk

Moderator: Dr. Kalachand Sain

4 Presentations - (4x5 mins) 20 mins

Special Talk and Interaction with Students by Prof. Manik Talwani, Schlumberger Professor at Rice University, USA 20m

My fifty years of adventures with measuring gravity over the oceans

18:00-18:30 Hrs - **Tea/Coffee** **Venue: Open Ground**

18:30 Hrs - **Cultural Program** **Venue: NCAOR Auditorium**

19:30 Hrs - **Dinner** **Venue: NCAOR Open Ground**

NOVEMBER 4 (WEDNESDAY), 2015

08:30- 09:00 Hrs - **Registration** **Venue: Near NCAOR Auditorium**

Two Parallel Sessions

09:00-11:15 Hrs - **Technical Session 3** **Venue: NCAOR Auditorium**

SOLID EARTH GEOSCIENCES
(EARTHQUAKES, GEO HAZARDS & DEEP STRUCTURE)

Chair: Dr. D. Srinagesh

Co-Chair: Prof. Malay Mukul

Invited Talk by Prof. VP Dimri, INSA Senior Scientist, CSIR-NGRI Scaling Approach for API in Geophysics 15 min

10 Oral presentations - (10x12 mins, 10 minutes presentation followed by 2 minutes discussion) 120 mins

09:00-11:15 - **Technical Session 4** **Venue: Seminar Hall**

MARINE GEOSCIENCES (IODP, GAS-HYDRATES AND STRUCTURE)

Chair: Prof. Manik Talwani

Co-Chair: Prof. Rima Chatterjee

Invited Talk by Dr. Dhananjai K. Pandey, Program Coordinator, IODP India 15m

Deciphering Climate-tectonic interactions in the Western Himalaya through scientific drilling in the Arabian Sea: IODP Expedition 355

Dhananjai K. Pandey*, Peter D. Clift, Denise Kulhanek and Expedition 355 Scientists

10 Oral presentations - (10x12 mins, **10 minutes presentation followed by 2 minutes discussion)** 145 mins

11:15 -11:35 Hrs - **Tea Break** **Venue: Open Ground**

11:35-13:35 Hrs - **Technical Session 5** **Venue: Near Auditorium**

Inauguration & Poster Session

13:35-14:30 Hrs - **Lunch**

14:30-16:00 Hrs - **FIGA Session A** 90 Mins
Venue: Auditorium

Chair:

3 invited talks - (3x30 mins)

16:00-16:20 Hrs - **Tea Break** **Venue: Open Ground**

16:20 - 17:50 Hrs - **FIGA Session B** 90 Mins
Venue: Auditorium

Chair:

3 invited talks - (3x30 mins)

20:00 Hrs - **Dinner** **Venue: Open Ground**

NOVEMBER 5 (THURSDAY), 2015

Two Parallel Sessions

09:00-11:15 Hrs - **Technical Session 6** **Venue: Auditorium**

SOLID EARTH GEOSCIENCES (EARTHQUAKES, GEO HAZARDS & STRUCTURAL GEO SCIENCES)

Chair: Dr. M.J. Nandan
Co-Chair: Dr. Mrigank Ghatak

Invited Talk by Prof. P. Rajendra Prasad, Sir Arthur Cotton Geospatial Chair, Andhra University 15 mins

Challenges and opportunities in water resources sector: An Indian perception

10 Oral presentations - (10x12 mins, **10 minutes presentation followed by 2 minutes discussion)** 120 mins

09:00-11:15 Hrs - **Technical Session 7** **Venue: Seminar Hall**

SPACE, PLANETARY & ATMOSPHERIC SCIENCES

Chair: Prof. A.K. Gwal
Co-Chair: Dr. R. Rawat

Invited Talk by Dr. R.K. Tiwari, Chief Scientist, CSIR-NGRI 15 min
Climate change: Problems and perspective for predictability

10 Oral presentations - (10x12 mins, **10 minutes presentation followed by 2 minutes discussion)** 120 mins

11:15 - 11:30 Hrs - **Tea Break**

Two Parallel Sessions

11:30 – 13:21 Hrs) - **Technical Session 8** **Venue: Auditorium**

Solid Earth Geosciences (Experimental & Exploration Geophysics)

Chair: Dr. P.R. Reddy
Co-Chair: Dr. Ajay Manglik

Invited Talk by Dr. RN Singh, Professor, AcSIR, CSIR-NGRI 15 min
Indian oceanic lithosphere: Departures from cooling plate model

8 Oral presentations - (8x12 mins, **10 minutes presentation followed by 2 minutes discussion)** 96 mins

11:30 – 13:21 Hrs) - **Technical Session 9** **Venue: Seminar Hall**

SOLID EARTH GEOSCIENCES (THEORETICAL & EXPERIMENTAL GEOSCIENCES)

Chair: Prof. N. Sundararajan
Co-Chair: Prof. M.L. Sharma

Invited Talk by Dr. Sukanta Roy, Project Director, Borehole Geophysics Research Laboratory, Karad 15 min

Scientific deep drilling to study reservoir triggered earthquakes at Koyna, western India

Harsh Gupta, Sukanta Roy, N. Purnachandra Rao, H.V.S. Satyanarayana, V.M. Tiwari, Kusumita Arora, Prasanta Patro, D. Shashidhar, K. Mallika, Surajit Misra, Vyasulu V. Akkiraju, Deepjyoti Goswami, Pinki Hazarika, Nagaraju Podugu, Satyabrata Das, Amrita Yadav, Rakesh Tiwari, G. Sriharipprasad, Digant Vyas, Gaurav Athavale, Vikrant Bartakke, B.K. Bansal and Shailesh Nayak

8 Oral presentations - (8x12 mins, 10 minutes presentation followed by 2 minutes discussion) 96 mins

13:21-14:20 Hrs - **Lunch**

14.20 - 15.00 Hrs - **General Body Meeting** **Venue: Auditorium**

15:00-16:00 Hrs - **Valedictory Function** **Venue: Auditorium**

16:00 Hrs - **Tea** **Venue: Open Ground**

The End

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SOLID EARTH GEOSCIENCES

SEISMIC HAZARD STUDIES IN INDO GANGETIC PLAINS

D. Srinagesh
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The Indo-Gangetic Plains (IGP) is a foredeep basin which follows the trend of the Himalayan collision zone. The basin is filled with thick alluvium deposits of varying degrees of compaction. Estimates of sediment thickness in the IGP, varying between 0.5 and 3.9 km, have been reported from gravity and borehole data and receiver function analysis with maximum thickness observed along the foot hills of Himalayas.

The near-surface geological structures, especially soft soils in basins, are known to dramatically amplify seismic waves and cause great damage and deaths even at sites relatively far from the epicenter. A well-known extreme case is the lake-bed zone of Mexico City where 1985 Michoacan earthquake (Mw8.0, R ~ 400 km) caused unprecedented damage and left ~ 10,000 dead. As the IGP lies in the close proximity of the seismically active Himalayan collision zone, this region has experienced repeated strong shaking due to large and great earthquakes. For this reason, there has been great concern about the impact of Himalayan earthquakes on major, highly populated, cities such as Delhi, Chandigarh, Dehradun, Kanpur, Lucknow, Allahabad, Varanasi, and Patna located in the IGP.

In spite of an extremely high seismic risk exposure, very little is known about the characteristics of ground motion, amplification of seismic waves, and probable nonlinear behavior of the soil in the IGP. The main reason for this lacuna is almost total absence of permanent seismic station in the IGP. We provided the first quantitative estimation of amplification along a 10-station N-S profile in the IGP by computing Standard Spectral Ratios (SSRs) from earthquake recordings of shallow focus earthquakes. They found a broadband amplification and a fundamental frequency of ~ 0.13 Hz near the foothills of Himalaya where the sediment thickness is ~ 4 km. The amplification at this frequency was between 20 and 60.

To predict ground motions in the IGP from future earthquakes along the Himalayan arc it was crucial to deploy a relatively dense network of permanent seismic sensors and record on-scale both weak as well as strong ground motions. The vast potential of such a network for studies of seismic hazard in this unique continent-continent collision zone could hardly be overemphasized.

In response to these urgent needs, a seismic network, called the Central Indo-Gangetic Plains Network (CIGN), which consists of 26 strong-motion velocity seismographs, was installed in the IGP in 2012 (Fig. 1). It recorded the devastating Gorkha, Nepal earthquake of 25 April 2015 (M_w7.9) and its larger aftershocks. We shall be discussing the first results of ground motion in the IGP due to this earthquake.

EARTHQUAKE FOCAL MECHANISMS AND STRESS FIELD IN THE KACHCHH RIFT BASIN, GUJARAT, INDIA

A. P. Singh*[1], L. Zhao[2], Santsoh Kumar[1] and B. K. Rastogi[1]
[1]Institute of Seismological Research, Gandhinagar, Gujarat, India
[2] Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan
**Presenting Author: apsingh07@gmail.com*

Aftershocks of magnitude up to 5 are still occurring in the rupture zone of 2001 Mw 7.7 Kachchh earthquake. However, some surrounding faults in about 50 km radius are showing triggered earthquakes of magnitude ≤5.1. We have determined the focal mechanism solutions of 47 small and moderate earthquakes ($3.2 \leq M_W \leq 5.1$) occurring in the Kachchh Rift Basin, India between February 2007 and December 2014 ,using three-component P and S waveforms recorded by local and regional broadband stations. The area covered is of about 50 km radius. We observe that most of the nodal planes in the focal mechanism solutions correlate well with the local trends of the known tectonic faults. The earthquakes near the 2001 Mw 7.7 earthquake primarily show reverse-faulting mechanism. However, earthquakes in the surrounding areas show predominantly strike-slip mechanism. Most of the earthquakes occur in the lower crust at depths between 15 and 35 km. The P axes of the earthquakes in the Kachchh Rift Basin region are oriented roughly horizontally in north-south direction, while the T axes are oriented mostly east-west. However, the orientations of the P- and T- axes exhibit more complexity near the source of the mainshock, which could be attributed to the strong heterogeneities of the crustal rocks present in the region. Stress field inversion of the focal mechanism solutions also yields maximum compressional axes trending north-south, which is consistent with the ambient tectonic stress field owing to the northward motion of the Indian Plate with respect to the Eurasian Plate. Results obtained in this study also corroborate well with geodetic observations.

SITE EFFECTS: CASE STUDY OF THE 2001 BHUJ EARTHQUAKE DAMAGES IN THE AHMEDABAD CITY, GUJARAT, INDIA

B. Sairam*, B. K. Rastogi, Vandana Patel and Vasu Pancholi
Institute of Seismological Research, Raisan, Gandhinagar-382009, Gujarat, India.
**Presenting Author: sairam.b78@gmail.com*

The Ahmedabad city is prone to earthquake hazard as thecity falls in seismic zone III where a damage intensity of VII or VIII is expected due to earthquakes. Moreover, there is apossibility for site effects in different parts of the city due to soft soils, which can enhance intensity of damage. The 2001 Bhuj earthquake caused severe damage and loss of life in the city even though it is 250 km away from the epicenter. The earthquake caused heavy damages to mid-to-high-rise buildings along the old path of the Sabarmati River (western-side of the river) and the lakes and ponds whereas Low-rise buildings in the Old city (Eastern side of the River) remained almost intact. This non-uniform distribution of damage is studied in terms of the possibility of site effects using shear-wave velocity estimations, Geotechnical investigation and Site Response (SR) observations in Damaged and Undamaged areas. The Vs profiles have been obtained using MASW and PS-logging at 65 selected sites. At ten sites, Geotechnical investigations were carried out to a depth of 50 m. In the study area, the average Vs of the top 30 m (V_{S30}) is varying from 265 m/s to 360 m/s. Comparison of Vs30 map with the damage pattern in the city during the Bhuj earthquake shows that the lowest V_{S30} (265-280 m/s) areas experienced more damages compared to the higher V_{S30} (320 -360 m/s) areas.The SR of the study area shows that maximum peak amplifications are up to 4 in the frequency of 0.6-5.0 Hz.

These frequencies match with the fundamental frequencies of mid-to-high-rise buildings. Hence, these frequencies can lead to resonance effect to mid-to-high-rise buildings and amplify the vibration of buildings. Lower amplifications are found in the frequency range of 5.0-10 Hz, which correspond to 1-2 floor buildings. These results imply that multistory buildings (i.e., more than three floors) in the city area require careful seismic design. The site characterization map of the Ahmedabad city shows higher site effects along the western bank of the Sabarmati River and also along the lakes and ponds, where maximum damages occurred.

INFLUENCES OF GROUND MOTION ON SOIL AND ITS GEOTECHNICAL ATTRIBUTES IN NATIONAL CAPITAL TERRITORY, DELHI: IMPLICATIONS FOR EARTHQUAKE HAZARDS.

H.S.Mandal* and O.P.Mishra

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At more than 449 sites, shallow and deep geotechnical drilling has been carried out and soil samples were collected from the area of 1483 km^2 of National Capital Territory (NCT), Delhi to estimate the ground motion parameters at surface level to assess the impact of future earthquake shaking and earthquake hazards. Time series of peak ground acceleration (PGA) at engineering bedrock (Vs>760 m/s) are generated at each site using probabilistic seismic hazard approach (PSHA). The PGA values at each site further simulated with the site specific geotechnical attributes for the entire soil column up to the depth of 30 m and estimated the surface level seismic hazard parameters. Zero period acceleration (ZPGA) at surface level found amplified and varied from 1.5 to 3.5 times the ZPGA reported at rock level. Accordingly, the duration of design spectra also varies from soil to rock sites. Long duration of design spectra are observed in soil sites and vice versa at rock site. Soil liquefaction characteristics are also estimated due to shallow water table condition in Holocene age group soil. The spatial variation of hazard parameters was assessed for the entire study region. We found limitations in processing our soil data set because of the mismatch of results derived from the laboratory test and input ground motion based on past earthquakes. Some constraints, such as extrapolation of shear wave velocities from Vs (30) up to engineering bedrock depth and seasonal variation of water table also played an important role in reducing the accuracy in computation of hazards due to liquefaction.

SEISMIC HAZARD EVALUATION TO NATIONAL CAPITAL (DELHI) REGION DUE TO SOHNA FAULT ZONE

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The National Capital Region (Delhi), India lies in the geological realm of Penisular India and in Seismic Zone IV which implies that the region is exposed to severe seismic hazard. The occurrence of the earthquakes cannot be predicted in time and space hence society has to learn to cope up with these disasters. The first step towards this is the seismic hazard mitigation. The records of strong ground motions from the past earthquakes can provide a wealth of information for this purpose but in NCR no record of accelerogram due to moderate/large size earthquake occurred in the region is available. Therefore, we have to simulate the strong ground motions time histories for future moderate/large

size earthquakes using semi-empirical technique for the region. The efficacy of the semi-empirical envelope technique has been demonstrated by modeling the empirical accelerograms of 2007 earthquake in NCR. The main features of the simulated accelerograms have been found to be consistent with those of observed ones. We have identified Sohna fault zone as source based on the past seismicity and generate the earthquake strong ground motions at bed rock due to scenario earthquake of M 6.0 in NCR at 144 sites distributed on a spatial grid with an interval of 0.4° x 0.4°. The site effects have been incorporated to generate the accelerograms at the surface level. It has been observed that the site effects have changed the character of the accelerograms. We have obtained a PGA value of 0.1g -0.6 g at the surface. One attenuation relation for the variation of pga with distance has also been identified for the region. The high pga values obtained at the sites near to the faults are found to be in agreement with those of reported in the literature. The spatial distribution of peak ground acceleration values for the scenario earthquake due to the identified source zone has been estimated and the cities like Sonepat, Faridabad, Delhi, Gurgaon, Moradabad in NCR show high to severe seismic hazard. The spatial distribution of the spectral accelerations for different periods at Delhi and surrounding regions corresponding to scenario earthquake at identified fault is also presented. Also the estimates of the population exposed to seismic risk in the NCR due to Sohna Fault zone have been determined.

THE NATURE OF THE BACKSTOP IN THE DARJEELING-SIKKIM-TIBET HIMALAYAN WEDGE

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The Himalayan continental-continental collision boundary has a thin-skinned style wedge-shaped geometry characterized by a basal decollément or the Main Himalayan Thrust (MHT) in arc-perpendicular, transport-parallel cross-sections between the Himalayan foreland and the Indus-Zangbo suture (Schelling and Arita, 1991; Nelson et al, 1996). The backstop of the Himalayan wedge is considered to be the Tibet Plateau north of the Indus-Zangbo suture. The slip on the MHT is postulated to originate at the backstop and propagate south along the MHT to the Himalayan foreland. The slip is transferred all the way to the Himalayan front and the Main Frontal Thrust during great earthquakes with little or no internal deformation in the wedge (e. g. Lave and Auovac, 2001; Bilham et al., 2001); this typically occurs when the deforming wedge becomes critical (Mukul et al., 2007). The slip-transfer along the MHT, therefore, occurs along the transport-parallel width of the Himalayan wedge, which is about 300-400 km. We used high-precision GPS measurements and Boundary Element Method (Crouch and Starfield, 1983) based Dislocation Model, to explore the nature of the Himalayan backstop in the Darjeeling-Sikkim-Tibet (DaSiT) wedge. Dislocation models of slip along the MHT with a width of 300-400 km was able to simulate the convergence velocities measured in the frontal part of the DaSiT wedge south of the South TibetDetachment (STD), to within ~3mm/yr. However, the models broke down north of the STD. The best-fit dislocation model had an infinite width and simulated the velocities measured in the hinterland of the DaSiT wedge to within ~4mm/yr. However, the modelled velocities converged and returned stable solutions with a dislocation width > 1200 km. This suggests that the backstop of the DaSiT wedge is not rigid like most fold-thrust belts and is being deformed in a ductile manner. Elastico-frictional dislocation models simulate measured velocities in the frontal part of the DaSiT wedge better than its hinterland, indicating that ductile deformation models may be more appropriate for the hinterland of the Himalayan wedge.

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LITHOSPHERE-ASTHENOSPHERE BOUNDARY BENEATH CAMBAY RIFT ZONE OF INDIA

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Continental rift zones form as passive response to plate extensional forces or due to the presence of a thermal anomaly in the upper mantle. Continued extension may lead to complete separation of the two sides of the rifted zone and formation of an ocean basin; and in other cases a rift may stop extending further after the initial separation, i.e., it may become an inactive failed rift. Cambay Rift Zone (CRZ) is an ancient rift that had last witnessed volcanic and rifting activity 68-65 million years ago, when the Indian plate migrated over the Deccan plume. Lack of any neotectonic features, such as earthquakes, suggests that the rift is inactive today. The surface heat flow at CRZ is high, potentially signifying the presence of a shallow LAB. Here we apply Shear-to-compressional wave (S-to-p) technique to a teleseismic earthquake dataset to image the mantle below the CRZ. We place the Lithosphere-Asthenosphere Boundary (LAB) beneath this rift at a depth where a ~10% drop occurs in shear wave velocity. The seismic velocity structure indicates that the lithosphere thickness varies from ~60 km beneath the rift to ~110 km beneath rift walls. Furthermore, the upper mantle discontinuities (410 and 660 km discontinuities) are found to be thinner by ~2 sec (i.e. ~20km) with delayed 410-km discontinuity and normal 660-km discontinuity. We infer that this might have been caused by a thermal anomaly in the upper most mantle and a colder transition zone. A geothermal gradient extrapolated from the surface heat flow shows that such a gradient would intercept CO_2-bearing mantle peridotite solidus at 60 km, and thus could signal the presence of small amounts of carbonatite-type magma. Our observations suggest that there exists thermal anomaly in the upper mantle above the transition zone that might begin to generate small amounts of magma after a ~65my hiatus.

A UNIQUE BOREHOLE SEISMIC NETWORK FOR ACCURATE LOCATION OF MICRO-EARTHQUAKES TOWARDS PRECISE DELINEATION OF FAULTS IN KOYNA-WARNA REGION, WESTERN INDIA

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The Koyna-Warna region of western India continues to be the most prominent site of reservoir triggered seismicity since the occurrence of largest earthquake of M 6.3 in the vicinity of Koyna Dam on 10 December 1967. Recently, a borehole seismic network has been established by CSIR-NGRI in this region as a part of the ongoing scientific deep drilling program, an initiative by the Ministry of Earth Sciences, Government of India. One of the main objectives of this borehole network is to estimate the precise earthquake hypocentral locations to enable accurate delineation of the site for scientific deep drilling. The location accuracies, at present are limited to about 300m using the surface broadband seismic network. This is mainly due to inaccessibility of the near source region and the presence of thick basalts on the top. To resolve this problem a borehole seismic network of 8 stations is planned, to be installed at the bottom of the exploratory boreholes at 1.0 to 1.5 km depth drilled under the preparatory phase of the scientific deep drilling program. Deployment of borehole seismometers has been successfully completed in 6 boreholes so far. Micro-earthquakes of magnitude less than M_L 0.1 have been clearly recorded at these borehole stations. Analysis of the data for the period from March-September 2015 demonstrated a remarkable increase in the number of earthquakes located with the help of borehole seismometers. A distinct improvement of more than 60% is achieved in the average travel time residual error from 0.11s to 0.04s. The data also indicate an increase in the seismic activity corresponding to the unloading phase of the Koyna and Warna reservoirs. Also, preliminary results from the borehole seismographs are presented.

HOT CRUST AND LITHOSPHERIC MANTLEBENEATH KILLARI AND KOYNASEISMIOGENIC REGIONS, DECCAN VOLCANIC PROVINCE, INDIA

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The 65 Ma Deccan Volcanic Province covered by a thick suite of volcanicrocks,considered one of the largest flood basaltic eruptions on the surface of the earth has beenexperiencing moderate seismic activity since historical times.Many of the earthquakes,which occurred over this terrain, were destructive in natureleading to heavy loss of human life and property. This includes twoprominent events, 1967Koyna (M 6.3)and 1993Killari (M6.2). Both of them are associated with low heat flow (41-43 mW/m^2) regimeand thus envisaged tohave a cool crust and thick lithosphere underneath. However, recently carried out geological, geophysical and petrophysical studies indicate an extremely unusual crust beneath them,largely containingmetasomatised mid-crustal assemblages like transitional granulites, upperfaciesamphibolites and tonalities. From these areas, much of the radiogenicallyrich upper crust has been eroded due to continuous uplift/exhumation and retrogression.Consequentlly,the lithosphere is thin (~100 km) and mantle heat flow is high, exceeding 30 mW/m^2. Similarly, estimated Moho temperatures are also highat about 540^{o}C below Killariand about 600^{o}C below Koyna. The cause of

low heat flow in these areas can explicitly berelated to low contribution of radiogenic heat from the lesser enriched mid to lower crust,towards the buildup of surface heat flow. We advocate, it is rather mantle,than thesurface heat flow, which governs the lithospheric thermal regime.

DISTINCT TECTONIC SCENARIOS IN ADJOINING SEGMENTS OF THE HIMALAYAN ARC: A COMPARISON BETWEEN THE 2015 NEPAL AND THE 2011 SIKKIM EARTHQUAKES

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The tectonic scenario of the Himalayan arc is generally described by shallow under-thrusting on low-dip-angle faults in the northward direction. However, transverse faulting across Himalaya on deep seated, vertical sub-crustal faults has also been reported. These transverse faults are known to be responsible for partitioning the Indian plate convergence into various segments in the Himalayan belt. The recent 25 April 2015 Nepal earthquake of Mw7.8 and the 18 September 2011 Sikkim earthquake of Mw6.9 in the vicinity, offer a new opportunity to compare the characteristics of these two distinct but adjoining tectonic regimes co-existing in Himalaya. We propose that the trans-Himalayan faults play a key role in confining the rupture length, and hence the magnitude of the earthquakes. Additionally, they also accommodate a large part of the convergent strain budget in Himalaya through transverse plate tectonics, similar to the eastward extrusion in Tibet further north. The above two factors may be playing a key role in reducing the seismic hazard levels in Himalaya.

ASSESSMENT OF GROUNDWATER CONDITIONS IN WATERSHEDS COVERINGOPEN CAST IRON ORE MINES IN GOA

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The mining belt in Goa has two known aquifers, viz., top laterite layer and the powdery iron ore formation at depth. The top layer with laterite cover is quite extensive in the area and even though mining activities have denuded some of these areas of laterite cover, still some areas are left out, with sufficient laterite cover. Herein, the water is under perched water table condition. The friable powdery iron ore at depth is highly porous, permeable and is completely saturated with water. The ore bodies (aquifers) are exposed and water seeps into the mine pits under pressure from them during mining operations. Assessment of groundwater conditions in the watersheds covering 8 different iron ore mines of M/s. Sesa Goa and M/s. Fomento Resources in North Goa District and 9 iron ore mines in South Goa district with regard to groundwater conditions due to iron ore miningwas carried out through hydrogeological and geophysical investigations during 2010-12. Different geological cross sections of iron ore mine workings have provided clues regarding self protection mechanism of groundwater regime in the iron ore mining environment through encapsulated in situ Manganiferrous/ Limonitic/ Phillitic / dyke clays on the iron ore formations. Suggestions for water management in different mining scenarios were analyzed with regard to water quality for water disposal in the nearby streams and rivers. The hydrogeological setup, lithologic details, in situ infiltration rates and resistivity measurements in all mine watersheds indicate that there is no necessity for construction of water

harvesting structures in these mine leases. The overlying high resistivity formations may not allow fast water infiltration as well as lateral groundwater movement within the mine areas. To ensure safe mining of iron ore,ground water extraction in the open cast mines needs to be confined tovery small withdrawals within the microwatersheds. Runoff water harvested in existing mine pits is being used for dust suppression on the mine benches. The garland canals and mini check dams on the stream courses constructed for arresting sediment transport in runoff water during monsoon season from mine lease areas and routed through settlement ponds before reaching the natural stream courses are indirectly helping harvesting of rain water to some extent in the mine lease area.

MAPPING SHALLOW SUBSURFACE HARD AND SOFT ROCK STRUCTURE IN COMPLEX GEOLOGICAL TERRAIN FOR GROUNDWATER PROSPECTING AND EXPLOITATION IN ANANTAPUR DISTRICT, ANDHRA PRADESH

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The prospecting, exploration and exploitation of groundwater is a major issue in a complex geological terrain underlain by soft and hard rocks. One such study was carried out at Tadipatri mandal, Anantapur district, Andhra Pradesh. The study area comprises fallow pasture, rainfed and agricultural lands, which lie between latitudes 15°-15° 05′ and longitudes 78° -78° 5′ in Survey of India toposheet no. 57I/4. The area is generally drought prone and falls under semi-arid agro-climatic zone. The average annual rainfall is in the range 670-700 mm. Geologically, the area lies within Cuddapah basin. The regional geology comprises Bairankonda quartzite (older upper Cuddapah group) and Banganapalle quartzite, Narji limestone, Owk shale and Paniam quartzite (younger Kurnool group). The limestone, which is the predominant rock in this area, belongs to the Narji stage of Jammalmadugu series. Hydrogeologically, Narji limestone and shales underlying quartzites forms the water bearing zones. Groundwater occurrence and movement are controlled by the depth of weathering, occurrence of bedding planes, fractures and faults and the presence of solution channels/cavities in limestone. Groundwater occurs mainly under semi-confined conditions.

In the present work two dimensional (2D) electrical resistivity tomography survey was conducted in accessible area and collected good quality datasets up to a maximum depth of 220m at 11 sites with the objective of delineating potential groundwater zone(s) in diverse geological set up from shallower to relatively deeper depths. Interpretation of the high density 2D resistivity data revealed the most prospect groundwater scenario at three sites, namely, at Tummalapenta, Ayyavaripalli and Guruvanipalli. Two dimensional inverted resistivity model at Tummalapenta site revealed a groundwater potential zone towards SW direction between lateral distances 500-640m in the depth range of 110-180m. The resistivity of this potential groundwater zone ranges between 121-250 Ohm.m. This groundwater zone is overlain by the limestone formation with variable resistivity. Towards the NE side, the resistivity data indicates presence of hard limestone formation,within the depth range of 34-150m. The inverse resistivity model structure at Ayyavaripalli site shows a comparatively better groundwater prospect scenario in the eastern direction , compared to the western side. The geological formation is more weathered towards the eastern side with a resistivity contrast of 500 Ohm.m. The high resistivity formation indicates presence of the shale formation with a different degree of compactness and hardness .The resistivity ranges between ~100 to 12297 Ohm.m. In the eastern side the groundwater prospect zone lies at a shallower depth of 30-100m.Groundwater zone with a resistivity of ~15 to <100 Ohm.m

is located between 540-620m lateral distance towards east .This is hydrogeologically more favourable zone. 2D inverted resistivity model at Guruvanipalli site shows a large resistivity contrast ranging from ~10 Ohm.m to ~38000 Ohm.m. Towards the southern side and between lateral distance of 480m to 640m, a clear cut groundwater prospect zone is inferred with a resistivity value between 15 to 150 Ohm.m. This prospect zone is quite prominent from 35m up to 200m depth. The areal extent of this zone is also increasing from ~35m to the deeper ~200m depth with a resistivity contrast of 100-150 Ohm.m. The host rock is more weathered and saturated in the southern side, while it is harder in the northern side. The results at these three sites are confirmed by drilling borewells up to a maximum depth of 192m. Ground water has been tapped from all the three sites, with yields ranging from 310 to 4929 liter/hour. This shows a wide variation in water holding capacity in the subsurface geological strata. The collected lithologs of the drilled sites are expected to aid in calibrating and refining the interpreted model results at the remaining sites. This may eventually help in building near realistic conceptual model of the aquifer system of the study area.

DELINEATION OF SALINE WATER INTRUSION USING REMOTE SENSING, GIS AND GEOPHYSICAL TECHNIQUES IN COASTAL AQUIFER SYSTEM OF SOUTHERN INDIA

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Application of Remote Sensing (RS) and Geographical Information System (GIS) with the help of ground truth studies like Vertical Electrical Soundings (VES), Electrical Resistivity Tomography (ERT) and water quality measurements gave a comprehensive picture on saline water intrusion pathways in the structural controlled aquifers of Uppanar and Cauvery River systems located in Sirkazhi and Mannanpandal coastal areas of Southern India. The detailed geomorphic units and lineaments were mapped using IRS LISS-III (1:50000 Scale) and SRTM Elevation Digital data under GIS environment. The area mainly consists of alluvial deposits of Holocene Age and classified into three major geomorphic units (i.e., fluvial, fluviomarine, and marine geomorphic units). The identified lineaments are mostly trending North-northeast (NNE) - South-southwest (SSW), Northeast (NE) - Southwest (SW), Northwest (NW) - Southeast (SE), East-West (EW) and East-Northeast (ENE) -West-Southwest (WSW) directions. Some of them are potential for occurrence of fresh groundwater. The lineaments trending NE-SW, NNE-SSW, and ENE-WSW act as pathways for saline water intrusion. The lineament L1 (NNE-SSW trending) conformed as a sinisterly shifted fault played a significant role in saline water intrusion. The area within the parallel lineaments L2 and L3 oriented ENE-WSW direction, indicate low topography, beach ridges, paleo-channel sinuosity, large aerial extent of tidal flats, and back water inundation. All the above geomorphic units gave indirect evidence of land subsidence, which was confirmed by geo-electrical signals obtained through VES, ERT and in-situ groundwater quality measurements. Integrating all the above results, the saline water spread and fresh water pockets were identified.

QUANTITATIVE USE OF GEOPHYSICAL LOGGING DATA FOR COAL MINE GEOTECHNICAL STUDIES

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Geological investigations for coal mining should not be just about determining the thickness, continuity and quality of the seams to be mined. They should also address the geotechnical characteristics of the surrounding strata so that geotechnical engineers can design mine openings, which behave according to the mine plan. For underground mining, the most important of these geotechnical considerations are the roof support requirements and, if longwall mining is being practiced the caving behaviour of the strata. In open cast mines, wall stability and blasting/digging requirements are major geotechnical concerns.

Geophysical logging of exploration boreholes provides a means for providing such geotechnical information. In this paper we illustrate the geotechnical use of geophysical logging with examples from Singareni Mines in India and the Bowen Basin of Australia. Desirable logs are those which can be used to indicate the clay content of the strata (natural gamma, resistivity and neutron logs), the porosity (density and neutron logs) and the strength characteristics (sonic log). From these basic rock properties, the lithology and a rock rating we can establish the Geophysical Strata Rating (GSR). Depositional conditions can also be inferred and allow further useful insights into the geotechnical conditions. In general terms, results are improved by running more logs.

Another advantage of geophysical logs is that because they provide closely spaced quantitative petrophysical measurements along the borehole wall, it is possible to interpolate measurements between holes. Geological and geotechnical models in both two- and three-dimensions can therefore be obtained. From these models, geotechnical engineers and geologists can visualise and plan their mining operations.

To obtain the benefits that geophysical logging can provide, the logging tools should be well calibrated. Mining companies should also closely supervise geophysical logging operations to ensure the quality of the results. Given that geophysical logging can be undertaken in holes drilled by cheaper rotary and percussion methods, the amount of expensive core drilling can be reduced. It may be worth directing at least some of these savings into the geophysical logging to increase the likelihood of successful outcomes.

AUTOMATED ROCK RECOGNITION FROM GEOPHYSICAL LOGS: EXAMPLES FROM SCCL MINES, INDIA

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Geological and geotechnical information is traditionally derived from analysing drill core from a borehole. However, in many cases, the core cannot be fully recovered and geophysical logging is an alternative method to provide the required information. The prime benefit of geophysical logging is that it allows detailed interpretation of non-cored holes or holes where core has been lost. It permits either substitution of diamond drilling or extension of drilling programs on the same budget as non-cored holes are cheaper to drill. Geophysical logs can provide rock properties independent of core recovery, offering scope for grade prediction and rock mass characterization as well as ore body delineation and litho-stratigraphic interpretation.

Manual interpretation of geophysical logs is often a labour-intensive task and the results are often subjective, based on the analyst's experience and understanding of the data. In this paper, we aim towards automating the geophysical log interpretation of lithology using the *LogTrans* algorithm developed by CSIRO. We use the logging data from Adriyala and Kakatiya longwall blocks of Singareni Collieries Company Ltd (SCCL) as examples to illustrate the potential applications of *LogTrans* at SCCL mines.

LogTrans exploits the contrasts between petrophysical signatures of different rock types and performs rapid analysis of multi-parameter logs. The rock types or interpretational classes differ by lithology, stratigraphy, grade, mechanical properties, or combinations of these. *LogTrans* makes the assumption that the physical properties of a given rock type will be statistically invariant over a usefully large volume. It entails three steps:*Statistical characterization* (with program GRSTAT), involving determination of the centroids (means or medians) and ranges (standard deviation or spreads) of the distributions of each petrophysical parameter for each class, based on a representative control data set;

Discrimination (with program FLUSTER), in which data points are assigned to the nearest control class in multi-parameter space.

To characterise the number of clearly distinguishable rock types in the wireline log data, we firstly applied the self-organising map (SOM) method to the data analysis, and then tested its suitability for routine automation with the *LogTrans* analysis. The SOM analysis reliably recognised the main geological rock types (coal, siltstone, claystone, sandstone) at both Adriyala and Kakatiya. Additionally, it identified six different classes of sandstone in the interburden of Adriyala, but only two at Kakatiya. Each interburden unit is characterised by a group of these sandstone classes and highlights a clearly defined stratigraphic variation.

The rock classes defined during the SOM analysis were then validated with the *LogTrans* analysis method as a first step towards a reliable automated interpretation system. An overall success rate of 82% for rock classification by *LogTrans* has been achieved for both Adriyala and Kakatiya boreholes. It clearly demonstrates that automated log interpretation at SCCL mines is feasible.

NEW EVIDENCE FOR NI-CU-PGE SULFIDE MINERALIZATION IN SARNI MAFIC-ULTRAMAFIC COMPLEX, MADHYA PRADESH, CENTRAL INDIA

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Sarni mafic-ultramafic complex emplaced in the Mesoproterozoic Betul fold belt in central India comprises gabbro-anorthosite suite of rocks. It occurs as lensoidal body in Ghatakeda-Sarni section and forms the NW part of the well known Padhar ultramafic-mafic layered complex (Betul). The mafic/ultramafic rocks are represented by gabbro, pyroxenite, gabbro-anorthosite and amphibolites, which are differentially metamorphosed. An integrated geological and geophysical study was undertaken after we stumbled upon geological evidences for Ni-Cu-PGE mineralization. Visible sulphide mineralization was noticed in the form of sheared and silicified horizons and several sulphide bearing mineral phases of Cu, Fe, Ni, Pb, Rh, Rh-W, Zn-Fe and few rare tungsten bearing phases were identified in this suite using Scanning Electron Microscope coupled with Energy Dispersive Spectrometer (SEM-EDS). Some of the altered and sulphidic metagabbros are mainly composed of disseminations of pyrite, minor chalcopyrite, pyrrhotite and pentlandite as well as fine specks of bright palladium and rhodium bearing mineral phases. Time domain induced polarization (TDIP) investigations in conjunction with high resolution electrical resistivity tomography were carried out initially at 2 sites in Sarni. The 2D inverted resistivity model shows high resistivity of the order of 900 Ohm.m to a maximum of 2900 Ohm.m for the deeper strata while the 2D inverted chargeability section developed from IP results shows a sharp and prominent anomaly from ~45m to a depth of 86.2m where the highest value of chargeability of ~22.6 mV/V was recorded, which is corroborated with distribution of (sulphide) mineralized body associated with the host rock. The whole-rock geochemistry of sulfide bearing mafic/ultramafic samples shows relatively high concentrations of Ni (116ppm to 1017ppm) and Cu (59ppm to 558ppm) and platinum group element values (∑PGE=167-1524ppb). The REE and PGE patterns, trace element ratios of PGE especially Pd/Ir ratios of Sarni gabbro-anorthosites are comparable to those of the fractionated/upper part of the layered mafic intrusions characteristic of many Archaean-Proterozoic intrusive mafic-ultramafic complexes of the world. We plan to do grid geological sampling in an area ~40 sq. km (4 x 10 km) around Sarni anomaly during ongoing field season followed by high resolution resistivity imaging and magnetotelluric studies to understand the deep source for such a Ni-Cu-PGE mineralization. The genesis of Ni-Cu sulphide-PGE mineralization is related to primary magmatic differentiation and secondary remobilization processes in the altered, silicified and sheared metagabbros and its variants of the Sarni complexes. These new results of PGE mineralization in association with silicate phases, Fe-Ni-Cu and base metal sulphides opens up a new horizon for Ni-Cu-PGE exploration in the Betul ultramafic–mafic complexes emplaced in the Betul fold belt in central India. However, further studies are to be carried out to better understand the potential of the mineralization and its genetic aspects.

STUDY OF ENVIRONMENTAL POLLUTION USING MAGNETIC SUSCEPTIBILITY MEASUREMENTS ON ROAD DUST SAMPLES OF HYDERABAD METROPOLITAN REGION, TELANGANA STATE, INDIA

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Local or global Environment is in need of care and attention. In developing countries industrial and heavy traffic pollutions are playing main role in degrading the environment. Magnetic Susceptibility method provides an effective tool for study of pollutions due to Industrial & Heavy traffic. In the present workMagnetic mineral studies of anthropogenic magnetic phases in road dust from the heavy traffic and industrial zones of Hyderabad (GHMC) city, Telangana state, India, using magnetic susceptibility measurements, which are proxies for environmental changes, have been carried out. This magnetic investigation reveals that pollution in Hyderabad city has greater concentrations of ferrimagnetic minerals like magnetite, hematite in recent collected dust samples of three seasons starting from January 2014 to December 2014. The variations of the magnetic susceptibility on 1304samples along all the major roads including industrial zones of Hyderabad are interpreted and presented in terms of the relative degree of pollution.

SEISMIC STUDIES FOR GEOTECHNICAL SITE CHARACTERIZATION IN HIMALAYAN TERRAIN

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Subsurface stratigraphy, bed rock topography and quality required for locating a dam across Sutlej river near village Kian in Bilaspur district, Himachal Pradesh were deciphered economically using seismic refraction technique employing a 24-channel signal enhancement seismograph over undulating Himalayan terrain along 38 profiles on land and underwater near dam site, powerhouse site and cofferdam site. A large quantity of clay required for the impervious core of the dam was to be borrowed from an adjoining area, where the amount of usable clay available was estimated using the same technique along 12 profiles conducted in the borrow area in Panjgain valley. Explosives were used as energy source for generating seismic waves on land and in water. Geophones on land and hydrophones underwater were deployed as receivers. Continuous seismic refraction technique was employed for the data collection and 'Reciprocal technique' was used for data interpretation. Pink limestone and grayish white dolomite with a transitional zone are the country rocks near the dam and power house sites. Loose river borne material in the upper part and partially cemented conglomeritic breccia in the lower part are present in the dam site. In the water covered portions of the area, in general, a two layer section comprising overburden of compressional (P-) wave velocities from 1600 m/sec to 2000 m/sec and weathered rock with velocity from 2000 m/sec to 2500 m/sec was revealed. However, at some locations, the rock was exposed to the riverbed. At the Dam site, Powerhouse site and cofferdam sites,two/three layer section comprising loose overburden, compact overburden/weathered rock and rock was delineated. Depth to the rock varied considerably from profile to profile. Rock having velocity greater than 4000 m/sec was inferred to be good quality rock. In the borrow area, a three-layer section comprising overburden,

saturated overburden and hard strata was deciphered. The thick alluvial columns of about 25 m i.e. overburden and saturated overburden would cater to the need of filling of dam core.

HOST ROCK CHARACTERISTICS AND CONTROLS ON CU-AU-AG MINERALIZATION AT COPPER MOUNTAIN PORPHYRY DEPOSIT, SOUTHERN BC, CANADA

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The Copper Mountain porphyry Cu-(Au-Ag) deposit has a current total production of 205Mt at an average grade of 0.53% Cu, and proven and probable reserves of 217Mt at 0.27% Cu, 1.07 g/t Ag and 0.1 g/t Au at a 0.12% Cu cutoff (Holbek And Joyes 2014 [1]). This, in addition to the loss of ~500Mt through fluvial erosion means the Copper Mountain porphyry system originally contained a Cu reserve in excess of 1000Mt.

The deposit is temporally and spatially associated with several Late Triassic-Early Jurassic alkalic intrusions emplaced into the basaltic-andesitic, largely fragmental and brecciated, Nicola Group volcanic rocks. Intrusive rocks include the zoned syenite to diorite Copper Mountain Stock (CMS), and the largely diorite to monzonite Lost Horse Intrusive Complex (LHIC), which displays a predominant dike and plug geometry. Post-ore units comprise Cretaceous felsite dykes and Tertiary volcanic rocks and sediments of the Princeton Group.

Copper-(Au-Ag) mineralization is predominantly associated with small, but multiple intrusive units of the LHIC emplaced at different depths ,which vary from small fingers of <1 metre to larger intrusions up to 30 metres thick.New field, petrographic and geochemical observations from this study show at least 3 texturally and compositionally distinct phases of the LHIC: LH1 diorite, which displays no close relationship to mineralization, exhibiting equigranular plagioclase feldspars (300-600μm), augite (200-400μm), disseminated apatite (<50μm), very fine (<50μm) titanite (trace) and low Th, Zr and Nb. LH2 porphyritic monzonite, which displays a close spatial relationship to chalcopyrite-bornite-chalcocite mineralization, characterized by plagioclase (200-500μm) and high relief augitephenocrysts (50-200μm) in a fine (<50μm) K-feldspar groundmass, with a sporadic geochemical distribution attributed to pervasive sodic and potassic alterations. LH2a porphyritic monzonite displays no close relationship to mineralization, has coarse euhedral plagioclase phenocrysts (1-9mm), anhedralaugite (50μm – 1mm) and high Th, Zr and Nb.

Mineralization consists of vein-stockworks and disseminated sulphides, with lesser matrix filling within hydrothermal breccias. Sulphide mineralogy includes chalcopyrite, bornite and hypogene chalcocite with pyrite and magnetite gangue. This study documents several occurrences of structurally controlled molybdenite with mineralization. Re-Os geochronology of molybdenite allows us to constrain an age of mineralization to 203.3 ± 1.0Ma, confirming an age of the LHIC after the intrusion of the Copper Mountain Stock (CMS) (205.5 ± 1.1Ma; Mihalynuk et al., 2009[2]). Study on the CMS intrusive unit indicates 3 mineral phases, syenite, monzonite and an equigranular diorite containing

plagioclasefeldspars (100-300μm), augite (100-200μm), 5% biotite (200-700μm) and fine-grained disseminated magnetite (~50μm), displaying high-grade chalcopyrite-bornite mineralization on the peripheries of the diorite.

Mineralization is associated with potassic, K-feldspar – biotite, and sodic, largely albite, alterations. Both potassic and sodic alteration range from structurally controlled veins to large zones of intense pervasive replacement. Potassic alteration typically overprints sodic alteration and has a closer temporal and spatial relationship to ore mineralization (Stanley et al., 1995[3]; Holbek and Joyes, 2013[4]).

Our new data provides a better understanding of the intrusive evolution and associated mineralization at Copper Mountain and will provide a framework for magmatic complexity of similar known porphyry camps in British Columbia, Canada.

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STATE OF UNCONFINED AQUIFERS IN CAUVERY BASIN ALONG EASTERN COAST FROM PUDUCHERRY TO CHIDAMBARAM, TAMIL NADU - A CRITICAL ANALYSIS BY ELECTRICAL RESISTIVITY SURVEYS

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Deterioration of water quality in the coastal zones along Bay of Bengal due to saltwater infiltration into the freshwater aquifer has become major concern. With the aim of providing valuable information on the hydro geologic system of the aquifers, the subsurface lithology and delineating the quality of groundwater, electrical resistivity sounding surveys (VES) were carried out utilizing ground resistivity Schlumberger arrays with electrode spacing varying between 1 to 100 m. The area, part of the Cauvery sedimentary basin is bounded by Achaeans in west and northwest, extends into the offshore in the east. Younger Paleocene and Eocene sediments occurring as sub-crops overlie the Cretaceous sediments. Quaternary sediments occur as cover over a large part of the Cauvery basin. The sources of freshwater include the shallow unconfined aquifer below the dry unconsolidated layer as well as a series of confined aquifers associated with poorly consolidated sandstone formation. Backwaters are a network of inter connected canals, rivers and inlets with the sea acts as conduits for carrying seawater into the mainland. The invasion of seawater into the land is caused by the action of waves and shore currents.

The study area consists of number of major rivers connecting with the sea in the east, starting from Gingee River in the north to Vellar in the south including Mallattar, Ponnaiyar, Gadilam and Uppenar in between flowing on different direction. The resistivity survey reveals the significant resistivity variations for subsurface layer model. The four layer subsurface model indicated higher resistivity ranges for top unconsolidated layer (100-800 Ohm-m), freshwater layer (30-200 Ohm-m), brackish water layer (10-30 Ohm-m) and saltwater layer (1-10 Ohm-m). The resistivity surveys brought out low resistivity values for shallow aquifers in the regions of rivers, canals and inlets which are connected to sea indicating infiltration of seawater into the shallow aquifers. The groundwater samples collected in the area from shallow dug wells, hand pumps and ponds were analyzed for complete chemical analysis for correlation with resistivity sounding data. The higher cut off values of Total Dissolved Salts (TDS) and Chloride were observed mostly along the river courses confirming resistivity data, suggesting the infiltration of saltwater into the shallow aquifers. The subsurface resistivity variations have helped in identifying the degree of variation in the water quality for shallow layers. The present surveys were useful in demarcating the saltwater contaminated areas and causes for the contamination.

SEISMIC STRUCTURE OF THE LOWER MANTLE BENEATH THE INDIAN OCEAN GEOID LOW

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The Indian Ocean Geoid Low (IOGL) that spans a vast areal extent south of the Indian subcontinent is a spectacular feature on the Earth, whose origin is still debated. In this study, we investigate the shear wave velocity and anisotropy of the lower mantle below this geoid low utilizing the travel time, amplitude residuals and shear wave splitting of high quality S and ScS phases. For comparison, we also perform a similar exercise for a region of geoid high in the vicinity. Differential travel time residual results reveal large variations in the ScS travel times indicating that the lowermost mantle beneath the IOGL region is heterogeneous. The ScS-S differential travel times are ~3 s slower than those predicted by the IASP91 model, primarily due to velocity increase in the lowermost mantle beneath the IOGL region and ~2 s higher than the IASP91 beneath the geoid high region, due to velocity decrease in the lowermost mantle. The largest negative residuals (7.72 s) are concentrated below the IOGL. Modeling of the differential travel time residuals reveals that the maximum positive and negative residuals can be explained in terms of a reduction in shear wave velocity of 0.9% and an increase of 1.6% ,respectively in a 1000 km thick layer above the Core Mantle Boundary. Also, the ScS/S amplitude residuals beneath the IOGL are positive, implying high impedance contrast at the Core Mantle Boundary, owing to the presence of high velocity material. The observed high velocities are attributed to the presence of dehydrated high density slab graveyards atop the Core Mantle Boundary beneath the Indian Ocean. Further, the splitting results from high quality ScS phases corrected for receiver and source side upper mantle anisotropy reveal significant VTI anisotropy in the D" layer beneath the IOGL. Lattice Preferred Orientation (LPO) deformation of the paleo-subducted slabs experiencing high shear strain atop the Core Mantle Boundary (CMB) is a plausible explanation for the observed anisotropy. Evidence for the presence of dehydrated high density slab graveyards at the CMB below the Indian Ocean Geoid Low region comes from modelling of ScS-S travel time residuals.

Release of water at the mid-to-upper mantle depths due to the dehydration of subducted slabs causing a reduction in density and velocity of the ambient mantle, could be responsible for the geoid low.

BASEMENT STRUCTURE OF THE FORELAND CENTRAL GANGA BASIN ALONG THE BHIND – SARDA DEEP PROFILE BY MAGNETOTELLURICS

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The geological and tectonic fabric of the Indian plate in the Ganga basin is masked by alluvial sediments deposited in the basin by a network of major rivers and their tributaries. We have carried out a broadband magnetotelluric study along the 285 km long Bhind - Sarda Deep (Nepal Border) profile across the central Ganga basin to delineate the basement structure. The electrical resistivity image obtained by combining 1-D Occam inversion models of 24 sites reveals a significant contrast in the subsurface structure along the profile. The highly resistive Bundelkhand massif extends up to 80 - 90 km profile distance beneath 250 - 400 m thick sediments. Our results suggest the presence of this massif beyond its earlier demarcated subsurface contact with the surrounding mobile belt. Based on the resistivity image, we infer the basement depth of > 6 km at Shahjahanpur where the top of the Bahraich Formation (~ 1600 Ma old meta-sediments) was encountered at 3126 m in a 3351.8 m deep exploratory well. The resistivity structure of the Sarda Deep is distinct, that a 60 km wide extremely low resistivity zone around 250 km profile distance extends over the entire 12 km depth of the image section. A comparison with the earlier published results along another profile about 130 km east of the present profile indicates that the basement depth in this region should be considerably larger than > 9 km depth obtained for that profile. A 4224 m deep exploratory well in this region also ended in the Bahraich Formation. The low resistivity of thick sedimentary sequence in this region together with low shear wave velocity and high Vp/Vs in the top 4 km imply poor consolidation of sedimentary sequence and thus high seismic hazard potential of the region.

CRUSTAL DENSITY MODEL OF SAUSAR FOLD BELT A TREASURE HOUSE OF MANGANESE MINERALS IN CENTRAL INDIA

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The Sausar Fold Belt (SFB) which is well known for some of the largest manganese ore deposits in Central Indiais an important constituent of the Central Indian Tectonic Zone (CITZ). It constitutes the southern boundary of CITZ and is bounded by Central Indian Suture zone (CIS) on its south. The Precambrian (Mesoproterozoic to Neoproterozoic) meta-sedimentary sequence of Sausar groupis 300 km long and 70 km wide. The ESE-WNW to E–W to ENE–WSW trending orogenic belt is bounded by two cratonic blocks, the BundelkhandCraton (BKC) in the north and BastarCraton (BC) in the south. The central portion of SFB comprises a stable platform sequence of manganese bearing pelite-arenite-carbonate rocks along with TirodiBiotite Gneiss (TBG) and intrusive granitoids. The metamorphic grade in the Sausarsupracrustal rocks vary from green schist to upper amphibolite facies, whereasgneissic rocks adjacent to the Sausar Group in the north and south contain enclaves of pelitic and basic granulites known as Ramakona-Katangi Granulite (RKG) belt andBhandara-Balaghat Granulite (BBG) domain,

respectively.Since, the Sausarsupracrustal belt is devoid of mafic rocks, high resolution gravity survey was very effectivein delineating the shallow subsurface high density manganese ore deposits in Sausar belt of Nagpur and Bhandara districtsof Maharashtra.

To understand the deep crustal structure and evolution of SFB, new gravity data was acquired at 1.0 km spacing along a 250 km long profile across the belt. Gravity anomalies showa prominentshort wavelength high over RKG domain superposed on a large wavelength regional high over the BKC in the north, which decreases towards the south over the BC and forms a bipolar anomaly.Gravity field towards the south of SFB shows short wavelength highs and lows associated with BBG, mafic volcanics andgranitoids, respectively. 2½ D modelling of gravity anomalies was carried out across the SFB incorporating inputs from seismic,metamorphic petrology and geochronology. The inferred density section shows upthrusted high density upper mantle and lower crustal material at shallower depth beneath the RKG domain in the north. This tectono-thermal eventled to metamorphism of the Sausarrocks during Grenvillian time. Based on crustal density structure, it is suggested that the tectonic domains in the Sausar fold belt are the result of early subduction followed by continent-continent collision from south to north.

LITHOSPHERIC ELECTRICAL STRUCTURE ALONG RAMPUR-BANSWARA TRANSECT, RAJASTHAN, INDIA

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The northwestern part of the Indian subcontinent consists of the Thar desert, sedimenatry basins like Jaisalmer and Barmer, Proterozoic Aravalli-Delhi mobile belt in addition to major outcrops like Malani igneous suite .Among the known Archaeancratonic regions (Dharwar, Bundelkhand, Bastar, Singhbhum and Marwar) that constitute Indian continental block, the Marwarcraton forming a part of NW India is the least studied. The known geological history indicates the collision process between Marwar and Bundelkhandcratons in the Proterozoic period and influence of the Reunion mantle plume during 80-65 Ma. In order to delineate the lithospheric structure and also to assess the imprints of the various past tectonic processes operated in the region, a magnetotelluric (MT) experiment was carried out along a 600 km long NW-SE oriented transectextending from Rampur (west of Jaisalmer) in the northwest to Banswara in the southeast.This transect cuts across the Delhi-Aravalli Proterozoic mobile belt. Broad-band (0.001 – 1000 s) Magnetotelluric data has been acquired along this traverse with a station interval of 6-8 km. In addition, long period (30 – 30,000 s) data has been acquired at every third site (20-25 km spacing) ,with a recording period of 4 and 20 days, respectively. The high resistive ($>10^4$Ohm.m) Marwarcraton is reflected in the deeper section (up to ~150 km), with its eastern boundary limiting at Sirohi. A low resistive (1000-2000 Ohm.m) lithospheric block has been identified between Sirohi and Udaipur. In the region west of the Aravalli mountain range there is a change in the geological scenario from a typical mobile belt setting to that of a stable intracratonic platform lithopackage. Sirohi Town is the region where such a changeover can be noticed, hence Sirohi is not only a boundary to the vast arid zone bordering the Thar desert, but its geological record also replete with evidences marking the transition from orogenic to anorogenicmagmatism. The resistivity features observed in the two-dimensional model are discussed in light of geodynamics of the region.

DEEP CRUSTAL SEISMIC IMAGING AND ITS TECTONIC SIGNIFICANCE IN THE REWA BASIN OF CENTRAL INDIA

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Rewa basin of Central India is a potential hydrocarbon bearing Gondwana sedimentary basin of India, which is part of the Son-Mahanadi rift basin. It is an intracratonic rift graben having number of criss-crossed ENE-WSW trending faults and is confined between Son-Narmada North Fault (SNNF) and the Central Indian Tectonic Zone (CITZ). The basin has thick sequence of lower and upper Gondwana sediments deposited with Barakar and Raniganj formations of coal seams with massive shales and sandstones making the region important for hydrocarbon exploration because shales act as source rocks and sandstones are reservoir rocks. There are basalt exposures toward south of the Rewa basin due to outpouring of lavas because of Deccan Volcanism (65 Ma) during Late Cretaceous-Paleocene and the region is largely infested by mafic dykes and sills. Hence the region is geologically very complex and difficult to image the Gondwana sediments hidden below the basalts for hydrocarbon exploration as well as delineate deep crustal structural features down to the Moho. To image both shallow and deep crustal structures and understand the tectonic and geodynamic settings of this region, deep seismic data have been acquired in 2014-2015 along the 170 km long N-S profile from Rewa to Shahdol covering a mosaic of different rock types exposed on the surface such as Gondwana, Deccan basalts, Granites, Gneisses, Schists, Limestone, Shales etc. The modeling and imaging of seismic data acquired along this profile shows the presence of thick low-velocity Gondwana (>2.5 km) with velocity 3.5-4.0 km/s overlained by high-velocity Deccan basalts of 5.0-5.5 km/s in south of the profile towards Shahdol with basement depressions forming a sedimentary graben. Towards the north of the profile there is no signature of the presence of Deccan basalts and the basement is up-warped forming a horst structure with granites/gneisses of the Vindhyan Super Group rocks at very shallow depth. The inversion of wide-angle seismic reflection data depicts very well the upper-crust (10-12 km), mid-crust (20-24 km) and Moho(35-37 km) with velocities of 6.5 km/s, 6.9 km/s and 7.3 km/s along this profile with a signature of the presence of the extension of the of major ductile shear zone (CITZ)towards south of the profile. The presence of numerous faults cutting across the Gondwana sediments with alternate horst and graben structures of the basement facilitate as the conduits of the emancipation of volcanic lavas forming dykes and sills in this region, which are considered as lower crustal mafic rocks due to the Deccan plume.

SITE CHARACTERIZATION OF KOLKATA MEGACITY IN THE LIGHT OF SEISMIC THREAT TO BENGAL BASIN

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The State of West Bengal, located in the western foreland of the Assam-Arakan orogenic belt, Himalayan foothills and Surma Valley is facing constant seismic threat from both the near- and far-field seismogenic sources like Bihar-Nepal seismic zone in the Central Seismic Gap, Assam Seismic Gap, Shillong Plateau, Andaman-Nicobar seismic province, Bengal Basin itself, and the N-E Himalayan

extent. Its capital city of Kolkata with 14 million populations has encroached into the back swamp and marshy land to the east filling up extensive areas of the megacity that has been placed at the boundary of Zone III and IV of Seismic Zoning Map of India. Sitting on a sedimentary basin of 7.5 km thick fluvio-marine sediment above the crystalline basement it is highly vulnerable to earthquake disasters.

Geomorphologically Kolkata is a typical deltaic flat land with surface elevation ranging between 6.4 to 9.5m above msl sloping mostly towards south. Effective shear wave velocity (V_s^{30}) for 30m soil column is used in the site characterization of the terrain derived from geotechnical investigations at 654 boreholes, MASW survey along 120 profiles and Microtremor survey at 1200 locations in the city. The non-liner regression analysis has established relations between the corrected SPT 'N' values and the 1-D shear wave velocity (Vs) profiles derived from Down-hole seismic tests for various subsurface lithostartigraphic units at different depth levels. These in turn are used for calibrating MASW generated surface consistent shear wave velocity profiles turning those into in-situ shear wave velocities as would have been obtained through down-hole seismic survey at those locations which eventually benchmark the inverted HVSR driven 1-D shear wave velocity profile and thus assesses effective V_S^{30} for site classification purposes at 1200 locations in urban Kolkata spreading over 435 sq km. The Horizontal-to-Vertical (H/V) response spectra reflect the fundamental site frequency thus facilitating generation of a Predominant Frequency distribution map of Kolkata on GIS platform exhibiting a variation between 0.5 Hz to 3.1 Hz, which on quasi-resonance with the building natural frequency will cause heavy damage to total collapse of the building in the event of an earthquake striking the city even with magnitude M_w 5.0. Site classification of Kolkata performed based on NEHRP, USGS and FEMA regulations places the City in D1 (V_s^{30}: 320-360 ms^{-1}), D2 (V_s^{30}: 320-280 ms^{-1}), D3 (V_s^{30}: 280-240 ms^{-1}), D4 (V_s^{30}: 240-180 ms^{-1}) and E (V_s^{30}: <180 ms^{-1}) classes. Using the input time series obtained from stochastic simulation of both the near- & far-source earthquakes at engineering bedrock and 5% damping for all soil types, site amplification at each location is estimated ,which is defined as the ratio between the Fourier spectra of the rock to the soil. The average site amplification curves for different site classes as though representing generic site response for each site class with a high of 6.10 and a low of 2.80, have been generated. Site effects by short-period (0.1 to 0.5 s) and long-period (0.4 to 2.0 s) site coefficients viz. F_a and F_v, according to site classes have been quantified for the design response spectra of buildings. Shepard's diagram of the city's subsurface that exhibits highly liquefiable sediments viz. sand, sand-silt clay, sandy clay, silty sand and silty clay upto about ~5 m while in contact with the shallow groundwater fluctuations between 0.1-7.7 m is expected to trigger soil liquefaction under earthquake loading and is, therefore, considered a major contributor to induced seismic hazard potential in Kolkata thus forming a part of the site characterization of city.

DELINEATION OF ANOMALOUS SUBSURFACE ELECTRICAL STRUCTURE IN THE TATAPANI HOT SPRING AREA, CHHATTISGARH, USING 3D MAGNETOTELLURIC STUDIES

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The Tatapani hot spring area located in the Balrampur district of Chhattisgarh state is considered to be one of the most significant geothermal areas in the country. During the last more than three decades, several organizations including GSI, CSIR-NGRI have carried out a wide spectrum of

geoscientific investigations. The results of these studies point out to a significant potential of this area from the view point of exploitation of geothermal energy. The primary thermal reservoir is conjectured to lie at deeper levels. Estimated isotherms at different depth levels in the depth range of 300-1500 m, suggest an increase of areal extent of the thermal reservoir with depth. But the actual configuration of the reservoir is yet to be identified. Mapping of subsurface electrical structure is known to play a crucial role in understanding the subsurface geothermal conditions of the area. Keeping in view of the high geothermal potential of the area, the NTPC Ltd. has recently sponsored a project to NGRI for further evaluation of subsurface conditions to deeper levels to facilitate drilling an exploratory cum production well that would pave the way for setting up the first geothermal power generation plant in the country. Accordingly, as part of these efforts the NGRI has carried out a detailed subsurface modeling of the available magnetotelluric (MT) data in the Tatapani area. Further, in order to fill the data gaps and to have a realistic 3D subsurface model we have also acquired data at additional MT stations during 2015 field campaign with the support from SHORE project of CSIR-NGRI. We present here the subsurface electrical structure of the Tatapani area based on modelling of MT data including the 3D modeling results.

While the general character and configuration of the upper crustal conductor in the study area has been obtained from 1D and 2D models, the 3D model brings out further details. The 3D MT model, besides bringing out the configuration of the anomalous shallow (2-3 km) conductive zone in the area including the presence of different high conductive block like features, irregular nature of the top surface of the conductor, also points out to presence of additional conductive bodies at relatively deeper levels (5-8 km). The high conductive blocks in the 3D MT model tend to be located in the areas close to intersection of the transverse faults with the Tatapnai fault. The hot spring area appears to be closely linked to shallowing of the conductive feature delineated in the area and is spatially correlatable with such intersection zones of the crustal conductors.

INTEGRATED GEOPHYSICAL SURVEY ALONG PURNEA-SEVOKE TRANSECT IN BIHAR AND WEST BENGAL

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To delineate the thicknesses of the lower Siwaliks/Gondwana formations above the Archaean basement, if possible, and to prepare a meaningful crustal model , the study area bounded by latitudes 25°52' N to 27° N; longitudes 87°28' E to 88°28' Ewas surveyed using gravity, magnetic and deep electrical resistivity techniques. Deep electrical surveys were undertaken in the area at 10-15 km interval along Purnea-Dalkhola-Sevoke (NH-31) transect along with gravity and magnetic observations.

Due to high conductivity of the overlying sediments, the basement depth could not be delineated everywhere except only at few locations. The apparent resistivity pseudo depth section prepared on the basis of electrical sounding indicated lateral changes in conductivity between km stone 452 and 483. This zone shows a highly resistive layer (1000-2000 Ohm-m) is seen to be unconformably disposed at much shallower depth over a rather conductive substratum. It is difficult to speculate the nature of this resistive body. However, the resistivity depth pseudo section brings out clearly that the Siwalik

floor is quite undulatory in this part of the frontal foredeep region of the Himalayas.At km stone 452 (ES-4), a fault is discernible, which probably marks the eastern limit of the Purnea-Kishanganjgraben. East of this graben the Gondwanas are probably absent.

The gravity profile along NH-31 from Purnea to Sevoke brought out two basinal structures. Two faults dipping SW, one at 435 km and other SW of Kishanganj have been delineated, based on a sharp change in gradient of anomaly profile. Spectral analysis of the said gravity profile brought out three interfaces at ensemble average depths of 18.4 km, 3.2 km and 0.112 km, indicating possibly the Conrad discontinuity, the depth to the Archaean basement and the thickness of alluvium in the area. In order to understand the variations of Bouguer anomaly in terms of crustal structure i.e. mass distribution, 2D gravity modeling was done over the Purnea-Sevoke gravity profile. A four layer crustal model was assumed keeping in view the local geology and the intercepts from the frequency analysis data. The thickness of the composite sedimentary column varies from 0.5 km to 5.5 km, from southwest to northeast. Two basins (?), as shown in the gravity profile have been delineated. 2D gravity modeling along the above transect indicates thickening of crust towards NE. Thickening of crust towards north following isostatic consideration causes continuous fall in gravity value in the area. The corrected Bouguer anomaly map is presented as a contour map in intervals of – 2 mGal between Panjipara to Sonapur along NH-31. The gravity values vary from – 69.6 mGal to – 130 mGal from southwest to northeast of the area. The gravity map reveals that crustal thickness increases from southwest to northeast. A gravity high structure is seen around north of Chopra and east of Sonapur. This information could be of interest for oil exploration.

The magnetic vertical force (VF) anomaly profile between Purnea to Sevoke shows two basinal structures, one between station 457 km to 470 km and the other SW of it. This finding is supported by gravity survey. After station 470 km stone magnetic anomaly shows high plateau depicting the possibility of trap underneath. Fluctuations in magnetic anomaly are seen beyond station 550 km possibly due to the presence of intrusive.

At least three prominent deep seated faults and a gravity high structure have been interpreted from the present study. These structures may prove to be of significance from the point of oil exploration in this area.

GEOPHYSICAL STRATEGY IN DELINEATION OF PGE HOST ROCK, T3 SECTOR OF TASAMPALAIYAM, SITTAMPUNDI ANORTHOSITE COMPLEX, TAMIL NADU

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Gravity, magnetic, resistivity, induced polarization, multi-electrode resistivity imaging and multi-parametric geophysical logging techniques helped in delineating the strike continuity and depth persistence of thin and narrow chromitite and chromiferous meta-pyroxenite bands hosting PGE mineralization within anorthosite in parts of T3 Sector of Tasampalayam block, Sittampundi Anorthosite Complex (SAC), Southern Granulite Terrain (SGT). SAC in Tamil Nadu is characterized by a group of rocks ranging in composition from anorthosite, amphibolite, pyroxenite, meta-pyroxenite, garnetiferous pyroxene granulite and chromitite.

The Bouguer gravity and magnetic anomaly maps have brought out the structural features associated with regional folding. The gravity, magnetic, IP and resistivity signatures helped in delineating the lithological contact between the anorthosite and garnetiferous pyroxene granulite. Prominent high dominant magnetic anomaly is noticed over anorthosite in the north and low magnetic anomalies of pyroxene granulite in the south. Subtle magnetic variations of the order of 10 to 20 nT are recorded over chromitite or chromiferous meta-pyroxenite bands, the host rock for PGE mineralisation within the anorthosite, trending in ENE-WSW direction.

Moderate to low gravity anomalies are noticed over anothosite in the central part.They show gradual rise in the form of gradients to the south towards denser rocks represented by garnetiferous pyroxene granulite. Gravity map brings out feeble, residual gravity highs of around 0.15 mGal within the broad gravity low zone, over chromiferous meta-pyroxenites within the anorthosite, trending in ENE-WSW direction. Resistivity low and chargeability high values are recorded over kaolinised zones associated with fault / fracture / shears associated with chromiferous meta-pyroxenite bands within the anorthosite, extending on either side, trending in east-west direction. High chargeability values are also recorded over garnetiferous pyroxene granulite in the south, corroborating with resistivity low values. They may be due to textural variations.

Multi-electrode resistivity imaging indicating the presence of prominent low resistivity anomaly zone at a depth of 22m and beyond along Tr: E250 in the east, associated with chargeability highs is corroborating well with residual gravity highs and borehole geophysical logs. Taking the geological dips into consideration these seem to be dipping steeply towards south. Making use of this aspect, a borehole is recommended at Tr: E250 at station S25 with 45^0 angle towards north to intersect the above said anomaly zone. It is also suggested that alternatively a vertical borehole may be drilled at Tr: E250/S05 to intersect the causative source.

VERY LOW FREQUENCY ELECTROMAGNETIC (VLF-EM) INVESTIGATION FOR URANIUM IN DHOFAR REGION, SULTANATE OF OMAN

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The history of uranium exploration began during early 1980s in Sultanate of Oman, wherein a number of target areas have been identified. Subsequently, a couple of sites were selected on the basis of prevailing radiation, which prompted further investigation based on geophysical and geochemical methods. Accordingly, VLF-EM survey has been carried out to delineate the subsurface targets. The very low frequency electromagnetic (VLF-EM) method is a simple and an efficient geophysical system that has been used in the investigation of uranium deposits in Dhofar region.The in- phase and out of phase components of VLF- EM field along 11 traverses were recorded at two different transmitter frequencies viz. 16 KHz and 16.4 KHz at an approximate line interval of 20 m with a measurement interval of 10 m in the study area to map structures favorable for uranium occurrence. The measured in- phase and quadrature components were subjected to Fraser and Hjelt filtering in order to decipher the nature of the subsurface conductor. The Fraser filtered of VLF-EM components peak over the top of the conductor. On the other hand, the Hjelt filtered in-phase component yields the depth to

the source as 3.4 m -8.0 m in the case of transmitter frequency of 16.0 KHz and 3.0 m - 8.3 m at transmitter frequency 16.4 KHz. Further, the computed Fourier log amplitude spectra of a couple of traverses have shown that the depth to mineralization to be in the range of 5.0 m to 7.7 m, which fairly agrees with the depth obtained from Hjelt filtering. Overall, the interpretation of Fraser and Hjelt filter output suggests a mineralized conductive zone in a faulted area aligned NW-SE indicating peaks at 300 m, 150 m and 120 m respectively along the traverses.

OPTIMUM WAVELET SELECTION: APPLICATION TO GEOPHYSICAL WELL LOG DATA

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Identification of litho-logical boundaries from well log signal stemming from heterogeneous subsurface structures assumes importance in geo-exploration studies. Well log data acquired from the various geological settings generally display non-stationary/nonlinear characteristics with varying wavelengths and frequencies**.** Modelling of such complex well-log signals using the conventional signal processing techniques either fails to catch-up abrupt boundaries or at the best, do not provide precise information on insidious litho-logical discontinuities. Here, we propose continuous wavelet transform (CWT) method to model the abrupt changes from well log data by taking care of nonlinear characteristics of the signal by using five different wavelets:e.g. Haar, Gaus1, Gaus3, Morlet , Db2. Prior to applying the method on the geophysical well data, we tested the algorithm on synthetic signal generated by the simple first order non-stationary auto-regressive model and rectangular boxcar model . Upon successful testing on synthetic data, the method is applied to actual well log dataset obtained from the KTB bore hole, Germany. Here CWT is employed on five log datasets :e.g. density (RHOB), neutron porosity (NPHI), spectral gamma ray (SGR), seismic p-wave transit travel time (DTCO) and electrical resistivity (LLD) in order to identify not only the space-localization of the formation zone but also to determine the optimum wavelet that best suits to well log data analysis. While the choice of the mother wavelet is very important for analysis of any geophysical signal, the scalogram analysis of each log signal corresponding to each wavelet offers effective means in identifying the litho-logical boundaries. The present scalogram- based analysis suggests that the Haar wavelet can be appropriate to localize the correct depth of the formation tops. But in some cases, Gaus1wavelet-based results are found to be superior to the Haar wavelet-based results in solving litho-logical boundaries. Further, histogram analysis of CWT coefficients was done to examine the above observation. Histogram plots of respective CWT coefficients depict the number of times the same CWT coefficient values occurred. Histogram analysis also suggests that in some cases, the number of occurrences of CWT coefficient is higher for Haar wavelet than both the Gaus1 and Gauss3 wavelet and in other cases Gaus1 and Haar both can be competitive in determining the proper depth of the boundary. Detailed comparative results suggest that superiority of non-Haar wavelet based results is not consistent. Moreover, in order to match the abrupt changes of the liho-logical boundary, Haar wavelet, resembling step function is used to emulate the inherent blocky/stepping nature of discontinuous well log record of KTB, Germany. The depth of the formation boundaries, which are estimated from scalogram analysis are well matched with known depth estimated from published results over KTB drilled site.

FAULT GEOMETRY ESTIMATION VIA BAYESIAN NEURAL NETWORK INVERSION OF GRAVITY DATA

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A majority of the earthquakes of the Himalayan seismic belt are of the thrust type. In addition to thrust faulting along Main Central Thrust (MCT), Main Boundary Thrust (MBT), Main Frontal Thrust (MFT), there are several other strike-slip faults (e.g., West Patna, East Patna, Monghyr-Saharsa pair fault, Malda-Kishanganj fault etc) oriented transverse to the strike of the Himalaya and continued towards south into the estuary of the river Ganges. The only transverse fault in the Darjiling-Sikkim region that has been physically mapped is the NNE-SSW trending Gish Transverse Fault (GTF).It is a sinistral strike-slip fault in the zone of transition between the Dharan salient and the Gorubathan recess. GTF fault zone consists of fault gouge in a zone ~500 m thick dipping steeply to the west and could be the northward extension of the west-dipping Kishanganj fault. These crustal features were believed to be reactivated due to N-NE convergence of the Indian plate, and likely responsible behind the incidences of damaging earthquakes in the Eastern Indian Shield and surrounding regions. Therefore, mapping of faults and its geometry particularly, delineation of blind fault geometries (e.g., length, width, depth, strike) from gravity data assumes a special significance to understand the earthquake hazards in the Eastern Indian Shield and surrounding regions. While blind faults do not have geologic surface expression, characterizing such fault geometries from state-of-the art gravity method involves the analysis of appropriate mathematical inverse modeling technique. Since the geophysical inverse problem is highly non-linear, estimation of model parameters of fault geometry from gravity data using conventional linear inversion methods is not appropriate. Alternatively, a Bayesian neural network-based inverse modeling approach is proposed to figure out the possible geometry of blind thrust and strike-slip faults on the basis of gravity data over north and south of Kishanganj, and its adjoining area, eastern Indian shield where both blind strike-slip and thrust faults can be examined.

SHORT-TIME FOURIER TRANSFORM WITH OVERLAPPING WINDOWS FOR SPECTRAL DECOMPOSITION OF SEISMIC DATA

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Short Time Fourier Transform (STFT) was introduced in 1946 by Dennis Gabor for analysis of non-stationary signals. Often new time-frequency analysis techniques are compared with STFT for accuracy.Major advantage of STFT is that it is based on Fourier Transform and is easy to understand and implement.Major shortcoming of STFT is that it provides coarser time vs frequency picture of signal. STFT has a fixed resolutionand hence width of the windowing function determines time and frequency resolution of the output.

Seismic data is non-stationary in nature and consists of various seismic events which are related to subsurface rock layers.Time-frequency analysis of seismic data provides information on frequency

content of seismic events. Various studies show that seismic events associated with hydrocarbon saturated rock layers show frequency anomalous behavior.

We have developed STFT based algorithm with implementation of four window functions namely Boxcar (rectangular) window, Hamming window, Hann window and Cosine window.While execution, the input signal is multiplied with window and then Fourier transform of the output is taken.This window is shifted in time and abovementioned step is repeated. This algorithm is tested on different numerical signals for accuracy. Length of window and overlap between consecutive windows can be changed in algorithm.Length of window is crucial parameter for generating good spectrogram of signal. Larger window length provides better frequency information at the cost of time information while shorter window length provides better time information at the cost of frequency information. In the present paper, methodology of this algorithm is demonstrated with analysis of synthetic and real field seismic traces.The spectrograms generated with different windows are compared.It has been observed that Hamming window produces optimal time vs frequency picture of signal.

DEVELOPMENT AND APPLICATION OF TIME DOMAIN SINGULAR SPECTRUM ALGORITHMS FOR 2D AND 3D SEISMIC DATA PROCESSING

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Seismic data processing and interpretations suffer from noise. The signal amplitudes distorted due to the presence of such noise and mislead the physical interpretations.In particular, complex noise (mixture of random, correlated and chaotic noises) creates serious problem than the simple random noise. Conventional filtering techniques, which depend on non-data adaptive (Fourier based) and semi data adaptive (Wavelet based) based techniques, generally render artefacts in such a non-linear and non-stationary seismic data processing. Here in order to circumvent the above problems of complex noise and domain conversion related issues, we present the following time domain data adaptive Singular Spectrum Analysis (SSA) based algorithms for seismic data processing.

i. Time Domain SSA frequency filtering technique for band pass filtering
ii. Time Slice Singular Spectrum Analysis for de-noising and data gap filling
iii. Optimized SSA based post stack de-noising
iv. Factorized and Windowed SSA techniques for faster computations
v. Time Slice Multichannel SSA based 3D seismic data de-noising and data gap filling
vi. Multichannel SSA based horizon processing
vii. TSSSA de-noising for generalized inversion based deterministic Wavelet estimation.

We tested the robustness of algorithms on synthetic data contaminated with complex noise at different levels and compared the results with appropriate conventional processing techniques. Further, the methods are applied to the 2D and 3D seismic reflection filed data. The interpretations provided from the output of the above algorithms are verified using the borehole data and discussed with reference to the geological inferences. Finally, we conclude that the Time Domain Singular Spectrum algorithms are robust for seismic 2D and 3D data processing.

TIME DOMAIN ELECTROMAGNETIC METHOD – AN EFFICIENT TECHNIQUE FOR DELINEATION OF DEEP AQUIFERS IN SEDIMENTARY BASINS

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Kachchh basin isone of the water scarce regions of western peninsular India and ground water has become important source to meet the water requirements of various sectors. However, Tertiary and Mesozoic formations, present in the area, in general do not form promising aquifer, mainly because of the clayey nature and poor groundwater quality.The upper Bhuj (Mesozoic) and Kankawathi (Tertiary) series constitute a relatively good aquifer because it has in general low salinity. Time domain electromagnetic method (TDEM) has been successfully applied in various shallow subsurface applications. The method is highly sensitive to electrically conductive targets, provides excellent vertical and lateral resolution, and, contrary to traditional resistivity methods, can be easily employed in terrains with electrically difficult surface conditions such as clay zones, dry sands, hard rocks, etc. The objective of present work is to identify aquifers and palaeochannels in Kachchh region for possible location of potable ground water.

TDEM soundings at twelve sites ineastern part of the Kachchh basin (Anjar -Rapar corridor) and fifteen sites close to Khaririver 5km west of Bhuj, Kachchh were carried out to map potential aquifer layer and the aquifer zone associated to palaeochannels of the Khari river respectively. At each sounding location 100m sided transmitter loop was laid and 9.5Amps of current was injected into the loop with different transmitter current frequencies (32,16,8,4,2, 1 Hz). Induced voltage due to time varying magnetic field is measured as a function of decay time using a receiver coil. Apparent resistivity estimated from induced voltage at each site is used for one-dimensional inversion (1-D) of the data.

The modelled 1-D section after combining the 1-D results of 12 sites along Anjar-Rapar corridor reveals a 20 to 50m thick conductive layer of 10-15 Ω.m resistivity with its top surface at 10-15 m depth. We infer this conductive layer as a probable aquifer comprising of saturated sandstone with moderate salinity. At some places along the Anjar-Raparcorridor, we have obtained a second aquifer layer at deeper levels (150-250 m) overlying a relatively low resistive layer probably comprising of clay and/or clayey sand.The results are integrated with a well-log data to better constrain the geophysical inferences.

The resistivity section obtained after combining 1-D results of the sites nearKhaririver shows a 15-20 Ω-m moderately resistive layer with 40-50m thicknesswhich is inferred as an aquifer zone at depths 30-40m. Considering the local geology and geomorphological scenario of the study area, the inferred aquifer layer could be associated with nearby palaeochannel of the Khaririver.

SURFACE AND SUBSURFACE STRUCTURES OF NORTHEAST TAMILNADU: A STUDY BASED ON GROUND MAGNETIC INVESTIGATIONS AND REMOTE SENSING TECHNIQUE

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The combined analysis of remote sensing data and ground magnetic investigations proved very useful in understanding the structure and tectonics of the Northeast Tamilnadu, which is the

crossroad between Southern Granulite Terrain (SGT),DharwarCraton (DC) andEastern Ghat Mobile belt (EGMB). The use of satellite remote sensing in delineating the structural trends has been proved beyond doubt owing to its spectral, spatial and temporal capabilities. Most of the tectonic activities that take place deep inside the surface of the earth, however, have their own surficial implications, which enable the remote sensing tool to be useful in identifying those regions. A part of northern Tamilnadu, which exhibits a complicated tectonic history, has been selected for the present study, which extends from 78°56′22″ to 79°54′36″ in the East and 12°30′to 11°31′32″ in the North. The major rivers Sankarabarani and Ponnaiyar flow through the area. The Landsat 8 data product is used for interpreting Geomorphology of the area and ASTER elevation data is used to understand the terrain topography. Most of the lineaments are identified from the DEM. DEMis proved extremely helpful in identifying major lineaments, faults, river channels and palaeo river channels. Deflections are observed in channel route, wherever it crosses faults/ major lineaments indicating neotectonic activity. Considerable low magnitude seismic activity has been noted in the area, with occurrence of few intermediate magnitude earthquakes. Seismicity analysis of the area suggests that the earthquakes fall in line with the lineaments and sometimes associated with offshore extension of lineaments. Such a scenario has been earlier noticed by NIO scientists. Overlapping lineaments and geomorphic anomalies also indicate that this region is subjected to recent tectonic activities.The ground magnetic data, collected along a 65 Km long E-W profile crosses faults, lineaments, river channels andmafic dykes. A prominent shear zone, which has no surficial expression has been identified using the remote sensing data.Its presence has been subsequently confirmed by the magnetic anomaly data. Application of various filters like analytical signal, upward and downward continuation, and vertical derivative helped in identifying major structures and terrain boundaries. The Geophysical model derived suggests that the Gangavalli shear zone (GSZ) may be acting as structural divide, which marks the different trends of mafic dykes in the area.

NEAR-FIELD GROUND MOTION SIMULATIONS FOR GORKHA EARTHQUAKE

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The 25 April 2015 earthquake that hit Nepal caused destruction on a massive scale. The rupture propagated more than hundred km eastwards at 2.8 km/s (Avouac et al. 2015). High-rate GPS and InSAR data were used by Galetzka et al, 2015 and found the width of slip pulse to be approximately 20 km and its duration to be about 6 sec. Using the source model reported in Avouac et al., 2015 we have simulated ground motion at important cities of India. Peak ground displacement (PGD), peak ground velocity (PGV) and peak ground acceleration (PGA) contours are produced for use in engineering design. As the DST-IITR installed stations were not operative during this earthquake, ground motion simulations from this work will serve as an important source response evaluation of critical infrastructural facilities.

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MARINE GEOSCIENCES

DRILLING THE ARABIAN SEA INDIAN MARGIN OMZ: A PROPOSAL TO THE IODP

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The Oxygen Minimum Zones (OMZ) ecosystem represents one of the most extreme oldest ocean environments (Levin, 2003). There is a wide interest within the paleoceanographic community and environmentalist to investigate OMZ variability in world oceans, becausethe open ocean hypoxia has profound impact on the biological processes and deep ocean biosphere. With global warming and increasing hypoxia in world oceans, it is essential to understand various factors controlling oxygen condition at thermocline depth and its consequences on marine biota on various time scales. A clear understanding of how marine biota responded to the past oxygen deficient conditions, will reveal how they will behave in future? The OMZ is also a region of de-nitrification which is the major sink for oceanic nitrate and provides a primary control for the oceanic nutrient inventory, which in turn influences global primary productivity and CO_2 sequestration by the biological pump (Suthhof et al., 2001). Thus, the strength of the OMZ modulates the de-nitrification intensity and it may have an impact on global climate.

The eastern Arabian Sea hosts one of the most intense OMZ in the world, and its history is yet unknown. The OMZ impinges the Indian margin where oxygen concentration reaches values > 0.05 ml/l leading de-nitrification. In recent paleoceanographic studies from the western Indian margin, millennial scale changes of the OMZ intensity in tune with global climatic perturbations has been documented (eg. Singh, 1998, 2007; Naidu et al., 2014; Singh et al., 2015). But the history of evolution of the OMZ since its initiation, and factors (atmospheric and/or oceanic) driving changes of its intensity on orbital to tectonic scales are still poorly known. Not much information is available about changes of thermocline circulation and ventilation history and their linkages with global ocean circulation and climate. Therefore, the seminal importance of paleoceanographic studies of the OMZ region warrants retrieving long sediment recordsfrom the western Indian margin in order to address crucial scientific issues in context of future climate change and its consequences for marine ecosystem. In this effort, an APL (Ancillary Program Letter-819) drilling proposal has been submitted to the IODP in cooperation with international scientific community (Singh et al., 2013). Societal relevance and scientific importance of this proposal and best drilling strategy for reaching the overall goals, and possibility of formulating a full IODP drilling proposal will be discussed.

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SEISMIC ATTENUATION IN GAS HYDRATE BEARING SEDIMENTS IN KRISHNA-GODAVARI BASIN - SEISMIC TO LOG SCALE

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Gas hydrates bearing sediments show a significant increase in seismic velocity compared to the host sediment, intuitively implying that there would be a reduction in the seismic attenuation (Q^{-1}) of such sediments. However, the attenuation measurements carried out in the sonic frequency range from various gas hydrate provinces show that there is a marked increase in seismic attenuation within the gas hydrate layers and the results obtained are counter-intuitive. In the present work, we try to understand the reasons for this inconsistency by computing the seismic attenuation in both the seismic and sonic frequency range using the multi-channel seismic (MCS) and sonic data respectively from the same location in Krishna-Godavari (KG) basin. The attenuation is computed by applying the frequency shift method to both the seismic and sonic datasets. The role of complex geology in attenuating the seismic signal is also studied by generating synthetic seismic data for different geologic models and by computing the corresponding attenuation. It has been found that the Q^{-1} obtained from the field seismic data compares well with the Q^{-1} computed for a simple layered geological model. The results obtained from this study indicate that the Q^{-1} (0.0035) derived from the field seismic data is much lower than Q^{-1} (0.0125) obtained from the sonic data for the gas hydrate bearing sediments in the KG basin.

SULFUR –IRON-CARBON SYSTEMATICS IN MARINE SEDIMENTS: A STUDY OFF MAHANADI BASIN, BAY OF BENGAL

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Marine geochemical cycles of carbon, sulfur and iron are highly integrated. Microbial sulfate reduction, sulfide oxidation, organic matter degradation and sulfurization of iron and organic matter control the S-Fe-C geochemical cycles. In order to study the S, Fe and C relationship a sediment core (MD161-19) was recovered from the Mahanadi offshore basin. The 39 m long core was recovered onboard *Marion Dufresne* ata water depth of 1480 m(Lat: 85° 41.1669E; Long: 18° 59.1020N).The pore-water sulfate concentration profile shows quasi-linear trend with a gradient of 1.61 mM/m. The sulfate methane transition zone (SMTZ) lies within 1500-1900 cmbsf. The total alkalinity increases steadily down core and reaches a maximum of 22 mMin the SMTZ and subsequently decreases. Total organic carbon content ranges from 0.19 to 2.14 wt%. Chromium reducible sulfur (CRS-pyrite) was

extracted from the sediments using boiling 1M $CrCl_2$(in 6N HCl) in an oxygen free reaction vessel with continuous nitrogen flow. H_2S trapped by reduction of sulfide is trapped as CdS in a cadmium nitrate solution and subsequently re-precipitated as Ag_2S by adding $AgNO_3$. A total of 249 samples were analysed for CRS concentrations and sulfur isotope ratios. Remarkable ^{34}S depletionsin CRS (down to $^{34}S_{CRS}$ -49‰ VCDT) have been observed in the core. The CRS concentration varies from 0.002 to 0.64 wt% and shows multiple zones of high concentrations. The CRS concentration is controlled by the reactive iron contents as well as dissolved hydrogen sulfide availability in the sediment porewaters. On the other hand,$^{34}S_{CRS}$ depends on the microbially induced S isotope fractionation factor and relative importance of early and burial diagenesis. Burial diagenesis normally results in precipitation of ^{34}S enriched pyrite.The ^{32}S enrichment may be attributed to disproportionation of sulfur intermediates like S^0 or sulfate reducers capable of carrying out large fractionation during sulfate reduction.

CONTROLS ON EVOLUTION OF GAS-HYDRATE SYSTEM IN KRISHNA-GODAVARI BASIN, OFFSHORE INDIA

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In this study we analyzed rockmagnetic, sedimentological and geochemical records of sediment core retrieved from proven gas-hydrate location to understand the stages of evolution of gas-hydrate system in a geologically complex sedimentary environment of Krishna-Godavari (KG) Basin. Based on sediment magnetic and geochemical signatures, four distinct sedimentary units are identified. The decrease in magnetic mineral concentration, magnetite particle size, FeD and high TOC in Unit – I (1.4 - 11.2 mbsf) represent the diagenetic environment. The Unit - II (13.6 - 45.7 mbsf) is marked by low magnetic susceptibility and relatively higher CRS concentration represents a zone of pyritization. An anomalous zone of enhanced susceptibility in Unit - III (52.0 - 160.4 mbsf) coincides well with the gas hydrate stability zone. The electron microscopy on the magnetic extracts confirms the presence of well preserved unaltered buried Fe-Ti rich coarser magnetic grains in this zone. The Unit - IV (180.0 - 198.4 mbsf) with marked decrease in magnetic signals lies below the BSR and possibly represents the remnants of the incomplete pyritization of Unit – II. Analysis of high-resolution seismic, bathymetry, and sub-bottom profiler data suggest the existence of regional fault system in KG Basin. Three major fault system (F1, F3, and F4) and four gas-hydrate bearing layers (L1, L2, L3, and L4) have been identified. A pronounced discontinuity in all gas bearing horizons and the movement of this fault system has resulted in the formation of seafloor mound in the study area. We hypothesize that the major fault system got activated at the base of Unit – II which further provided a permeable pathway for the migration of free gas along the fault system within the sediment column. The enrichment of CRS and marked decrease in susceptibility, FeD and Mo anomaly suggest the period of enhanced methane seepage which consequently lead to anaerobic oxidation of methane. As a result large amount of hydrogen sulphide was produced which reacted with available Fe-oxides resulting in formation of authigenic carbonates. This finding supports the hypothesis.

At the sametime, the gas hydrates might have been accumulated in the hydrate stability zone (Unit - III) which leads to the formation of gas hydrates and burial and preservation of detrital coarse magnetic grains. It is highly possible that the hydrate in this zone acted as an impermeable layer and eventually leads to the closure of fault system. We believe that the deactivation of the fault system occurred at the top of Unit – II and the present day deposit (Unit - I) do not show any magnetic signatures of methane seepages or dissolution of magnetic minerals. A conceptual model explaining the evolution stages of gas hydrate system in KG Basin is developed by summarizing all findings.

ABIOGENIC GAS HYDRATES: A CASE STUDY FROM THE INDIAN OFFSHORE REGION (BAY OF BENGAL)

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The matter of origin of hydrocarbons has been debated since long; especially it has been debated strongly during past 50 years. Even now, most of the westerners (Americans and Europeans) believe that hydrocarbons are biogenic, Russians are firm believer that abiogenic processes are mainly responsible for formation of hydrocarbons on this planet Earth's. The details of this debate are nicelyreviewed by Glasby (2006) and Etiope and Lollar (2013).We feel that this aspect needs to be reckoned with the Indian context so as to explore the hydrocarbon deposits in the offshoreregion so as to increase hydrocarbon production. Drilling by JOIDES Resolution have shown the almost absence of gas hydrates in the Arabian Sea whereas presence of world's largest and thickest gas hydrates deposits in Bay of Bengal. Although preliminary studies on the cores collected by JOIDES Resolution show that the methane for the formation of gas hydrates in Bay of Bengal isof microbialorigin (Collett et al., 2014; Kumar et al., 2014). We argue against these results and propose abiogenic source of methane could a possible reason for the formation of gas hydrates in the Bay of Bengal. Further studies are in progress for comprehensive understanding of the process involved in this part of study area. Nevertheless, it must be reiterated here that, with regard to gas hydrates exploration, the Bay of Bengal seems to highly promisingand we need to develop new strategies for its future exploration.

A NEW METHODOLOGY OF PORE PRESSURE PREDICTION FROM SEISMIC DATA IN KRISHNA-GODAVARI BASIN

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Predrill estimation of pore pressure (PP) from seismic data is a standard practice followed by many major oil companies. PP information guides the development of the mud schedule, casing program, rig selection and wellhead ratings. Pore Pressure analysis can be useful in understanding geological influences on maturation and migration of hydrocarbons, and their ultimate trapping in reservoirs that are reachable with the drill bit. In recent years prediction of pore pressure based on 2D/3D seismic allow scanning to provide alternative well locations and to see the distribution of pressure with respect to the structure and geology. In this paper, we describe the procedure of PP prediction from 2D marine seismic data acquired over NGHP-01-10 site in the Krishna-Godavari

(KG) offshore, India.PP has been predictedin the gas hydrate bearing sedimentsin KG basin at site-10 of National Gas Hydrate Programme (NGHP) Expedition-01 using multilayer feed forward neural network (MLFN). A series of elastic parameters namely P-wave velocity (Vp), S-wave velocity (Vs), density (Dn), Vp/Vs, P impedance (Zp) and S impedance (Zs) have been derived from seismic data using pre-stack inversion. PP has been predicted using MLFN network for the study area with above mentioned seismic sections including four wells. PP estimated from the sonic transit time log has been calibrated with pressure core measurement for the depth interval 1060-1280 m and its magnitude is ranging from 10.5 to 12.9 MPa where the vertical stress varies from 10.7 to 13.4 MPa at the same depth interval. The estimated PP has been treated as target log and Zp, Zs, Vp/Vs and Dn have been used as input parameters during the training of MLFN. The trained network is then used to generate subsurface PP along two 2D multi channel seismic section (line-X and line-Y) at site NGHP-01-10 within the time interval of 1420 – 1620 ms corresponding to the depth interval of 1060-1280m. The result shows the pressure is hydrostatic within gas hydrate bearing sediments and above-hydrostatic below the gas hydrate bearing zone.

THE CHAIN-KAIRALI ESCARPMENT: DOES THIS TRACE REPRESENT EXTENSION OF THE VISHNU FRACTURE ZONE?

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The bathymetry map of the southwestern continental margin of India clearly depicts the presence of an escarpment, referred as Chain-Kairali Escarpment, which borders the northwestern boundary of the Alleppey-Trivandrum Terrace Complex located in the southwestern continental margin of India. The satellite gravity map of this region shows that the Chain-Kairali Escarpment is collinear with the trend of the Vishnu Fracture Zone, which connects the magnetic lineation in the Arabian and Central Indian basins. Based on this observation, several researchers considered the Chain-Kairali Escarpment as the landward extension of the Vishnu Fracture Zone. The plate reconstruction model at chron 22ny (~49.0 Ma) shows that the trace of Vishnu Fracture Zone is conjugate with the Mauritius Fracture Zone while plate reconstruction model at chron 34ny (~83.0 Ma) shows that the Chain-Kairali Escarpment is conjugate with the Mahanoro Fracture zone. If the Chain-Kairali Escarpment is the landward extension of the Vishnu Fracture Zone, the same feature cannot be conjugate with two different fracture zones which are ~300 km apart and therefore this inference is inconsistent with the plate tectonic evolution of the Western Indian Ocean. We carried out detailed investigations in this region to address this problem, using the latest available magnetic anomaly picks and rotation parameters that depict the evolution of the Mascarene Basin, complemented by the satellite-derived free-air gravity anomalies and published seismic sections. The spatio-temporal evolution of the tectonic elements from the conjugate margins of India and Madagascar were examined based on plate tectonic reconstruction. Our study clearly shows that the Chain-Kairali Escarpment represents the trace of the transform segment of the plate boundary existed between the Alleppey-Trivandrum Terrace Complex and the southeast continental margin of Madagascar during the India-Madagascar break-up, which was initiated slightly before chron 34ny (~83.0 Ma). During this period, the spreading between India and Madagascar was nearly in E-W direction and a major spreading reorganization took place soon after chron 33no (~79.1 Ma), with an average spreading direction of ~ N50°E till the extinction of spreading in the Mascarene Basin. This inference on the reorganization of the spreading centre, computed from the rotation parameters, is consistent with the curved nature of the fracture zones in the Mascarene

Basin. At around 60.25 Ma, the spreading in the Mascarene Basin was ceased and as a consequence, the spreading centre forming the conjugate Arabian and Eastern Somali basins was connected with the spreading centre forming conjugate Central Indian and Madagascar basins. This long offset transform fault initiated the formation of the Vishnu Fracture Zone in the Indian side that limits the western boundary of the Central Indian Basin. Our study clearly shows that though the Vishnu Fracture Zone and the Chain-Kairali Escarpment are collinear in nature, they are two independent features formed at different stages of India-Madagascar relative motion. Therefore, we infer that the Chain-Kairali Escarpment does not represent the landward extension of the Vishnu Fracture Zone.

SEISMIC MAPPING OF GAS HYDRATE DEPOSITS IN ANDAMAN SEA

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We analyse2-D seismic data for the delineation of gas hydrates in complex geological setup of the Andaman Sea. The bottom simulating reflectors (BSRs), which often coincide with the gas hydrate stability thickness, have been identified along several seismic profiles.The gas hydrate stability thickness, estimated from modelling of bathymetry data along the seismic profiles using in situ measurements, ranges from ~430 m to ~ 640 m below seafloor (mbsf) at water depth varying between ~1200 m to ~2100 m off little Andaman. The gas hydrate stability thicknessof ~610 mbsf along the seismic line crossing the Site NGHP-01-17 matches quite accurately with the drilling information. This is one of the deepest BSRobserved worldwide. To understand the unusualdepth of BSR, we performed geothermal modelling of the base of gas hydrate stability zone (i.e. BSR) and estimatedthe heat flow from the BSR depths using a 1-D conductive model. The BSR-derived heat flow values varyup to ~42 mW/m^2in the study area and follow the bathymetry trend of dominant North-South ridge, and can be explained with the east-ward increase in heat flux toward the currentseafloor spreading centre. We also modelled the estimated heat flow using 2-D/3-D topographic modelling approach. Our analysis suggests anextensively variable base of gas hydrate stability zone in the Andaman Sea, controlled mainly by overall low geothermal gradients due to prevailing volcanic sediment cover. Consistent local minor variations were observed with lower heat flow values over prominent topographichighs and higher values in valleys or troughs due to focusing and defocusing effects of the topography respectively.

EVOLUTION OF THE SHELF-SLOPE ARCHITECTURE ALONG THE WESTERN CONTINENTAL MARGIN OF INDIA

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The movement of Indian plate between 90 and 50 Ma stands unique in its geological history because of a number of relatable events that shaped Western Continental Margin of India. Most of these events are a result of plume-crust interactions. Further there is an uncanny link between some of these events, namely, formation of Saurashtra Igneous province, Palitana Ridge rejuvenation, sudden spurt in Deccan eruption at around 65Ma, and northward acceleration of India, indicating a common external cause.

There has been an extensive investigation by employing geophysical, geochemical and geostratigraphic techniques. Analysis of data thus obtained suggests the presence of a huge crater beneath the Indian Western Continental Margin dating roughly 65 Ma. A massive bolide creating this feature and triggering rapid eruption of the Deccan Flood Basalt Province is by far the most probable answer to this query.

We examine the physical and thermal forces contributing considerably to the evolution of the shelf-slope architecture along the Western Continental Margin of India.

TSUNAMI MEMORY AND ITS SEDIMENTARY ORGANIC VALUES

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The Indian Ocean Tsunami,2004 generated by the submarine earthquake was measured as of 9.3 magnitude on Richter scale had fatal the Southern Indian Coastal areas causing the human,cattle and agricultural havocs heavily. The Nagapattinam–Cuddlaoreshelf was reported as concave shape with slopes.Further the geophysical reports had indicated the existence of the megalineaments which had shaped the morphology with faulty structure had favored the wave run ups to height for inundating the coastal areas.The tsunamigenic sediment deposited in the affected coastal areas of Pondicherry region were collected for physical and chemical analyses to assess the tsunami depositional characteristics. The affected villages are Ariyankuppam, Thengaithitoo, Kalapeth, Panithitoo and in some adjoining Tamilnadu state coastal areas. Total 80 sediment and 25 groundwater samples were collected for analyses. Some shallow depth groundwater samples were affected by tsunami water intrusion showing salinity.

For the sediments samples, the inorganic and organic chemical analyses were done to assess the tsunami characteristics. In Inorganic analyses, pH, Conductivity, available N, P, K was determined as agricultural analyses. Similarly, the same inorganic analyses were conducted by the respective experts in Karaikal region of Pondicherry, Andaman, Cuddalore, Villupuram, Nagapattinam,Chennai districts of Tamilnadu. The pH values had been different from acidity to alkalinity ranges which led to argumentative. But the salinity ranges were recorded in the analyses.The available Phosphorus values were found exorbitantof maximum 80 kg/ac which were abnormal.

Further the organic analyses were done for the sediments by using Infra-Red, Mass Spectrometric methods. In some cases, Ultra Violet spectrometric analyses were also conducted to explore the biomarkers.The IR absorption at 1000 and 1350 cm^{-1}as wave numbers represent the presence of Phosphatic compounds as esters and acids.The P compounds undergo degradation in P cycles. Another significant compound as Phosphonate (RPO_3^{2-}) group was also detected by IR peaks at 1000,1730 and 2350cm^{-1}The Phosphonate cannot undergo degradation and it is recalcitrant depicting the palaeo-environmental indicator.The P compounds are considered as the key components in tsunamigenic marine sediments. The available P enrichment also confirmed the P anomaly.

Another compound identified was the sterol derivatives as cholestene as acid and alcoholic fractions.The IR peak at 1050 cm^{-1}, Mass spectral diagnostic fragmentary peaks at m/z 213 and 231 plus Ultra Violet spectrometric absorption in 200 nm,270-289nm support the presence of Cholestene compounds which were also representing old geologic formation. So the analyses results propose

the tsunamigenic sedimentary origin was from the old geologic bathymetry deposits. Acenone as Acetophenone compound was also found from the observance of IR peak at 1690 cm^{-1} as wave number, Mass spectral fragmentary chief constituent peaks at m/z40 (for –CO) and m/z43 (-COH_2).Alkenone series produced mainly by haptphyte algae vary with salinity,temperature nutrients conditions. They show degradations to oxic condition rather than anoxic states.

MARINE VALUES: The presence of P as Phosphatic and Phosphonatic derivatives form the chief tsunamigenic marine compounds. The P compounds are the key compounds to generate the primary productivity in the ocean and it is associated to ATP molecularfunction.The presence of Phosphonate support the old geologic bathymetry formation. Due to time lag of chemical analyses to realize the organic P sedimentary deposit utility and due to the immediate rain spells, the organic P manurial values equivalent to about 5 Tons of Superphosphate was washed away by rainwater as wastes. The C-20 cholestene-carboxylic acid and alcoholic compounds(Etienic acid and Etien-ol) function as Anti Fertility drug formulation synthesis.Alkenones /acenones suggested as a novel proxyfor sea level changes especially in fossil isolation basins.

PORE WATER SULFATECONCENTRATIONS AND SULFATESULFUR ISOTOPE RATIO MEASUREMENTS FROM IODP 353

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IODP Expedition 353 conducted drilling operations in the Ninety East Ridge, Bengal Fan, Mahanadi and Andaman basins. Pore waters were extracted and concentrations were measured for sulfate ion, total alkalinity, ammonium and metals onboard JOIDES resolution. Sulfatesulfur isotope ratios (□34Sso4) were measured at NIO, India. In this study we present pore water sulfate concentrations and □34Sso4values from Mahanadi (site U1446B) and Andaman (site U1447B) basins. Pore water sulfate concentrations decreases with depth and reaches to near zero values at ~16 and ~23 mbsf at Mahanadi and Andaman basins respectively. An enhanced slope in the sulfateconcentration profile is observed within the depth zones of ~7.3-9.5 and ~4.4 - 6.9 mbsf in Mahanadi and Andaman cores respectively. Below 6.9mbsf sulfate concentration profile follows concave down patternat Andaman site. □34Sso4 values increase with depth and reache upto 54.6 and 94.7‰ (VCDT) in Mahanadi and Andaman basins respectively. The difference in the extent of enrichment is possibly because of the variation in sulfate reduction rates and/or nature of sulfate reducing bacteria present in two basins. □34Sso4profiles also show slope changeat depths corresponding to the slope changes observed in sulfate concentrations. Further studies on sediments are required for better understanding of the pore water profiles

SPACE, PLANETARY & ATMOSPHERIC SCIENCES

IONOSPHERIC PLASMA TURBULENCE IN VLF RANGE OBSERVED BY DEMETER SATELLITE DURING EARTHQUAKE: A STATISTICAL ANALYSIS

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Observation of ionosphericplasma turbulence in very low frequency (VLF) range registered by DEMETER satellite is investigated. The anomalous variations of the electric field have been seen during high seismic activity. The ICE payload of the DEMETER French microsatellite allows to measure electric field with high temporal resolution in the ionosphere over the seismic regions. In the present work, analysis of the very low frequency fluctuations of the electric fields for three selected earthquakes in Carlsberg Ridge (2008),Chile (2009), and Indonesia (2009) are givenspecial attention to studyvariation in spectral characteristics and search for non-linear effects, using the statistical and wavelet based techniques.The enhancement in statistical parameters shows the coherent structure and intermittent phenomenon, which is the signature of turbulence. The characteristic features of VLF disturbances have further been studied using the wavelet and bi-spectral analysis tools, which provide useful information on the plasma turbulence.A more interestingresult emerges when the low-frequency turbulence emissions produceturbulence in VLF range. Finally, the relevance of various turbulence mechanisms and their importance in ionospheric turbulence is discussed. The mechanism of energy transfer from earthquakes to the ionosphere is not clear, but the behavior of the ionospheric plasma and the search for instabilities, which could be a possible source of electromagnetic turbulence will be discussed in the presentation. A brief description of spectral characteristics and multi-spectra is given. Attention is particularly given to the effect prior to the earthquake, when a nonlinear interaction leading to a lower hybrid wave generation was directly seen.

ROLE OF ATMOSPHERIC WAVES IN SEEDING THE EQUATORIAL SPREAD F: FIRST RESULTS

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The study deals with the observational confirmation for the role of atmospheric waves in seeding the Equatorial Spread F (ESF), an enigmatic phenomenon in the equatorial/low latitude ionosphere. Though many theories have been proposed to explain the formation of ESF, the exact causative mechanism remains inexplicable. The widely accepted theory for the formation of ESF is the collisional Rayleigh-Taylor instability, which is believed to be triggered by the forcing like short period waves of lower atmospheric origin. However, the role of such waves in triggering the formation of ESF is not well studied primarily because of the lack of simultaneous observations on both neutral and plasma parameters at these altitude regions. In this context, the present study aims at investigating the role of atmospheric gravity waves in seeding the formation of ESF using the data from collocated Portable Nighttime Photometer and Digital Ionosonde over Trivandrum (8.5^{o} N, 77^{o} E, 0.5^{o} dip lat.), a geomagnetic dip equatorial station in India. The analysis of the mesopause temperature and ionospheric parameters obtained from the aforesaid instruments during the March 2014 period revealed that the gravity waves of lower atmospheric origin play a major role in the generation and sustenance of the ESF. It has been observed that, in general, the gravity waves of 0.5-1 hour period were found to be

amplified in the mesopause temperature whenever ESF occurred. On the other hand, no ESF was observed when the wave gets weakened. It is inferred that the enhanced wave activity at these altitude regions plays a major role not only in seeding the ESF, but also in the sustenance of the phenomena .This is a classical example of the vertical coupling between neutral atmosphere and Ionosphere and the study discusses these aspects in detail.

THE ROLE OF THE PROMPT PENETRATION ELECTRIC FIELD ON THE NET DISTRIBUTION OF ELECTRON DENSITY OVER THE INDIAN LOW LATITUDE REGIONS: STUDIES BASED ON SEVERE, INTENSE AND MODERATE STORM EVENTS

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The response of equatorial and low latitude ionosphere–thermosphere system to a geomagnetic storm/ sub-storm event has remained an enigmatic issue though several studies have been carried out so far. As is known, during geomagnetic storms large amount of energy enters in to the Earth's atmosphere because of the interaction between the Earth's magnetosphere and the interplanetary electric field. As a result of enhanced energy during the disturbance period, the ionosphere differs significantly from its quiet time behavior. Large variations on a global scale in the neutral dynamics, electrodynamics and chemistry of the atmosphere - ionosphere system have been shown to exist during such events. Geomagnetic storms may affect the generation or suppression of the equatorial spread F. Such ionospheric irregularities degrade the trans-ionospheric transmissions strongly.

Unlike high latitude ionosphere, though the equatorial and low latitude regions are not directly connected with the interplanetary electric field, there are two ways in which the electro dynamical coupling happens at the equatorial low latitude regions. These are (a) the prompt penetration on a short time scale (hours or less), and (b) Disturbance dynamo on a 1 to 2 day time scale. While the penetration of the electric field is due to the dynamical interaction between solar wind and the magnetosphere, the disturbance dynamo is because of the changes in the thermospheric circulation as a result of auroral heating. At the time of prompt penetration, the dawn to dusk convection electric field penetrates almost instantaneously from the high latitudes to the low and equatorial latitudes. Since any change in the equatorial electric field directly affects the distribution of plasma over the low latitude regions via the fountain effect, the studies dealing with the efficiency of prompt penetration electric field and its impact have always remained important.

In the present paper, relative roles of the prompt penetration electric field and the neutral wind in the distribution of the electron density over the Indian region during the periods of geomagnetic storms have been discussed. Four geomagnetic storms of varying strength but same local onset time have been analyzed with the help of measurements from ACE satellites, magnetometer, GPS satellites and TIMED/GUVI satellites. The magnitude of prompt penetration electric field was estimated with the help of measured strength of equatorial electrojet, whereas the electron density distribution over the Indian region was quantified using GPS derived vertical total electron content (VTEC) at the equatorial, low latitude, crest and mid latitude end of crest locations.

Our results show that though the signatures of prompt penetration electric field was present for all the storms considered whose main phase was during local day time, the strength of the penetration

electric field was directly proportional to the latitudinal extent of perturbations in the plasma density. During a severe geomagnetic storm on 15 May 2005, the gradient in electron density extended till Shimla, a mid-latitude station, while it remained limited to the anomaly region during a moderate geomagnetic storm on 20 May 2015. The ratio of O/N2, estimated using TIMED/GUVI satellites, which directly indicates modulation is the neutral density, show no proportionate changes to explain the increase in the plasma density in equatorial/ low latitude region during the geomagnetic events. Our analysis shows that at least during the day of storm onset, the penetrating electric field is the important factor controlling the electron density distribution in the low latitude region.

ATMOSPHERE-IONOSPHERE COUPLING DURING COUNTER ELECTROJET EVENTS

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This paper discusses different coupling processes in the equatorial upper atmosphere during an enigmatic phenomenon, namely the Equatorial Counter Electrojet (CEJ). The analysis is carried out using the data from various optical and radio probing instruments over Trivandrum (8.5°N, 77°E, 0.5°N dip lat.), a geomagnetic dip equatorial station in India. It has been found that both the energetics and dynamics of the equatorial upper mesosphere lower thermosphere behave distinctly different during the CEJ events. The most important features observed associated with the CEJ events are: (i) an eastward increase in the zonal wind at 98 km altitudes, (ii) a clear-cut cooling in the mesopause, which in turn is proportional to the extent of the magnetic field reversal and (iii) an enhanced gravity wave activity of 1-2 hour periodicity in the equatorial mesopause temperature. In addition to these, the CEJs were observed to be occurring in a group with a quasi periodicity of 16-days associated with the northern hemispheric Stratospheric Sudden Warming (SSW) events. It is interesting to note that intense SSW events were associated with strong CEJs. These aspects are discussed in terms of the prevailing changes in the dynamics and electrodynamics over the equatorial region.

INFLUENCE ON CRITICAL LOAD CAPACITY OF SOIL DUE DEPOSITION OF DUST AEROSOLS IN THE DELHI REGION (INDIA)

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This paper reports air quality characterization and its implications for critical load capacity for the soil system in Delhi. The study was carried out by using data of MODIS-derived aerosol optical depth (AOD) and measured Suspended Particulate Matter (SPM), NO_2 and SO_2 values mapped using geospatial techniques across India. The results showed the significant differences in the levels of SPM, NO_2 and SO_2 across rural and urban sites. The north and central Indian districts have relatively higher SPM concentrations as compared to southern India due to high loads of atmospheric dust. Furthermore, a trend analysis of SPM, NO_2 and SO_2 in the Delhi region, which was carried out using the Central Pollution Control Board (CPCB) data, revealed a continuous increase in the SPM levels in the city. This led to the calculation of the critical load of atmospheric acidity for nitrogen and sulphur in order to check the vulnerability of the soil systems in Delhi. In this study, a Critical Load approach similar to the European method was applied to assess the vulnerability of natural systems to the present day

atmospheric pollution scenario in the capital city of Delhi. The calculated values of critical loads of sulphur (225 - 275 eq/ha/yr) and nitrogen (298 - 303 eq/ha/yr), for the soil system in Delhi, were calculated with respect to Anjan grass, Hibiscus and Black siris. According to the results, present loads of sulphur (PL(S) = 26.40 eq/ha/yr) and nitrogen (PL(N) = 36.51 eq/ha/yr) were found to be much lower than their critical loads. This means that the present levels of acidity do not pose any danger to the soil systems. The study indicated that the system is still protected due to buffering capability of calcium derived from soil dust, which can be considered as a natural tool to combat acidification in the Indian region. The results showed that the pollution status in Delhi is still within the safe limits in terms of acidification. However, at the pace at which the city is growing, it is likely that in coming decades, it may exceed these critical values.

REGIONAL ANOMALIES OF GREAT GEO-MAGNETIC STORMS RECORDED IN INDIA

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The source of magnetic storm is a ring current circling the Earth in equatorial plane. The geomagnetic variation caused by the ring current is axially symmetrical and has no longitudinal/local time dependence. Most of the research work on the regional disturbances of the geomagnetic field has focused on its theoretical model. There have not been many statistical studies on this subject. Industries such as electricity networks and underground pipelines also rely on information of local magnetic field disturbances, but the present global space weather forecast cannot satisfy their requirement. The dependence of technical system on local magnetic disturbances will become stronger as science and technological innovations develop. Therefore, the local difference cannot be neglected, and a local magnetic field forecast based on global space weather forecast would be useful in the near future.

Considering the importance of anomalies of local magnetic field variations,**M**ulti-**D**imensional **S**caling of geomagnetic storm time ranges has been carried out in this study. Data of digital fluxgate magnetometer from Indian network of nine geomagnetic observatories-Alibag, Gulmarg, Hyderabad, , Jaipur, Nagpur, Pondicherry, Shillong, Tirunelveli and Visakhapatnam during powerful geomagnetic storms where the storm time ranges of sensitive horizontal (H) component exceeds 100 nTrecorded in the year 2011 and 2012 are considered for this analysis. Pondicherry and Visakhapatnam are very close to each other and Hyderabad which is geographically close to Pondicherry stands apart from all other observatories in respect of spanning distances measured by Multi-dimensional Scaling. It is suggested that data of Pondicherry Observatory can be taken as a prime value for comparing any geomagnetic phenomena. Analytical technique and the result of the analysis are detailed in this work.

INVESTIGATING THE TWO CONSECUTIVE SOLAR CYCLES 23 AND 24

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The primary sources of major geomagnetic disturbances witnessed at the Earth originate in the Sun. Major geoeffective solar wind flows are the interplanetary counterparts of coronal mass ejections (CMEs) known as Interplanetary coronal mass ejections (ICMEs) and corotating interaction

regions (CIRs). The CMEs are highly energetic (10^{27} ergs to 10^{33} ergs) transient sporadic emissions accompanying huge mass (10^{13} g -- 10^{16} g) that erupt from the solar corona with a speed ranging from a few km/s to nearly 3000 km/s. Full halo CMEs propagating along the Sun-Earth line cause intense geomagnetic disturbances. The solar activity exhibits ~ 11 years periodicity which is reflected in sunspot numbers, f10.7 cm solar flux etc. Different solar cycle phases are dominated by diverse geoeffective solar wind flows. During the ascending and solar maximum phases, ICMEs and sheath fields dominate. In contrast, the descending phase of the solar cycle is dominated by the occurrence of large polar coronal holes which extend from the polar regions to the lower solar latitudes during this period. The current solar cycle (24) following the deep solar minimum distinctly exhibits weaker activity as compared to the previous cycle (23) in several aspects. We present a comparative analysis between the two consecutive solar cycles 23 and 24. Both the cycles witnessed dual-peak as observed in the sunspot numbers, but for the cycle 24, second peak is higher than the first one. Interestingly, it is observed that during the entire interval between ascending to maximum phases of cycle 24, the southward directed Bz (Bs) and dawn-dusk electric field (Ey) were consistently weaker as compared to that during similar interval of cycle 23. The geomagnetic field response represented by Dst and SYM-H indices was in close correspondence with the solar wind-interplanetary conditions during both the periods. Intense storm occurrence rate revealed a reduction by a factor of about 1/5 during the current solar cycle as compared to the previous one. However, moderate geomagnetic storm occurrence is nearly comparable during both the periods. Drastic reduction in number of intense geomagnetic storms and insignificant difference between moderate geomagnetic storms during the current cycle indicate diminished occurrence of interplanetary coronal mass ejections and/or their sheaths in comparison to the corotating interaction regions.

MICROWAVE EMISSIVITY OF DESERT/ARID LAND SURFACES

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In contrast to land surface classes (such as forests, agricultural fields, waterlogged marshy land etc.), the accurate estimation of microwave emisivity over arid regions is a challenge. Low frequency microwaves have deeper penetration into dry soil media and hence, the effective radiating temperature of the soil medium deviates significantly from the skin temperature. This limits the accuracy of emissivity estimation for arid surfaces from satellite brightness temperature data. Limited attempts have been made to estimate emissivity over desert/arid regions, which cover nearly one-third of the continental area. These studies have been confined to the Saharan and Arabian deserts. In contrast to this, the emissivity patterns over the dry continent of Australia, which has 80% of its mainland covered by different types of deserts (ranging from gravel covered deserts to sand dunes), semi-arid regions, salt lakes, dry lake beds and dry savannas and grasslands, are least characterized.

As such, land surface microwave emissivity and its spatial and temporal variability over different types of arid regions that occur almost contiguously over Australia, has been taken up as a case study. An analysis has been made to evaluate the error incurred in emissivity estimation due to this temperature disparity. The characteristic features of dominant surface classes in Australia have been studied based on monthly mean emissivity estimation. In-situ measurements of soil temperature profiles over Australia confirms that an isothermal condition exists at around 00 UTC

and the emissivity estimated during this time window can be assumed to contain minimum errors due to invalid assumption of skin temperature as the emitting temperature. The emissivity variation in afternoon hours (1400 hrs LT) and night (0200 hrs LT) from that at morning hours (0800 LT) is studied for the summer month of January 2011. The emissivity is underestimated (0.02-0.03) in the afternoon hours. Averaging the emissivities estimated from satellite observations at different times of the day is found to reduce the errors in emissivity estimation caused due to the temperature disparity. Thus, for better emissivity estimates with minimum errors one has to use satellite observations during the morning hours (such as DMSP satellites) or preferably use daily average emissivity datasets based on observations at different times of the day (such as those from Megha-Tropiques and TRMM). The subsurface emission analysis over a desert soil can be extended to analyse the radiometric observations of planetary bodies such as Mars, Venus etc., at longer wavelength, where subsurface thermal emission is significant.

RADIATIVE IMPLICATIONS OF AEROSOLS OVER HIMALAYAN GLACIERS

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Deposition of absorbing aerosols on highly reflecting surfaces (like snow or ice) significantly reduce the surface albedo at the visible wavelengths and result in positive radiative forcing (warming) at the top of the atmosphere and potential implications on the regional climate and hydrological cycle. The surface darkening due to Black Carbon (BC) deposition is being increasingly projected by modeling studies as a major factor contributing to the faster snow melting over Himalayas. In the backdrop of the projected climate implications of aerosol induced snow darkening, extensive measurements of atmospheric BC have been carried out from several Himalayan glaciers during the short expeditions and continuous long-term measurements from few selected high-altitude stations and a chain of observatories along the Himalayan foothill regions, under ARFI project.

To understand the characteristics of BC aerosols near/over the glaciers, a pilot expedition has been undertaken to the Satopanth glaciers from 28 September to 5 October 2011. As we moved away from the valley to higher altitudes, the magnitude of BC in the atmosphere decreased significantly and we have observed almost a steady BC value of 190 ng m^{-3} at the remote Himalayan regions. Based on the optical and physical properties of composite aerosols measured at Hanle, clear sky direct radiative forcing (DRF) at the top of the atmosphere is estimated at 1.69 W m^{-2} over snow surface and -1.54W m^{-2} over sandy surface during pre-monsoon season. The estimated amount of BC in the snow varied from 117 to 1.7 μg kg^{-1} for wide range of dry deposition velocities (0.01-0.054 cm s^{-1}) of BC, snow depth (2-10 cm) and snow densities (195-512 kg m^{-3}). The diurnally averaged forcing due to snow darkening has been found to vary from 0.87 to 10.2 W m^{-2} for fresh snow and from 2.6 to 28.1 W m^{-2} for the aged snow, which is significantly higher than the DRF. The direct and surface albedo RF could lead to significant warming over the Himalayas during pre-monsoon.

ON THE DISTRIBUTION OF PLASMA OVER LOW AND MID LATITUDE REGION DURING THE INTENSE GEOMAGNETIC STORM OF MARCH 17,2013

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The impact of an active geomagnetic storm (Dst ~ -130 nT) of March 17, 2013 on the concentration and distribution of ionospheric plasma in the equatorial, low and mid latitude ionospheric regions has been studied. The storm had its onset coinciding with the local noon in the Indian ionospheric sector. An interesting aspect of the storm was a large fluctuation in IMF Bz, which kept on changing its polarity in quick succession for about 12 hours. It is known that a fast fluctuating IMF Bz results in a CEJ like situation at the dip equator due to the under-shielding of the prompt penetrating electric field by inner magnetosphere. It indeed was a case at Trivandrum on March 17 with the on-site Digisonde showing a sharp decrease in the daytime hmF2 (altitude of F-region peak density) by as high as 100 km compared to the monthly average at 16:00 LT, a signature of westward polarity of background zonal electric field resulting due to a CEJ. But the most interesting aspect of the storm was an almost simultaneous increase in the total electron content (TEC) in the entire Indian ionospheric region. In comparison with the monthly mean, there was a conspicuous increase in TEC at the dip-equator (Trivandrum, 8.5 N). The magnitude of increase compared to monthly mean, however, slowly receded and had almost no change in its magnitude at the anomaly crest (Bhopal, 23.8^{o} N ; and Gaya, 24.7^{o} N). Poleward of the anomaly crest, the TEC once again started increasing and at Shimla (31.1^{o} N), a mid-latitude ionospheric station, it had a value close to 2 times the monthly mean.

Increase in the TEC at the equatorial and low latitude region was understandable in the light of CEJ prevailing at the dip equator. The westward zonal electric field pushed the F-layer in this region down to an altitude where recombination and diffusion played minimal roles. With no loss of plasma due to diffusion and photo-production of ions still taking place, an enhancement in the electron density at equatorial/ low-latitude region was inevitable. In this case, however, there should have been a marked decrease in the TEC at the anomaly zone as the inhibited diffusion of plasma to this region from low latitudes should have resulted in a net loss of plasma. Still interesting was a marked increase in the TEC at regions beyond the anomaly crest. It was found that during the period when IMF Bz was fluctuating very fast, there was an abnormal rise in Auroral Electrojet (AE) index, a signature of an intense Joule heating at the polar ionosphere. We surmise that this Joule heating of the thermosphere at the auroral region gave rise to the Travelling Atmospheric Disturbance (TAD) which pushed the plasma from high-latitude down to the low latitude up to the equatorial anomaly crest. It supplemented the loss of plasma at anomaly crest, resulting in no change in the TEC and a marked increase in the TEC in the mid-latitude ionosphere. This is a first ever evidence of a positive ionospheric storm simultaneously occurring at the equatorial, low and mid-latitude regions, though reasons of the increase in TEC at different ionospheric were different.

YOUNG RESEARCHERS PROGRAM

TOMOGRAPHY OF WIDE-ANGLE SEISMIC DATA IN SELECTED GEOLOGICAL TERRAINS OF INDIA

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Seismic refraction / wide-angle reflection data contain useful information of the sub-surface earth, extraction of which is essential in understanding the geo-tectonics, identifying the mineralized zones and exploration of hydrocarbons. The conventional ray-based forward modelling and inversion approaches in which the model is parameterized by a selected number of velocity and boundary nodes cannot provide small-scale shallow velocity structure that links the subsurface with the surface geology. Even, it is difficult to derive a proper velocity model by conventional method in a complex terrain and in case of huge data volume. With a view to extract finer details of the subsurface, here we adopt seismic tomography in three different regions. This approach is based on finite-difference modelling and cell-based model parameterization, and can provide a measure of better resolution and uncertainty of estimated model.

First we apply the technique to seismic refraction traveltime data along a 200 km long profile in the Dharwar craton passing over contacts of different geological/tectonic units of Indian shield. The shallow structure with velocity varying between 5.7-6.4 km/s shows undulatory structure, which is terminated at a depth of 7 km, indicative of a probable detachment. The undulatory structure represents the fold-thrust belt developed during a collision in a transpressional tectonic regime. The steepness in velocity structure represents the near-vertical faults that match quite well with the boundary of various geological/tectonic domains.

Secondly, we apply tomography to the seismic refraction traveltime data along five profiles in the west Bengal sedimentary basin, and the results depict smooth variation of velocity (1.8-4.3 km/s) for Recent, Quaternary and Tertiary sediments deposited over the Rajmahal trap (4.8 km/s) underlain by the basement (5.8 km/s). The pseudo 3-D configuration of the basin shows that the depth of basement is shallow in the North and West and deep in the East and South. The depth of the basement on the stable shelf in the west gently increases to about 8 km and then dips to a maximum depth of 16 km in the deep basin part within a short distance in the east. Such a steep increase in sedimentary thickness demarcating the shelf break is referred as the Hinze Zone. This has been resulted during the breakup of the east Gondwana with the separation of India from the combined Antactica-Australia at ~130 Ma.

To extract still finer detail, we need to apply full-waveform inversion (FWI) that can exploit entire information contained into the data (traveltime, frequency, phase etc.). As a case study, we demonstrate how we can derive very fine-structure by employing computationally intensive FWI to ocean bottom wide-angle seismic data. The final result matches reasonably with the available sonic log data. We observe that for successful FWI, we need a very good starting model, preferably the traveltime tomography model, and inversion should be started from very a low frequency upward.

ROCK PHYSICS TEMPLATE OF SANDSTONE RESERVOIR USING WELL LOG DATA: A CASE STUDY OF KRISHNA-GODAVARI BASIN, INDIA

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In recent years, rock physics modeling is an important technique for reservoir characterization and it's a link between reservoir parameters and seismic properties. The relationship between various geological factors and seismic fluid and stress sensitivity have been analyzed by combining well log data and rock physics models. First, quartz cementation has been estimated from rock physics diagnostic models between elastic moduli and porosity. Hertz-Mindlin contact theory and Hashin-Shtrikman bounds theoretically predict the effective modulus of a mixture of grains and pores.A methodology is adopted for generation of Rock Physics Template (RPT) based on fluid replacement modeling for two wells (KE and KR) of Krishna-Godavari (K-G) basin. The well KE is located at Endamuru field and well KR at Suryaraopeta field of east Godavari sub-basin under same depositional characters in shallow marine environment.

Diagnostic rock physics modelsbetween elastic moduli and porosityof reservoir sands of two available wells have been developed with cementation varying from 2 to more than 6%. The ratio of P-wave velocity to S-wave velocity (Vp/Vs)and P-impedance of wells have been superimposed on RPTto detect shale, brine sand and gas sand with varying water saturation and porosity.The gas sands with porosity 14-16% have been observed in these wells. This RPT predicted detection of water and gas sands are matched well with conventional techniques.

THE EVOLUTION OF FLUVIAL LANDFORMS IN SEISMICALLY ACTIVE KATROL HILL RANGE, KACHCHH, WESTERN INDIA.

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Fluvial processes unraveling dynamic coupling between Quaternary climate oscillations and tectonic uplift has been the focus of several researches worldwide (Koons, 1989; Whipple, 2004). The tectonically active Kachchh peninsula of Western India is one such region in the western India which lies in the southwest monsoon trajectory and provides a rare opportunity to decipher the temporal changes in the climate-tectonic interaction in the evolution of the fluvial landforms. Katrol Hill fault (KHF) is a major tectonic structure in the Kachchh, which is geomorphologically expressed as a linear scarp and acts as drainage divide between the north-south-flowing rivers. Channel and valley-fill deposits along the Khari and Gunawari rivers, originating from the Katrol Hill Range (KHR), have been investigated for quantifying the climate and tectonic interaction. Presently the rivers have incised into the under-lying Mesozoic bedrock.

Reconstructions based on geomorphology, sedimentology, geochemistry supported by optical chronology suggest that the fluvial aggradation in the region was initiated during the onset of the

Indian Summer Monsoon (ISM) after the Last Glacial Maximum (LGM). A progressive strengthening of monsoon was observed between 17 and 12 ka and an overall strengthened monsoon with fluctuations is inferred between 12 ka and <8 ka. This was followed by a steady decline in monsoon strength during after 8 ka to 3 ka. Presence of the younger valley-fill sequences proximal to the present day river channel dated to ~1 ka indicates a short-lived phase of renewed strengthened ISM before the onset of present day aridity.

For the first time optical chronology suggests that the older (pre 17 ka) event of enhanced uplift led to the vertical incision and lateral planation of the Mesozoic bedrock which subsequently provided accommodation space for the post glacial valley-fill aggradation. The younger <3 ka uplift event is responsible for the incision of the valley-fill and the channel-fill sediments along with the incision of the Mesozoic bedrock. The time averaged incision rate indicates that the terrain is uplifting at a rate of ~4 mm per year.

In this presentation attempt will be made to ascertain the relative contribution of ISM and seismicity (tectonics) in the evolution of the fluvial landforms in the vicinity of the KHR.

PSHA OF DARJEELING-SIKKIM HIMALAYAN TRACT THROUGH A LOGIC TREE FRAMEWORK COMBINING SITE SPECIFIC SURFACE CONSISTENT NEXT GENERATION ATTENUATION MODELS AND GEOHAZARD REGIME

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The incidents of earthquakes in the Darjeeling-Sikkim Himalaya are broadly associated with the collision tectonics between the Indian plate and the Eurasian plate to the north and the Indo-Myanmar range to the east. An attempt has been made in this study to generate Probabilistic Hazard scenario in this earthquake province for 10% probability of exceedance in 50 years at surface level using polygonal seismogenic sources, linear tectonic sources, smoothen gridded seismic activity and site specific NGA models incorporating both aleatory and epistemic uncertainties through a logic tree framework. 41 polygonal seismogenic sources at two hypocentral depth ranges viz. 0-25km and 25-70km have been identified based on seismicity pattern, fault networks & similarity in the style of focal mechanisms and seismicity parameters of the region.186 linear tectonic sources have been identified from seismotectonic map of India and the additional from Landsat TM & SRTM data. 14 site-specific NGA models have been developed for the three tectonic types' viz. normal, strike-slip and thrust faulting mechanism of earthquake nucleation as per site classes A, B, C & D for different station elevation ranges. The PSH estimated through a logic tree framework for each depth range is integrated all together and also with those from the tectonic sources to establish the overall hazard scenario that estimates the surface level PGA distribution varying from 0.36g to 0.83g. Seismic microzonation endeavor is also undertaken to assess the likely effects of earthquakes as site specific implications for earthquake inflicted disaster mitigation and management. Therefore, seismic hazard microzonation has been achieved by integrating geohazard & seismological hazard themes viz. (i) PGA (ii) Geology & Geomorphology (iii) Site Class (iv) Landslide (v) Slope (vi) Topographic Position Index based landform classes (vii) Site amplification and (viii) Predominant Frequency on GIS platform through Saaty's Analytical Hierarchy Process. Thereafter, the entire region has been holistically microzoned into four broad divisions with hazard index defined as, $0.75 < HI \leq 1.00$ indicating 'Severe' hazard condition

in Gangtok, Singtam, Mangan and Gezing region, 0.50<HI≤0.75 indicating 'High' hazard condition mostly in Siliguri, Darjeeling and Aritar, 0.25<HI≤0.50 indicating 'Moderate' hazard condition in Kurseong and Padamchen, while HI<0.25 represent 'Low' hazard condition. The damage distributions due to 2011 Sikkim earthquake of M_w6.9 are mostly identified in the high to severe hazard zones. The resulting high resolution site specific seismic hazard and microzonation maps will contribute towards mitigation efforts against earthquake disaster in Darjeeling-Sikkim Himalaya.

MICRO-SEISMICITY AND FAULT PLANE SOLUTIONS IN THE WESTERN HIMALAYA

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The micro-seismicity of western Himalaya, especially in the Higher and Ladakh Himalaya is poorly understood due to lack of seismic network. Using data from 16 digital broadband seismographs operated during August 2002 to October 2003 covering the NW Himalaya and Ladakh, we located 306 earthquakes in the study region with a local magnitude range of 1.5 to 4.9. This data is used to map seismicity and behaviour of fault geometry from the Main Frontal Thrust (MFT) to Main Karakoram Fault (MKF) and Karakoram Fault (KF). Considerable numbers of earthquakes are observed between Main Central Thrust (MCT) and Southern Tibet Detachment (STD). Upper and middle crustal earthquakes are observed near the zone of great 1905 Kangra earthquake. We observe substantial number of earthquakes along MKF and KF spread over the entire crust. Few earthquakes are identified between STD and Indo Zangpo Suture (IZS) and along Kaurik Chango Rift (KCR) at shallow depths. A cluster of earthquakes occurred in the Hindu-Kush which is consistent with earlier results. Few uppermost mantle earthquakes are located in the Higher Himalaya. These shallow mantle earthquakes probably occur in the locally flexed Indian mantle due to its underthrusting beneath the Himalaya.

Fault plane solutions are estimated for 19 selected earthquakes. Most of the solutions show thrust faulting along the NW-SE trending MBT and MCT zone with NE-SW dip consistent with current understanding of the regional geodynamics. Strike-slip focal mechanism is observed where these faults shift at ~77° longitude. A mix of normal and strike-slip with thrust component are observed in the Higher Himalaya near to STD caused due thrusting and flexure of the Indian plate. The fault plane solutions of events along the MKF and KF show strike-slip similar to global solutions.

SEISMIC SIGNATURES OF FRACTURE FILLED GAS HYDRATE DEPOSITS

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Drilling/coring activities onboard JOIDES Resolution for hydrate resource estimation have confirmed gas hydrate in the continental slope of Krishna-Godavari (KG) basin, Bay of Bengal and the expedition recovered fracture filled gas hydrate at the site NGHP-01-10. High resolution multi-channel seismic (MCS), high resolution sparker (HRS), bathymetry, and sub-bottom profiler data in the vicinity of site NGHP-01-10 to understand the fault system and thermal regime close to the known gas hydrates site (NGHP-01- 10). In some cases, massive hydrate was visually observed in the sediment cores from

KG basin. The pressure core Xray images and resistivity at bit (RAB) images from Site NGHP-01-10, KG basin, show fracture filled gas hydrates in clay dominated sediments. The increase in interval velocity from the baseline velocity of 1600 m/s to 1750-1800 m/s within the gas hydrate stability zone (GHSZ) is considered as a proxy for the gas hydrate occurrence, whereas the drop in interval velocity to 1400 m/s suggest the presence of free gas below the GHSZ. The analysis of interval velocity suggests that the high concentration of gas hydrate occurs close to the large-scale fault system. The heat flow and geothermal gradient (GTG) in the vicinity of Site NGHP-01-10 is estimated from the depth and temperature of the seafloor and the BSR. An abnormal GTG increase from 38°C/km to 45°C/km at the top of the mound suggest that the fluid advection along the fault system is the primary mechanism that can explain the observed increase in GTG. Amplitude variation with offset (AVO) of bottom simulating reflectors (BSRs) is studied to estimate the spatial distribution of gas hydrate deposits across the fault system in the vicinity of site NGHP-01-10. The azimuthal behavior of BSR amplitude is used to estimate the fracture density (gas hydrate concentration) and fracture orientation (azimuth). Anisotropic AVA analysis of the BSR from the inline seismic profile shows 5–30% gas hydrate concentration (equivalent to fracture density) and the azimuth of fracture system (fracture orientation) with respect to the seismic profile is close to 45°. A first principal based rock physics model was developed to understand the interaction between the sediment grains of unconsolidated marine sediments as well as with hydrate. The P- and S-wave velocities of fluid saturated sediments are estimated using different friction parameters for background fluid- saturated marine sediment, and are compared with the observed velocities derived from sonic logs. The analysis shows that the shear velocity is overestimated for the Hertz-Mindlin contact theory, but can be accurately estimated for the Walton's smooth contact model. The friction-dependent rock physics model was extended for multi-grain contact (clay + quartz + hydrate) in which the effective modulus of sediment matrix is estimated by accounting for all possible contact combinations among the grains. Using the proposed model, the P- and S-wave velocities can be reliably estimated for the background sediment as well as gas hydrates bearing sediments.

QUANTIFICATION OF TOPOGRAPHIC PROFILES USING REAL TIME KINEMATIC-GLOBAL NAVIGATION SATELLITE SYSTEM (RTK-GNSS) CORRECTED SHUTTLE RADAR TOPOGRAPHY MISSION (SRTM) DATA

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Quantitative Topographic profiles are an essential part of understanding deformation and erosional processes on the surface of the Earth. These profiles have been typically constructed using the Shuttle Radar Topography Mission (SRTM) data as they were freely available (e.g. Sinha et al., 2014; Kar et al., 2014; Barnes et al., 2011, Falorni et al., 2005). However, the uncertainty associated with these profiles has been largely ignored. The SRTM goal was to obtain topographic data with 16m with 90% confidence or Linear Error 90 (LE90)/ ~10m RMSE vertical accuracy that was validated using Real Time Kinematic (RTK) Global Positioning System (GPS) transects around the globe (Rodriguez et al., 2005; 2006). It was also seen, however, that SRTM datasets contain a large number of outliers (e. g. Mukul et al., 2015 and references therein) and using raw SRTM without removal of outliers can result in RMSE in the order of 100s of meters.

We present Topographic profiles measured from Dehradun and Darjiling frontal Himalaya with dual-frequency RTK Global Navigation Satellite System (GNSS) at a resolution of ~10-15 cm and use the profile to quantify the uncertainty associated with topographic profiles constructed from SRTM C-Band data along identical transects. Outlier-removed SRTM data need to be corrected first for a difference in datum with RTK-GNSS data. The SRTM C-Band and the RTK-GNSS data are reported in EGM-96 and WGS-84 respectively. The datum corrected SRTM data were compared with the RTK-GNSS data at identical locations along the transects to determine the difference (error) associated with the two ellipsoidal heights. These errors were statistically analyzed and the mean bias of the errors removed from the SRTM dataset to generate corrected SRTM Topographic profiles. The corrected SRTM dataset can be used to generate better-constrained Digital Elevation Models (DEM) as well as topographic profiles from the study area. We have used this methodology to obtain well-constrained SRTM based quantitative topographic profiles from the Mohand Range, Dehradun in the N-W Himalaya and the frontal Darjiling-Sikkim Himalaya.

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POSTERS

APPLICATION OF FDR PSO FOR TRAVEL TIME AND CONSTRAINED AVO INVERSION

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Seismic reflection from gas sands show a wide variety of Amplitude Variation with Offset (AVO) characteristics. The AVO behaviour is observed mainly due to the zero offset reflection coefficient and the contrast in Poisson's ratio at the reflector. Inversion of AVO data provides us the elastic parameters (Vp, Vs and ρ) of various subsurface layers As different combinations of Vp, Vs and ρ may yield the same AVO response, we do not get unique result from AVO inversion. When we invert the data by layer stripping method, the error generated into upper layer gets percolated downward cumulatively. In order to overcome the above two problems, we have adopted an approach of constrained AVO inversion in which we estimate the Vs and ρ by keeping fixed the Vp and depth, derived from the travel time inversion..

We have computed the travel times and AVO responses for a four-layered gas hydrate model. The Vp and thickness of each layer have been derived simultaneously from the travel time data, added with some noise, using a new algorithm called the Fitness Distance Ratio (FDR) based Particle Swarm Optimization (PSO) (Peram *et al.,* 2003). We then estimate the Vs and ρ of each layer by AVO inversion using the same algorithm, i.e. FDR PSO by holding fixed the Vp and thickness of each layer as obtained by travel time inversion. The result obtained from this method demonstrates the convergence and uniqueness of all parameters.

The Fitness Distance Ratio (FDR) based Particle Swarm Optimization (PSO) is a variant of standard Particle Swarm Optimization (PSO) and found to have a much better convergence than standard PSO. The inversion scheme was applied on the synthetic data with 0 and 2% white Gaussian noise. For 0% and 2% noisy data, the algorithm shows very promising results with RMS misfit of the order of 10e-07 and .078, respectively. The Error function used for minimization is-- $(dato-datc)^2$, where 'dato' is the observed data and 'datc' the calculated response. The search space was taken as ±40% of true model parameters. The inversion is quite fast and achieved with just 15 particles and 1500 iterations. The sensitivity analysis is carried out by inverting the data with different search spaces. The obtained results are of the same nature indicating that the inversion is robust and independent of the constraints.

REMOTE TRIGGERING IN THE KOYNA-WARNA RTS ZONE, WESTERN INDIA

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Dynamic triggering due to remote large earthquakes has been observed in several regions globally. In this study we present evidence for dynamic triggering for the Koyna-Warna region in western India caused by the passage of surface waves from great earthquakes in the neighborhood. The Koyna-Warna region is known as a premier site of reservoir triggered seismicity (RTS), where the world's largest triggered earthquake of magnitude 6.3 occurred in 1967. Triggered earthquakes have been continuously

occurring in this region since the impoundment of the Koyna reservoir in 1962 and subsequently the Warna reservoir in 1985. Using data from a closely spaced seismic broadband network of about 20 stations being operated in Koyna-Warna since 2005, we carried out a systematic search for dynamic triggering due to several large to great earthquakes including the 2012 Indian Ocean earthquakes of M8.6 and 8.2, 2014 Chile earthquake and the recent Nepal earthquake of M7.8, which are likely to generate a minimum stress of 5 KPa in this region. Waveform data of 24 hours duration, comprising 12 hours each before and after the main event, are analyzed. Increased seismicity levels are quantified by β-statistics. Remote triggering is evident for this region, indicating that a small increase in the local stress due to triggering by a far away large earthquake can cause slip on the critically stressed fault system in the Koyna-Warna RTS region. Whether a combination of local reservoir triggering and distant dynamic triggering on a tectonically stressed region is more conducive for enhanced seismicity compared to other regions is an issue that requires detailed modeling studies in future.

DEDUCTION OF DEFORMATION OF CONVECTION CELLS AND THEIR PHYSICAL IMPACTS

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In the continuum mechanics Kirchhoff Hypothesis, Mindlin-Reissner Hypothesis and Three-Dimensional Degenerated Curved Shell concept can provide us a portal to findout the total potential energy, boundary conditions and other governing motion equations in terms of valid physical quantities for any shell or plate above the earth surface in field of constructional engineering.

Inside the earth, the convectional coils are supposed to have a spherical phase and the outer surface of any individual coil is considered to have continuum parameters to apply the plate theories on the external shell of the coil.

By applying the continuum equations on individual convectional coil we actually be able to define the deformation and can evaluate the total potential energy of that individual convectional coil.The boundary conditions tell us about the regions where the pressure field due to the magma is high or low.

The determination of high and low pressure fields gives us the intensity of high and low volcanism and zones of subduction on earth's crust, respectively.

ANALYSIS OF TIME SERIES USING DSP TOOLS

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The output from geophysical instruments has undergone various stages of development from mechanical, optical, analogue to digital. The digital revolution has provided the opportunities to learn the effect of various processing techniques on the data. The processing of digital data, however, does not appear to be easier. The flexible and sophisticated techniques are being used to process the data to get the 'signal' i.e. useful information devoid of 'noise'. Many tools of digital signal processing (DSP) - in time as well as frequency domain are available to process the data.

The effects of various DSP tools on the time series have been described and discussed in the present study. These include convolution, windowing, deconvolution, correlation, FFT and stacking. The effect of digital filters – Butterworth, Chebyshev – I,II type, Bessel and Elliptical on the parameters like peak ground acceleration (PGA), peak ground velocity (PGV) and Fourier amplitude spectrum (FAS) etc. has been illustrated and discussed. The synthetic data as well as recorded accelerograms of 1986 Dharmsala (Himachal Pradesh) earthquake has been used to investigate the effects of various DSP tools. The study is useful for the choice of different DSP tools for the processing of time series in general and of accelerograms in particular.

AVO ANALYSIS IN GAS-HYDRATE BEARING SEDIMENTS IN KRISHNA-GODAVARI BASIN, INDIA

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This paper highlights the indirect evidence of the Gas bearing sediments in the Krishna-Godavari basin from the seismic section pre-stack inversion. Elastic Parameters such as P-Impedance, S-Impedance, Vp/Vs ratio are determined. The Bottom Simulating Reflector (BSR) has been estimated from the log section and cross plotting technique. The BSR has been confirmed from the bright spot seen on the gathered seismic section after the well tie. This study includesseismic amplitude variation with offset (AVO) analysis along with simultaneous inversion. BSR horizon confirms a classic class III AVO effect where absolute amplitude increases with offset. Workflow of seismic inversion consists of three main steps: construction of initial model,the pre-stack inversion model and at lastperforming pre-stack inversion.Using the inverted results of P-Impedance, S- Impedance and Poisson's Impedance, discrimination of reservoir facies was effectively done. The inverted volume of the Vp/Vs ratio ranges from 4.7 to 4.9 due to the presence of gas hydrates. AVO parameters such as intercept and gradient are cross plotted and separated based on their class and are plotted in the seismic section. The product of intercept and gradient are plotted in the seismic section. It has been noticed that both the top and the bottom with the class III AVO anomaly indicates positive magnitude. Scaled Poisson's ratio is directly proportional to sum of the intercept and gradient. Due to the magnitude of intercept and gradient, scaled Poisson's ratio shows negative value at the top and positive value at the bottom of the gas sand reservoir with class III AVO gas sand.P-wave reflectivity, S-wave reflectivity and Fluid Factor are calculated. The AVO Fluid Factor commonly will show a strong deviation from Castagna's equations both the top and base of the reservoir.

MULTIFRACTAL DETRENDED FLUCTUATION ANALYSIS OF THE AFTERSHOCK SEQUENCE OF TALALA REGION, GUJARAT, WESTERN INDIA

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Multifractal detrended fluctuation analysis (MFDFA) is a relatively new technique that performs in nonlinear domain and used to bring out information hidden in a time series data. It is a technique well known for its simple implementation and effective use. In multifractal system, the structure repeats

itself on its subintervals. MFDFA determines the scaling behavior of data in the structure in presence of possible trends without knowing their origin and shape. In the present study, MFDFA technique has been applied on the aftershock sequence of the 6th November, 2007Mw 5.0 Talala earthquake to find the fluctuation functions. The data were collected by the Gujarat Seismic Network (GSNet), being operated by the Institute of Seismological Research (ISR) since 2006.Talala region is bounded on its four sides by major faults, namely, North Kathiawar Fault, eastward extension of Son–Narmada-Tapi lineament, West Coast fault and the West Cambay fault, and the region has a record of occasional incidences of moderate magnitude earthquakes in the past. The present study reveals that the value of Hurst exponents varies from 1.004 to 0.569 with increasing order of q (i.e. real-valued moment order or dimension order).The estimated Hurst exponents decrease with q indicating the multifractal and the random characteristics in the spatial dimension of the aftershock sequence. The magnitude sequence of the aftershock depleted catalogue is characterized by a right skewed multifractal spectrum of heterogeneous character. This generally indicates that the multifractality of the magnitude sequence depends mainly on the large magnitude fluctuations, which arises from the difference in magnitudes between earthquakes. The width of the multifractality spectrum is 0.6, which suggests that the magnitude series of the sequence is persistent.

CONVENTIONAL VERSUS UNCONVENTIONAL ARRAYS: RESULTS FROM A SULFIDE MINERALIZATION

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The conventional resistivity arrays such as Wenner, Schlumberger, gradient, dipole-dipole, pole-pole, pole-dipole, use four electrodes at a time for data collection.However, ZZ array-utilizes all electrodes simultaneously for measurements. Among all electrodes, two electrodes are used as current electrodes for imposing a constant DC and one electrode works as a common reference electrode and remaining electrodes simultaneously measure potentials for good coverage of an area to be studied. It also offers an advanced technique for large amount of full waveform resistivity data. The selection of the best possible array for a typical field survey depends on the depth of investigation, profile length, signal strength and sensitivity of particular array to vertical and horizontal changes in the subsurface resistivity.

In the present study we compare the results obtained from Wenner, Schlumberger and ZZ arrays. Wenner array is robust and relatively sensitive to vertical changes in resistivity parameter of the subsurface below the centre of the array. Thus, Wenner array is good in resolving vertical changes (i.e., horizontal structures), but relatively poor in detecting horizontal changes (i.e., narrow vertical structures). Schlumberger array is moderately sensitive to both horizontal and vertical structures and provides good compromise in presence of both the structures.

Electrical Resistivity Tomography (ERT) survey was carried out over a sulfide mineralization using Wenner, Schlumberger and ZZ electrode configurations. Subsequently, 2.5D resistivity inversions were carried out for all three arrays individually to generate the resistivity models for comparing the

features obtained from particular array. In general, resistivity model obtained from both Wenner and Schlumberger arrays identified a shallow conductor of resistivity less than 1.0 ohm-m with similar horizontal extent of ~ 350 m.The conductor starts appearing from a depth of ~ 25 m and extends up to a maximum depth of ~ 70m. However, resistivity model obtained from ZZ array also delineates the same conductor but with modified shape and size. The conductor now starts appearing at a depth of ~ 20m and extends upto~ 60 m. The horizontal extent reduces to ~ 220 m. ZZ results also show the presence of some near surface resistors. More details to bring out efficacy and limitations of different types of arrays will be presented.

ERROR ANALYSIS IN FINITE ELEMENT BASED STRUCTURAL MODELLING FOR A SUBDUCTING LITHOSPHERE

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The present analysis focuses on the error that creeps into the finite element solutions because of mesh discretization. These errors are often overlooked and can be fixed by evaluating the quality and adequacy of the mesh. The error in stress at each node is integrated over the entire volume of the element and the error so calculated is the energy error for the element. The optimum model parameters along with rheological parameters of the different layers are used for the finite element modelling. The basic procedure initially adopted with very coarse mesh and the analysis is repeated by gradually changing over to very finer meshes. The analysis is carried out with both triangular and quadrangular mesh elements. The mesh density is further increased in a region having high stress concentration for more accurate results. Mesh convergence study is conducted on different boundary and loading conditions. The energy error for the element is noted to be decreasing with increasing mesh density. The differences between peak values in successive iteration decreases with increasing mesh density and peak value of stress converges to a stable one. The result obtained from the case study reveals that the energy error-norm can be used to test the accuracy of the finite element solution.The analysis shows that the overall percentage error in energy must lie within 10% for the converged solution.

CHARACTERIZATION AND MANAGEMENT OPTION FOR PRODUCED WATERS OF ASSAM

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Several minerals, toxic and non-toxic elements are present in ground water. This paper tries to evaluate the physical and chemical parameters and properties of ground water, industrial produced water and municipality produced water of Assam. The produced water (PW) from industries and municipalities discharge large volume of liquid wastes containing both toxic and non toxic elements, which could harm both biotic and aquatic life forms. These wastes need to be treated because of the presence of several harmful constituents. These produced waters are complex mixture of organic and inorganic compounds. We directly cannot dispose it to the environment, without proper treatment of these liquid wastes. Produced water discharges into the environment have made produced water management a significant part of the industries and municipality. Several developing countries like

India are facing the problem of fresh water scarcity. Proper management, treatment and reuse of the produced water for the beneficial purpose of the mankind and environment can mitigate the scarcity of fresh water. This paper attempts to describe about characteristics of PWs, their pollutant profile, and management option to mitigate the adverse environmental impacts. Also tries to describe the isotopes, major and minor elements presents inPWs.

DELINEATION OF SUBSURFACE STRUCTURE OF SAURASHTRA PENINSULA USING GRAVITY SURVEY

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Bouguer anomaly map of Saurashtra, prepared from the high precision detailed gravity data, depicts several highs and lows of varying wavelength and amplitude. In western Saurashtra large amplitude circular gravity highs are associated with known volcanic plugs of Deccan Volcanic Province (DVP). In SE Saurashtra circular gravity highs coincide with partially exposed concealed plugs. The map also depicts number of relatively medium amplitude short wavelength gravity lows besides a broad gravity low centred over Jasdan. Gravity modeling has been carried out along selected profiles using constraints from other geophysical results and available bore well information.

Estimation of crustal thickness from power spectrum of Bouguer gravity map brings out the moho depth details of the area. After knowing the moho depth of the area and considering all depth constraints due to local geology, we have generated a 2-D density model along the Junagadh- Surendra Nagar and Rajula- Dhanduka profiles, by using GM-Sys 2D modeling software. 2-D models along profiles J-S and R-D have a 3 layered sub surface structure. Interpretation of density models suggests that the large wavelength residual gravity lows may be caused due to deep seated source and the small wavelength gravity lows due to presence of sediments below the trap. The east-west trending profiles show highs and lows of small wavelength. They are due to variation in the thickness of trap and sediments. Modelling of residual anomalies shows presence of sediments of varying thickness below the trap. Sources of all gravity highs are largely concealed under Deccan traps. However, processing of gravity anomalies has helped in delineating their circular shape and extent. The individual gravity anomalies are circular in nature but are connected with NE-SW oriented structural trends, indicating a deep-seated fault or a fracture zone along which these plugs are emplaced.

CLASSIFICATION OF LITHO-LOGY: USE OF MULTIVARIATE STATISTICS AND HYBRID NEURAL NETWORK MODELLING

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Classification of finer litho-logic structures from well log data is important for understanding of crustal heterogeneity, and mineralized fissure zones. Geoscientists/log analysts have been engaged in classifying litho-logy units from the recorded geophysical well log data using the conventional methods like graphical cross-plotting and other statistical techniques. But these techniques are semi-automated and require a large amount of data, which are costly and not easily available at every time.

While many attempts have been made to understand the intricacy of major rock forming minerals, their finer structural details and the prevalent fabrics, the present day geometry, remains to be solved for precise identification and prediction of finer structures. In the domain of KTB research, density, neutron porosity and gamma ray measurements play significant role for accurate detection of major rock alternating sequences of amphibole and gneiss. Further, the analysis of sonic transit travel time and electrical resistivity records are also found useful for precisely demarcating mineralized shear zone embedded in the major rock alternating sequences. Here, we developed and employed a hybrid neural network algorithm in Bayesian domain to discriminate finer structural details of such a complex litho-logy along the KTB borehole Germany, using five sets of well log data :e.g. density (RHOB), neutron porosity (NPHI), spectral gamma ray (SGR), seismic p-wave/compressional wave transit travel time (DTCO) and electrical resistivity (LLD). Prior to the application of neural network based supervised scheme, the unsupervised classification using cluster analysis (K-means and hierarchical) and principal component analysis were performed to obtain information about the data dimensionality and the number of class that supports the classification scheme. The robustness of the new Bayesian approach is also tested on the synthetic noisy data corrupted with different level of red noise. Our analysis suggest that in additions to major sequences of amphibole and gneiss along entire KTB litho-sections, Bayesian neural network analysis is also able to detect some more finer structures comprising rock boundaries, rock forming minerals and the rampant fabrics successions, which appear viable for understanding crustal heterogeneity, metamorphism and mineralized fissure zones along the KTB litho-sections. The uncertainty and colored noise sensitivity analyses provide useful insight for interpretations of KTB records. The present approach could be used for several other complex area of interest, where geological information is sometimes obscured by the superposition of complex well log geophysical signal.

VLF DATA INTERPRETATION FROM EAST INDIAN GEOTHERMAL PROVINCE USING CONSTRAINED DELAUNAY TRIANGULATION

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Eastern Ghats Mobile Belt in Eastern India consists of high grade metamorphic rocks. The area has many hot springs. One of the hot springs located near the village of Tarbalu, Nayagarh, Orissa, India shows a high concentration of fluoride. Many geological and geophysical manifestations exist at several places. A detailed Very Low-Frequency Electromagnetic (VLF-EM) study has been carried out around a hot spring in the Nayagarh district, Orissa that lies in the East Indian geothermal province to examine the fracture pattern and contaminated groundwater movement. The rectangular grid discretization is prevalent in the inverse modeling for VLF-EM data to delineate a complex-shaped anomalous pattern i.e. the fracture pattern. To deal with this problem, we evaluate a non-structured discretization method in which the subsurface is divided into number of Delaunay triangular blocks. Each mesh has the uniform physical property distribution. We test our method using synthetic data; all tests return favorable results. The discretization of constrained Delaunay triangulation provides a useful approach of computing and inverting the VLF EM data on the situations of complicated objects. From the field data, fluid flow pattern as well as interconnectivity of fractures around hot spring has been mapped. Detailed VLF study shows that fractures extend beyond 70 m depth.

ESTIMATION OF AQUIFER PARAMETERS FROM SURFACE GEO-ELECTRICAL METHOD

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Knowledge of aquifer parameters is essential for the assessment and management of groundwater resources. Conventionally, these parameters are estimated through pumping tests carried out on bore holes. But it may be costly and time consuming to carry out pumping tests at a number of sites. Hence, an alternate method is proposed in which the aquifer parameters are estimated from surface geophysical method. A total of 85 vertical electrical sounding (VES) with Schlumberger configuration were carried out over Sindhudurg district, Western Maharashtra, India. Geo-electrical sounding data is interpreted through resistivity inversion technique. Through resistivity inversion technique, the model parameters such as true resistivity and thickness are estimated from which the aquifer parameters such as Dar-Zarrouk parameters (i.e., longitudinal conductance and transverse resistance), mean resistivity, transmissivity and coefficient of anisotropy are estimated. Cross-correlation analysis has been done between these parameters, which subsequently used to estimate aquifer parameters over the study area. The cross-correlation results suggest that each parameter is interrelated to each other and each parameter plays an important role for management of groundwater of coastal system of western Maharashtra. In order to find the relative influence of each input parameter for predicting model output, we adopted further Automatic Relevance Determination (ARD) algorithm. The ARD-based modelling enables to the estimation of relative importance of each input parameter for prediction of aquifer parameter. The present results suggest that while predicting transmissivity, the coefficient of anisotropy is found to be more relevant among all other input parameters. Likewise the relative contribution of other aquifer parameter has been estimated for each input parameter. Finally the contour plot for these aquifer parameters has been constructed which reveals the precise distribution of aquifer parameters over the entire area resulting the assessment and management of groundwater resources of western Maharashtra. The present method combining DC resistivity inversion and ARD modeling could be useful in characterizing other complex hydrological systems in India.

A THREE-DIMENSIONAL MOHO DEPTH MODEL FOR THE EASTERN INDIAN SHIELD FROM INVERSION OF GLOBAL COMPLETE BOUGUER GRAVITY DATA SET

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The eastern Indian shield comprises one of the oldest nuclei(SinghbhumCraton) that amalgamated into a reasonably compact, large continental mass and remained a coherent entity throughout the Phanerozoic.This region has been and still is the focus of numerous geo-scientific studies mainly because of its complex evolutionary history andrich mineralisation. In this study, EGM2008 global complete Bouguer gravity data set (BGI: http://bgi.omp.obs-mip.fr/), is used to retrieve the three-dimensional geometry of the Mohorovičić discontinuity (Moho) of the eastern Indian shield using inversion of gravity data. Before applyingthe Parker–Oldenburg iterative inversion algorithm, the Bouguer gravity data is filtered in various stages to reduce the potential bias usually expected in Moho depth determination ,using gravity methods with constant density contrast assumption.Effect of

sediment is removed from the gravity data by retrieving sediment thickness and density information from a global sediment thickness map CRUST1.0 and the correction has been applied in a similar way as the Bouguer correction by using the density contrast of 0.24 g/cm^3. The sedimentary cover corrected complete Bouguer anomaly has been used for spectral analysis to find the information about a reference level and appropriate frequency range related to Moho deflection. We further performed several inversions using a range of critical parameters values close to one obtained by the spectral analysis. Final model parameters (34 km for the initial starting depth and a density contrast over the Moho of 0.40 g/cm^3) have been selected on the basis of lowest RMS value observed during the iterative processin the inversion.The results of the gravity inversion indicate that inversion Moho depth ranges from 18-24 km in the Bay of Bengal. A featureless Moho otherwise increases from 34 km along the coast to 38 km towards the SinghbhumCraton and Chotanagpur Granite Gneiss Complex in the north. In the northern part of the area, Moho undulates over 40 km ,under the confluence of Mahanadi-DamodarGondwana basins and the Ganga foreland basin.

GENERATION OF SURFACE MAP OF ANDAMAN REGION USING B-VALUE MAPPING

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The Andaman region is one of the most seismically active regions in the Bay of Bengal due to the presence of Andaman-Sumatra subduction zone. That zone has a rich history of higher magnitude earthquakes and frequent seismic activities. It is important to determine spatial and temporal variation of the plate motion rates along plate boundaries for the understanding of plate dynamics and henceforth practical applications such as earthquake hazard mitigation

In our study we discuss in detail spatial and temporal distribution of earthquakes by using the concept of b- value used in Gutenberg–Richter magnitude frequency relation. In bringing out importance of spatial and temporal distribution, we have made use of the well known empirical relationship in earthquake seismology, the Gutenberg–Richter magnitude frequency relation, which determines the frequency of an expected given size earthquake in a given time interval.

$$\log N = a - bM$$

We have carried out a case study of Andaman region, where the above detailed magnitude-frequency relation has been used, to look into the variations of the b-value & build the surface map of Andaman region. We have examined the Andaman region that lies between 5^0-15^0N and 90^0-97^0E using a catalog of 6629 earthquakes obtained by International Seismological centre (ISC) for a period of 47 years from 1964 to 2010. Significant variations of b-values have been measured in this tectonic and volcanic regime due to subducting slabs, near magma chambers, fault zones, and aftershock zones. We have prepared b value map of the study region that clearly depicts high and low b value zones. This map helps to identify temporal variations of tectonic movements by indirect method, i.e. studying their consequences by seismic b-values.

Rock fracture experiments have already indicated that the b-value is primarily a function of applied stress with high stress corresponding to low b- value. Hence, the regions with lower b-value are more prone to higher magnitude earthquakes. The minimum b value calculated for this region is 0.3.

ESTIMATION OF CODA WAVE ATTENUATION FOR NARMADA REGION USING LOCAL EARTHQUAKES

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One of the important factors in the assessment of earthquake hazard in a region is the knowledge of attenuation characteristics of the region. This information is required for the determination of earthquake source parameters as well as for prediction of earthquake ground motions. One of the most useful parameters in describing this attenuation is the seismic quality factor Q, which contains meaningful information even at short distances (Singh et al., 1982). The Gujarat region has three seismically active regions, viz., Kachchh, Saurashtra and Narmada, where Kachchh is the most and Narmada the least active regions. The Narmada region is active due to SardarSarovar Narmada Nigam Limited (SSNNL) Dam induced seismicity. In this study we estimate coda wave attenuation Qc ,using single back scattering model.Coda waves are back scattered body waves produced due to inhomoginities in the earth's crust and mantle.Qc, at different lapse time and at different frequencies, for Narmada region has been obtained by using seismograms of 84 earthquakes ($2.5<M<3.5$) recorded at 9 Broad-Band Seismograph (BBS) stations. Finally, we have arrived at a relation $Qc(f)=Qo(f)^{n}$, where $63<Qo<126$ and $0.85<n<1.15$.This relation, we opine, is appropriate for the region.

SPECTRAL APPROACH TO SOURCE DEPTH ESTIMATION FROM GRAVITY DATA OF NORTH-EAST OF GANGA RIVER, UTTAR PRADESH

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Spectral method is a well known and important tool for processing and interpretation of geophysical data. This method can be used to resolve source body depth, by its in-built mechanism for signal to noise ratio enhancement. The spectral analysis suggests different layer formations and their corresponding depth. The Bouguer anomaly of north east of Ganga River, Uttar Pradesh is analyzed by power spectral method. The power spectrum of Bouguer anomaly is calculated to derive the mean depth of the interfaces. In this study, the power spectrum is chosen over other techniques because of its ability to simultaneously perform multistage analysis and source depth determination, without a priori source information. In the present study radial power spectrum is calculated and corresponding crustal thickness estimated. Crustal thickness is found to be about 37.5 km from the slope of the least square fit line. Results are compared with the expected estimate for this region.

COASTAL EFFECT IN MAGNETOTELLURICS DATA – A SYNTHETIC MODEL ANALYSIS

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Magnetotelluric (MT) method is one of the deep passive geophysical techniques through which we can get resistivity information of the subsurface down to upper mantle. MT investigations in the vicinity of coast are in general affected by current channeling due to highly conducting sea water. These channeling of telluric currents lead to distortions inobserved MT impedance tensor similar to galvanic distortions. In the present study we have analyzed coastal effects in MT data by considering two synthetic models, one consisting of sea at one end of the profile and another without sea. The forward responses were computed using the code of Pek&Verner (1997). The resultant apparent resistivity and phase curves show strong splitting in the xy –mode (TE mode as we have taken E-W strike).From the apparent resistivity curves, we observe that the high frequency data are less affected as compared to low frequency data. As we move away from coast, only low frequency data are affected. However, for the sites close to sea, both high and low frequency data were affected. The resultant transfer functions (Tipper and Impedance tensor) are also analyzed using Phase tensor approach (Caldwell et al., 2014) and a method on ellipicitity criteria of telluric vectors (Becken&Bukhardt, 2004). The distortion indices like ellipticities, skew angle and distortion angles also infer strong spatial and frequency dependence of coastal effects in MT data. Thus, if study region is sufficiently close to Sea, deeper structure which is obtained from low frequencies are strongly influenced by the high conducting sea water which may lead to spurious results. Thus minimum influenced distance should be maintained in areas, which are close to sea before designing MT profile according to objective of the study.

SITE CHARACTERISATION OF THE NORTH-EAST REGION OF INDIA USING H/V TECHNIQUE ON EARTHQUAKE DATA

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Indian subcontinent is earthquake prone. In India the earthquake prone region is divided in to different earthquake zones.North east India is seismically one of the six most active regions of the world .There were as many as 17 large earthquakes of magnitude≥7.0 magnitude in the past century, within the latitude 22-30°N and longitude 90-97°E of the region. Site effects associated with local geological conditions constitute an important part of any seismic hazard assessment. Nakamura technique was first introduced by Nogoshi and Igarashi and used for soil amplification and site characterisation. We have used earthquake data of north-east region for reliable result. The spectral ratio of Horizontal to Vertical-H/V (Nakamura's technique) travelling seismic noise has become an important tool to estimate the frequencies and amplifications during ground motion. Several experimental studies on H/V spectral ratio technique were carried out over soft deposits by using the long duration ambient seismic noise and recorded earthquake data. Recently, this technique has been used for different purposes, like studies of sedimentary basins, faults, cavities and finally to estimate the fundamental frequency of buildings. The method has proven to be useful to estimate fundamental period of soft-sedimentary (soil) deposits. In addition this technique is also useful in calibrating site response studies at specific locations. 15 station data taken at different time intervals and distance and same magnitude

were processed using Geopsy software. H/V curves were obtained and H/V rotate analysis was carried out, using earthquake data. In the present study HVSR technique has been applied to recorded data to understand the behaviour of the ground under dynamic loading. The corresponding latitudes and longitudes of the stations are noted. Using the latitude and longitude of the site a contour map of the predominant frequency is plotted with the help of surfer software. The fundamental frequency has been obtained and the soil thickness estimated using formula $f0 = V_s/4h$. It could be noted that the f0 is associated with the depth of the bedrock. The smaller f0 value indicates greater depth of the bedrock. The topographic pattern is associated with the f0 value.

ANALYSIS OF WELLBORE STABILITY USING FAILURE CRITERIA IN KRISHNA-GODAVARI OFFSHORE

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Wellbore instability is the adverse condition of an open hole that does not maintain its gauge size and shape. Study of wellbore stability helps in developing a reasonable plan before drilling; require identification of challenging regions and improving of drilling operation. When a wellbore is drilled, the equilibrium in-situ stress is disturbed, which causes an increase in stress surrounding the wellbore.In order to sustain the stress release, induced by the drilling and to stop hydrocarbon invasion into the cavity, the borehole is filled with fluid. This process builds new stress patterns. Analysis of wellbore instability contains evaluation of formation mechanical properties and the state of in-situ stresses. In this analysis the only convenient factor is the mud weight i.e. the fluid density of the drilling fluid. If the mud weight is greater than the predicted, the mud will enter into the formation, causing tensile failure (fracture stress). On the other hand a lower mud weight can result in shear failure (collapse stress) of rock, which is known as borehole breakout. However the drilling risk can be lowered through the application of comprehensive geomechanical model by using suitable failure criteria. There are four types of failure criteria - Mohr–Coulomb, Mogi–Coulomb, Modified Lade and Tresca yield. To do the wellbore stability analysis, the integration of data (such as Young's modulus, Poisson's ratio, pore pressure, etc.) from wireline logs to calculate all necessary parameters are required to compute the shear failure criteria. The stability models have been applied to a borehole located in Krishna-Godavari (K-G) offshoreto obtain critical mud pressure required to maintainits stability. Then the finite element method has been used to show the validation and accuracy of predicted mud pressure. Monitoring of the induced stresses in the vicinity of the well is necessary .The stresses can be controlled by predicting a safe mud window, to prevent the generation of wellbore breakout and wellbore stability. It is observed that Mohr – Coulomb failure criteria overestimates the predicted mud weight for the safe drilling. On the contrary Mogi – Coulomb failure criteria is closer to the expected result.

PREDICTION OF P-WAVE VELOCITY USING NEURAL NETWORK MODELLING FROM WELL LOGS, JHARIA COALFIELD

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We have developed Multilayered Feedforward Neural Network (MLFN) model to automatically determine coal litho-units and P-wave velocity from well logs in Jharia Coalfield, India. The main objective of this paper is to use Back Propagation Neural Network (BPNN), which is a specific type of Artificial Neural Network (ANN) technique, to model the inter-relationships between four different well logs: bulk density, gamma ray, long normal resistivity and neutron porosity and to identify different litho-units for selected coal bearing horizons of Jharia coalfield as well as P-wave velocity using the proposed BPNN model. Five wells, which are viable for coalbed methane exploration are chosen for this study. MLFN model using IBM SPSS version 21 software consists of neurons that are ordered into three layers, namely, input layer, hidden layer and output layer. The network is trained to predict velocity and four coal litho-units such as: coal (litho-code 10), shaly coal (litho-code 20), carbonaceous shale (litho-code 30), and jhama (litho-code 40) from bulk density, gamma ray, long normal resistivity, and neutron porosity logs. The input parameters from well logs for this network are bulk density, gamma ray, long normal resistivity and neutron porosity. Output parameters are litho-units and velocities obtained from sonic logs. Different litho-codes are assigned to coal, shaly coal, carbonaceous shale and jhama. The number of hidden layer neurons has been chosen as 15 on the ground of good generalization. Training dataset of 917 data points are generated from three wells J1, J3 and J4 from coal, shaly coal, carbonaceous shale and jhama layers. The network is trained with 70% of the total available data. It is then tested on remaining 20% data.The hold out is remaining 10% data. The training dataset accounts for 70% of the entire dataset and is used to calculate errors and adjust connection weights and bias. The validation i.e., test dataset is used to avoid over-training or over-fitting through detecting the predicted results in validation group. The network is optimized with minimum sum-squared error of training and testing dataset for 800 epochs and 15 hidden nodes. The model predicted litho-codes for other two wells matches well with the observed litho-codes and velocities with R^2 = 0.94 and R^2=0.69, respectively. The model predicted P-wave velocity ranges from 2310 to3535 m/sec. It matches with the log values obtained from sonic velocity for two wells. This model is able to identify varied types of coal, namely,pure coal, shaly coal, carbonaceous shale and jhama from the well logs of any well located in and nearby areas of present study area.

DEAR BED BOUNDARY IDENTIFICATION USING WAVELET AND FOURIER TRANSFORMS FOR UPPER ASSAM SHELF BASIN, N-E, INDIA

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The identification of stratigraphic interfaces is of prime importance from well log data. The interfaces are not clearly discernible due to the presence of high and low frequency noise in the log response. Accurate bed boundary information are very crucial in hydrocarbon exploration and the problem has received considerable attention and many techniques have been proposed. Frequency

spectrum based filtering techniques aids us in interpretation, but usually leads to inaccurate amplification of unwanted components of the log response. Wavelet transform is very effective in denoising the log response and can be carried out to filter low and high frequency components of signal. The use of Fourier and Wavelet Transform in denoising the log data for obtaining stratigraphic interfaces is demonstrated in this work. The feasibility of the proposed technique is tested by most commonly used in the industry to decipher stratigraphic interfaces on wells belonging to the Upper Assam Basin, which are self-potential, gamma ray, and resistivity log responses.

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STUDY OF SITE AMPLIFICATIONS IN THE KACHCHH RIFT ZONE, GUJARAT AND DHANBAD, JHARKHAND

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A quantitative ground motion prediction acts as a key for assessing and mitigating the earthquake disaster. Three major factors controlling the strong ground motion are Source Effect, Path Effect and Site Effect. Site amplification is defined between the ground surface and bedrock and depends on several factors; the composition of soil layers, S-wave velocities, Soil densities and Internal Damping of the individual layers. The motion amplification depends on surface topography, sedimentary sites, and strong lateral discontinuities.

In our case, Site Amplifications for seven accelerograph stations in Kachchh, Gujarat, have been studied using spectral ratio (H/V) method using S-wave spectra from three-component records of local earthquakes of Mw 3.3-3.9. Average estimated site amplifications vary from 1 to 13 within the frequency range 0-10 Hz. The maximum SA of 13 is found at 5.6 Hz for the NDD site, which could be attributed to a thin top layer of slow shear wave velocity. The estimated SA suggests a value of ±1 within the frequency range 0-10 Hz for BAN, KBD and SLK sites, suggesting behaviour similar to a hard rock site. For BAN site, SA of individual events showing a maximum amplification of 3.0 at 9.75 Hz is noticed. Similarly, maximum amplification of 1.8 at 8.2 Hz is noticed at KBD site and for SLK site the maximum amplification is 1.7 at 8.4 Hz. From H/V spectral ratios estimated using individual event data, de-amplifications have also been noticed at KBD, SLK, BAN, and BUR sites, which could be attributed to the non-linear behaviour of top-soil associated with the propagation path of the corresponding event beneath the station. At KBD site, for individual event de-amplification of

-2.0 at 7.8 Hz is observed and that for SLK, BAN, and BUR sites are -1.7 at 1.8 Hz, -2.8 at 4.1-4.6 Hz and -5.0 at 8 and 9.2 Hz, respectively. However, it is essential to take into cognizance that we need several tens of events to obtain any reliable site amplification estimates through spectral ratio method. Thus, our present study using the data for only four Kachchh events at each station can provide only tentative or preliminary interpretations or inferences.

The estimated spectral ratios using the Nakamura's technique and background noise data from the ISM, Dhanbad, Jharkhand broadband site reveal that the average SA varies within ±1 at 0-10 Hz, suggesting a behaviour similar to a hard rock site, with an interesting fact that the 40 sec noise window giving more stable and smooth SAs.

The main lessons obtained from the physics of site amplification are: i) the growing reconciliation of the seismologists' and engineers' viewpoints on the non-linear effects of soils and, ii) the growing experimental evidence on the engineering importance of the 2D or 3D effects (wave diffraction by surface or the sub-surface topography).We opine that these results of SR estimation should be implemented in present day microzonation studies.

MOMENT TENSOR SOLUTIONS OF FIVE AFTERSHOCKS OF THE 2001 BHUJ EARTHQUAKE SEQUENCE

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The deviatoric moment tensor inversion of multiple point sources for regional (or local) earthquakes is applied on the broadband data of fiveBhuj aftershocks of M_w4.0-4.6 recorded at three-component 5–10 seismograph stations (epicentral distances < 90 km).Epicentral locations of these selected events are found to be associated with the north Wagad fault, which was the causative fault for the 2001 Bhujmainshock. Our results reveal that the dominant deformation mode associated with the NWF is mainly characterized by a reverse faulting with a small strike-slip component on a preferred south dipping plane, which is in agreement with the fault plane solution of the 2001 M_w7.7 Bhujmainshock. The deviatoric moment tensor solutions ofselected events show a larger (85–87%) double-couple (DC) component at 10–17 km depth, suggesting a domination of brittle failure (elastic deformation) in the upper crustbeneath the Kachchh region. However, the deeper events show a larger non-DC (i.e. compensated linear vector dipole, CLVD) component suggesting an increase in inelastic deformation in the lower crust (27–38 km depth), which could be attributed to the source complexity in the lower crust.

IMPLEMENTATION OF PICKETT'S PLOT FOR RESERVOIR CHARACTERIZATION IN CAUVERY BASIN, INDIA

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This work has been developed to evaluate well logs collected from different formations namely;Andimadam, Bhuvanagiri, Kudavasal Shale, Nannilam, Portonovo Shale, Kamalapuram Formations, and NiraviSandstone of Cauvery Basin, India. Ten numbers of wellhave been utilized for

this study purpose, out of these, seven wells are identified as promising for hydrocarbon exploration. The quick look interpretation procedure has been used for identification of hydrocarbon bearing zones from the conventional logs. The multimineral lithology such as: sandstone, limestone and dolomite exist in these formations. Pickett's plot has been applied to investigate petrophysical exponents.These petrophysical exponents are very much useful in preciseapproximation of fluids saturation. Pickett's plot is used to compute the petrophysical exponents "m", "n", and "a" for the clean formations. This plot is developed by Aguilera (…) to determine the parameters including cementation factor, capillary pressure, pore throat aperture radii, height above the free water table and bulk volume of water. This technique uses the log-log plots of porosity versus resistivity combined with empirical relationships for calculating the capillary pressure expressed as a function of permeability, porosity and saturation. The cementation factor (m) varies from 1.3 to 1.55 in these formations whereas permeability varies from 0.1 to 1000 md, capillary pressure varies from 10 to 400 psi, pore throat aperture radii varies from 0.25 to 8 μm and height above free water table 25 to 200 ft.These zones are characterized by resistivity varying from 0.8 to 500 ohm-m, neutron-density cross over. This technique of Pickett's plot modeling enables us to visualize the above-mentioned parameters on a single plot.

IMAGING THE MOHO - BEYOND CMP: A REVIEW FROM PRECAMBRIAN INDIAN SHIELD

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The Precambrian Indian continental crust shows a variety of geological features manifested at different times by different geotectonic processes. It is one of the best regions in the world for evaluating the assembly, evolution and dispersal of supercontinents during the earth's history. In this context, the crustal structure plays an important role to understand the global geodynamic processes. The crustal structure up to the Moho is generally delineated using seismic refraction / wide-angle reflection study and more accurately using Common Mid-Point (CMP) narrow-angle reflection study. Recently, the Common Reflection Surface (CRS) stack, a velocity independent approach, has been used to image the basement as well as the Moho, which could overcome some of the limitations of CMP method. In the present study, deep seismic reflection profiling data from three Precambrian terrains, namely the Aravalli Delhi Fold Belt, Central Indian Suture and Vindhyan Basin are used to image the subsurface structure using the CRS stack approach.

Deep seismic imaging with the CRS stack approach has clearly imaged different patterns of the Moho across the Indian shield with a variety of tectonic environments, which were either obscured or completely absent with the conventional CMP processing. Highly reflective lower crust and its termination at the upper mantle representing the Moho is spectacular in the present CRS stack approach.

The crustal seismic images derived from the CRS approach reveal a variety of geological features from the Precambrian terrains of the Indian shield. They suggest that the continental Moho exhibits variable characters in different tectonic domains. The CRS stack sections identified the Moho as a complex and variable laminated transition zone rather than a sharp static discontinuity. The Moho is dipping in major part of the Marwar Basin with a sharp subhorizontal boundary at 12.5 s twt in

the eastern part. The Moho is flat and located at a depth of 15.0 s twt beneath the Sandmata and Mangalwar Complexes of the Proterozoic Aravalli-Delhi fold belt (ADFB) region. On the other hand, large-scale crustal deformation associated with tectonic processes is still preserved in the Sausar orogeny of the Central Indian Suture (CIS) zone. A Moho-offset of 8 km is observed beneath the CIS, where the northern part of CIS near Katanagi exhibits a Moho depth of about 13.0 s twt and the southeren block near Beni, representing the Bastar craton shows a Moho depth of 16.5 s twt. The Moho in the Proterozoic Vindhyan basin is a sub-horizontal feature located at a depth of 13.0 s twt throughout the area.

The CRS stack approach has proven to be a powerful tool that provides high resolution deep seismic images of the subsurface and information about the structural and lithological relationship, especially when dealing with the Precambrian terrains.

DETECTION OF MINERALS USING PARTICLE SWARM OPTIMIZATION BASED INVERSION OF SELF POTENTIAL DATA

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Mineral exploration and its delineation are very important for the economic development of a country. The existing techniques for detecting ore bodies are magnetic studies, temperature measurement, remote sensing etc. in which one has to compromise with high drilling costs in case of temperature measurement, low spatial resolution after depth of 30m for remote sensing and usually a high spatial resolution of upto1m-10m with magnetic studies. The existing interpretation techniques for SP response are Fourier analysis(Roy and Mohan, 1984), least square approach (Adelrehman et al., 2008; El-Araby, 2004), curve matching method (Meiser, 1962; Murthi and Haricharan, 1985), along with other indispensable geophysical methods such as Gravity, Magnetics, Electromagnetics, Well Logging and Resistivity, still are in use invariably for detecting ore bodies, they have their own merits and demerits to resolve issues of accuracy, resolution and cost.Particle swarm optimization (PSO) algorithm, is a global optimization method, sometimes is related to Genetic Algorithm (GA),which approaches for a set of solutions in a given search space by finding the global optimum of the fitness function and the forward modelling. PSO based inversion using SP data searches for global minima in the dataset, restricts the observation result getting polarised in the case of response due to presence of multiple bodies. In the present study we demonstrate the usage of datasets obtained from Self-Potential (SP) survey. The observed SP anomaly and the forward modelling has been used to interpret the Self-Potential data of South Purulia Shear Zone, latitude varying from $23^0$1′N to $23^0$10′N and longitude varying from $86^0$20′E to $86^0$26′E. Prior applying to the real field data, the method has been tested successfully in synthetic data and model evaluation. Upon successful application on synthetic data, the method is used to characterize the model by inverting the data of two SP profiles acquired at an interval of 10m spacing of the region. The current PSO based inversion results delineates the presence of multiple bodies, which are often obscured by the conventional inversions schemes. The present inversion schemes is able to estimate depth, width and conductivity distributions with fair accuracy. The method could be applied further to solve other domain of geophysical problems in complicated geological settings of India and abroad.

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CORRELATION OF ULTRA LOW FREQUENCY MAGNETICANOMALIES WITH THE EARTHQUAKES (M>4) IN KACHCHH,GUJARAT

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The possible correlation of Ultra Low Frequency Magnetic anomaliesusing Induction Coil Magnetometer (LEMI-30) at MPGO, Desalpar with earthquakes in Kachchhregion during 2013-14, a two year period,is presented here.In this analysis, we first calculated the daily averages of Bx(nT),By(nT),Bz(nT) components for the whole period. We then calculated the Polarization ratios (Z/G and Z/H) for 5 different bands of frequencies ranging from 0.001to1Hz ,to extract any existing geomagnetic signature of the earthquakefrom the magnetic signal. The Polarization ratios are relatively small for the perturbations coming from the magnetosphere &ionosphere and the ratio increasesbeyond1 ,duringseismogenic activities.The Z/G and Z/H polarization ratios for 2013 and 2014 riseto 1 at f1 (0.001-0.005) and f2 (0.005-0.01) frequency band as these frequency bands are most sensitive for seismogenic activities. In 2013, two events have beenconsidered (30th March 2013(M 4.1) and 29th July 2013 (M 4.1)), which show sudden rise of polarization ratios at f1,f2 bands as observed just few days prior to the earthquake. In 2014, 9th March 2014(M 4.1) also showed littleenhancement just few days prior to the event regime.

We also performed the Principal Component Analysis (PCA) to investigate long-term variations due to different sources (e.g., geomagnetic variations, man-made noise and seismic variations).The procedure of calculating PCA is as follows:

For PCA to work properly we need to subtract the mean from each of the data dimensions; the mean is the average across each dimension(y). The data matrix $Y = [y]^T$ is obtained, where T denotes the transpose.

Calculate the covariance matrix $R = YY^T$.

Calculate the eigenvectors of the covariance matrix. Since the covariance matrix is square, we can calculate the eigenvectors and eigenvalues for this matrix. The eigenvalues decomposition of R is $R = VKV^T$, where K is the eigenvalue matrix with values $\lambda 1$, $\lambda 2$, and $\lambda 3$, and V is the eigenvector matrix

with columns v1, v2, and v3. Here, the subscripts 1, 2, and 3 indicate the order of magnitude (i.e., $\lambda 1 > \lambda 2 > \lambda 3$).The 3rd PCA component clearly shows the enhancement of signal at x, y, z components prior to the earthquakes both in 2013 and 2014 (90% change of PCA signal of Y,Z amplitudes prior to the 30th March 2013, 80% enhancement of the PCA signal on 29th July 2013and in 2014, 80% change of PCA signal on 9th March 2014).

SEISMIC HAZARD EVALUATION OF SIKKIM WITH A VIEW TO INTRODUCE NEWEARTHQUAKE RISK REDUCTION STRATEGY, CONSIDERING DETERMINISTIC APPROACH

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Seismic hazard, vulnerability and risk assessment are considered very crucial steps in earthquake risk reduction and loss estimation for pre-disaster prevention and post-disaster mitigation in an earthquake prone region like the Sikkim Himalaya. To meet this objectivewe have carried out detailed earthquake susceptibility analysis of the region, using SELENA/HAZUS relational analysis protocols. The probability of damage in each seismic hazard zone is estimated in relation with a given ground motion parameter like PGA with 10% probability of exceedance in 50 years at the surface level.In the present case, to evaluate building performance under earthquake loading for seismic risk assessment following the computation protocol of HAZUS, we have considered nine model building types viz. W1, C1L, C1M, C1H, C3L, C3M, C3H, URML and URMH. The demand spectrum curve of a spectral acceleration, through a judicious interaction with the building capacity curve and fragility curve, yields the damage state probability in terms of slight, moderate, extensive and complete damage in the terrain. Human casualty levels are also computed based on SELENA. The economic losses for building damage have been estimated within 400 socioeconomic clusters in the region. HAZUS has also been used to estimate the damage and loss associated with the essential facilities, transportation network and hydroelectric power stations in the terrain. A new perspective of Seismic Vulnerability, Risk, Damage and Loss opens up an avenue for disaster mitigation and management for the Sikkim Himalaya.

SENSITIVITY ANALYSIS OF ZZ – AN UNCONVENTIONAL ARRAY FOR A CROSS HOLE SURVEY USING COMSOL MULTIPHYSICS

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In recent times, multi channel and multi electrode full wave form resistivity acquisition systemis being used for acquisition of electrical resistivity tomography (ERT). The array used is called as ZZ array- an unconventional array. The acquisition strategy of 64 electrode ZZ array for crosshole survey is obtained by placing 32 cables ineach borehole. Normally a current source is placed in one borehole and acurrent sink in the other to ensure large voltages and to get the currentto preferentially flow through the inter-well medium of interest.Then 31 voltage differences are simultaneously measured relative to two reference positions for both boreholes, one in each cable, to yield $2 \times 31 = 62$ voltage waveforms for each current pair. There are $32 \times 32 = 1024$ possible combinations of the current electrodes using

this recording strategy and therefore, 62×1024 = 63488 number of voltage waveform can be recorded. The arrangement enhances amount of data collection for different arrays with significant reduction in the acquisition time.

Sensitivity of an array describes about the smallest degree of change of resistivity of subsurface that can influence the potential measurement. Higher the value of sensitivity function of any array better is the response of that array for small changes in resistivity of subsurface.Mathematically, sensitivity function is obtained from the Frechet derivative.The sensitivity calculation for the ZZ-array in cross-hole arrangement has been carried out for homogeneous half-space using COMSOL Multiphysics 5.1 software using 64 electrodes.As a material, a homogeneous half-space of 100 Ω-mresistivity thatserves as a reference model for forward algorithm. The computedsensitivity plot for ZZ configuration in crosshole shows higher sensitivity than conventional crosshole arrays such as pole-pole, pole-bipole and bipole-bipole.This configuration gives continuous high resolution imaging of area between two boreholes. High positive sensitivity is observed in the region between the boreholes while taking measurement of potential with respect to reference electrode.Thus, ZZconfiguration is best suited in terms of sensitivity, acquisition time, data collection capacity and flexibility in comparison to other conventional arrays.

QUALITY ASSESSMENT OF FORMATION WATER OF THE UPPER ASSAM BASIN AND ITS EFFECT ON TAP WATER DILUTION FOR ECO-FRIENDLY ENVIRONMENT

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The research workexamined the effect of the dilution factor of formation water by tap water to be discharged into the environment in an eco-friendly way pertaining to the Minimal National Standards. The formation waters were collected from the oil fields of Jorajan, Dikom, Bhogpara and Moran of Upper Assam Basin. Analysis of the mixture of formation water with tap water in various concentrations such as 10%, 50% and 90%wascarried out. The test results indicated thatthe dilution effect of tap water on the formation sample resulted in reduction of most of the parameters at both ambient and formation temperatures of 70-90°C. But some physiochemical parameters like pH, TDS, viscosity, density showed higher concentration values at formation temperatures than ambient temperature. From salinity test,it was observed that for concentration of 10% Bhogpara formation waterthe salinity was 25gm/l. On increasing the formation water concentration to 50%, the salinity was observed to be 100gm/l, which further increased to 167gm/l on increasing the formation water concentration to 90%.In chloride test, it was observed that the chloride content was 15.165gm/l, 60.66gm/l and 101.3022gm/l for formation water concentration of 10%, 50% and 90%, respectively. From alkalinity test,the alkalinity was observed to be 225.5gm/l, 943gm/l and 1435gm/l for the same respective concentrations as mentioned above.The organics and inorganics were detected in Gas Chromatography and Atomic Absorption Spectrometer, respectively.So, in order to safely dispose formation water with environmental regulation, dilution factor is an essential parameter.

CRUSTAL CONTRIBUTIONS IN TELESEISMIC P-WAVE TRAVEL TIMES AND THEIR EFFECT ON TOMOGRAPHIC MODELS BELOW INDIA AND TIBET

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The variations in crustal thickness and topography may affect the travel time anomalies and hence attribute significant contributions in the travel time delays into mantle. The delayed arrivals in Tibet and Himalaya are expected due to the thick crust and low average crustal velocities,whereas the arrivals are early in the regions of Indian shield compared to IASP 91and need significant crustal correction term to decipher an exact tomographic model of the whole region. As the near vertical arrivals of teleseismic P waves (distance range 30-90^0) make it difficult to resolve crustal scale features for their inability to cross at crustal depths, station terms along with crustal corrections can be used to incorporate the effects of unresolved features of crust and upper mantle and to avoid the mapping of crustal travel time anomalies into the mantle. Keeping in view that these corrections using 3D models are as good as their resolution, we prefer CRUST1.0 over CRUST 2.0 to modify IASP91 for the crustal part and the modified velocity model has been used to obtain the travel time delays, which may happen due to changes in velocity and thickness. The corrections are obtained for each event-station pair (ray or ray path) used in tomography and the times are subtractedfrom the input delay time vectors prior to inversion to prepare a modified tomographic model.

CHARACTERISATION OF SOME CRUDE OILS OF UPPER ASSAM BASIN

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This study pertains to the characterization of various crude oils obtained from the underground oil reservoirs of Upper Assam Basin. Crude oils were characterized based on the correlation index (CI) , characterization factor (K), API gravity, pour point, behaviour of crude oil viscosity with temperature and determination of water cuts. In this paper laboratory results of crude oil samples of Bhogpara, Jorajan, Lakwa, Nahorkotiya, Kothaloni and Borholla are presented. Some crude oils showed high pour point. This indicates high paraffin content, thus revealing the waxy nature of the crudes. The K factor and CI are a systematic way of classifying a crude oil according to paraffinic, naphthenic, intermediate or aromatic nature. It is observed that most of the crudes are paraffinic except for some, which are mixed base comprising of both paraffinic and naphthenic. Water cut from different oilfields has also been determined thus indicating that high water cut is not viable from economic perspective. Moreover, viscosity change of this crude oil with temperature variation can be an indicative for the implementation of a polymer based Enhanced Oil Recovery (EOR) process. This study is mainly aimed to determine the crude oil products assessment, based on the base of crude oil and applicability of polymer EOR in the oil fields under study.

MEASUREMENT OF AMBIENT SEISMIC NOISE AT SEISMIC OBSERVATORY, KURUKSHETRA UNIVERSITY CAMPUS

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Ambient seismic noise level at any recording station plays a vital role in the quality of seismic data recorded by a seismological station. The seismological observatory in Kurukshetra University campus is in operation for the past 4 years and recorded many local, regional and teleseismic events. The observatory is equipped with high dynamic range seismic digitizer (Quanterra Q330S) connected to tri-axial broadband seismometer (Model No. STS-2) with flat 3dB frequency response to ground velocity from 120 sec to 50Hz. The recorded ambient noise spectrum of the station has been compared to the 'minimum' and 'maximum' standard models of the United States Geological Survey (USGS) for various seasons over a 24hrs period and compared with noise-level at one of the standard seismological observatories of IMD located at Ridge, Delhi. A small diurnal variation in the noise-level has been noted at the site. There is more background noise variability in the long period band (periods larger than 10 sec) compared to short-period band, but mostly in the horizontal components. The signal-to-noise ratio of the events for various magnitude ranges occurred within 100km radius of the observatory have been compared. We have noticed that seismic ambient noise acts as an excitation function for the specific resonances of both buildings and subsoil. If the soil resonance frequency is the same as that of a building on that soil, a coupled resonance will be induced. The recorded seismic noise data has been analyzed to estimate the soil resonance frequency to identify such seismic amplification of the buildings close to the observatory.

APPLICATION OF VERTICAL ELECTRICAL SOUNDING (VES) AND GROUND PENETRATING RADAR(GPR) FOR IDENTIFICATION OF FRESH GROUNDWATER RESOURCES AT VIZAG STEEL PLANT(VSP), VISHAKAPATNAM

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Geophysical Survey involving electrical resistivity and GPR were carried out at costal terrain of Vizag Steel plant (VSP), Vishakapatnam, Andhra Pradesh, India to demarcate the geoelectric characteristics of the basement for identifying fresh water pockets and evaluate its groundwater potential in the study area. Vizag Steel Plant is situated in east coast and the entire area is underlain by recent alluvial formations, viz, sand, silt and clay.These formations are underlain by a basement consisting of Kondalitic rock formations. Ninety four VES , using Schlumberger configuration were carried out in the study area along with GPR (where ever no sufficient space was available). Ground Penetrating Radar is a surface geophysical method that depends on the emission, transmission, reflection and reception of electromagnetic pulses and can produce continuous high resolution profiles of the subsurface rapidly and efficiently at any desired location. Based on VES and GPR investigations few sites were recommended for drilling of bore wells at VSP plant and township premises. The hydrochemical study from existing well reveals that the Total Dissolved Solids (TDS) and Chloride concentration ranges from 189-3398 mg/l and 5-1610 mg/l, respectively. This information indicates

intrusion of saline water. While selecting favourable sites for bore well drilling we have made use of this information. The drilled bores well are found to yield good water to meet the demand of VSP, Vishakapatnam.

DELINEATION OF CRUSTAL STRUCTURE BENEATHTHE SURMA BASIN AND ADJOINING REGIONS USING GRAVITY DATA

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The study area lies between latitude 22 and 26°N and longitude 88 and 96°E, extendsfrom the terminal part of the Brahmaputra lineament to the southern segment of the Indo-Myanmar Ranges. The area is bounded to the northby the Shillong Plateau andnortheastern wedge of the Indian craton and inthe south by the delta of Bay of Bengal. In the present study we have attempted to delineate theMohoboundary along a N-S profile, using satellite gravity data.Spectral analysis shows that the Moho depth varies from ~30 km to the south of the SurmaBasin,41 km beneath this basin to ~44 km towards north near theShillongPlateau. Alternatively, the computed values of Moho based on Airy-Heiskanen modelshow ~30,~35 and ~42 kmbeneath those areas, respectively. A negative isostatic gravity anomaly found beneath the ShillongPlateau accounts forover compensation. The results for the Moho-depth are compared with earlier studies and found quite in good agreement.In addition, the theMoho depth from receiver function analysisalso supports the present observation. 2-D gravity modelling delineatesa ~5-10km thick high-density (ρ = 3.05 g/cm^3) igneous layer at a depth of ~ 25 km near the south of the Surma Basin, which further extends northwards beyond the Dauki fault. A high density material (ρ =3.01) is also identifiedat a depth of 40 km near theShillongPlateau area.

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) FOR FIRST ORDER SEISMIC HAZARD ASSESSMENT

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Rapid urbanization and infrastructural development can easily be seen in the country like India, which is on the edge of fast and diverging economic growth. Regardless of any boundary, these rapid multiplying concrete forests have surpassed the horizon of seismically active zones ignoring the severe impact on the society. Thus seismic hazard assessment is need of the hour and must be given priority considering the cost of life, property, economic and social disruption caused by the earthquakes. In this study, emphasis is made on the application of Geographic Information System (GIS) for first order seismic hazard assessment of Ahmedabad city of Gujarat.According to the past records some areas of the city are vulnerable to seismic hazard. For this study, five thematic layers viz., Peak Ground Acceleration (PGA), different soil types at particular depth, geology, groundwater fluctuation and bedrock depth are usedfor integration on GIS platform. The integration is performed following a pair-wise comparison of Analytical Hierarchy Process (AHP).Each thematic map is assigned weightage depending on its contribution towards the seismic hazard. Following the AHP, the approximate weightage assigned to each theme are: PGA (0.333), soil (0.266), geology (0.20), ground water (0.133) and bedrock depth (0.066). The thematic vector layers are overlaid and integrated using GIS. The peak ground

acceleration for the seismic sources were estimated based on the past earthquake records in the area. In this Analytical Hierarchy Process (AHP), the assigned weightage for different parametersare evaluated and summed up for the seismic hazard analysis. In this study, brief methodology to evaluate seismic hazard is mentioned with the help of Geographic Information System (GIS) and step wise procedures are categorized for first order seismic hazard assessment. This approach may be able to distinguish the most active seismic zones from the safer one considering above mentioned parameters. Hence, it may be helpful to delineate zones that will likely be more vulnerable to future great earthquakes and thus help in reducing the loss of human life and property.

IDENTIFICATION OF HEAT SOURCE FOR HOT WATER SPRINGS THROUGH DIMENSIONALITY ANALYSIS OF MAGNETOTELLURIC (MT) DATA IN THE SOUTHWESTERN PART OF CAMBAY BASIN

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Cambay rift basinis one of the major onshore oil bearing sedimentary basins of western peninsular India. Its evolution is connected with the northward movement of the Indian subcontinent after the break-up of Gondwanaland and subsidence during Tertiary. As the basin is close to seismically active intraplateKachchh region, seismic hazard potential is high due to its thick sedimentary environment. A significant number of geophysical studies have been carried out in the region to understand the importance ofsediment thickness, crustal architecture and basin margins. We present the results of dimensionality and directionality analysis of magnetotelluric (MT) data acquired along an approximatelyE-Wprofile of 30km length in southwestern part of the basin.The data have been processed and Earth response functions are estimated using MT data processing package, *Mapros*. Caldwell's theory of phase tensor analysishas been used for determination of dimensionality of the study area in addition to conventional dimensionality indices. Analysis of dimensionality parameters like Skew angle(β),major (φ_{max}) and minor (φ_{min}) axes of phase ellipses, swift (η) and Bahr skew (κ) indicate 2-D nature of subsurface structure. Further, strike analysis has been performed using Phase tensor technique in broad and different frequency bands.The multi-site multi frequency mode analysis suggests the strike direction of north-south for the entire study area,which is consistent with the N-S trending west Cambay fault. Interestingly, detailed strike analysis by single site multi frequencyapproach for four sites at 2km intervals in western segment of the profile suggests presence of two dominant geoelectricstrike directions, one along N-S and another along NNW-SSE. We relate the flow of telluric currents in the NNW-SSE transverse direction to the presence of a conductive body at deeper levels of the study area. This conductive body may be in partially molten state with high temperature ,which could be source of heat for hot water springs present in the vicinity of the profile. However, detailed geophysical, geochemical investigations are needed for further characterization of the conductive zone.

ROCKY COAST OF SAURASHTRA AS ARCHIVES FOR PALAEOTSUNAMI DEPOSIT?

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The Saurashtracoastal geomorphic assemblages have been studied and classified on the basis of their role during a high energy event scenario, i.e. conveyer, barrier,accommodator etc. During field, at the selected accommodating sites, the rocky coastline of southwesternSaurashtra showed presence of boulder/megaclast deposits, scattered above the high tide line upto tens of meters inland. The boulders are scattered for about 130 km stretch of the coastline of Saurashtra from Mangrol to Navibandar. The physical parameters of these boulders were studied to elucidate the type of wave responsible for their detachment from the jointed shore platform and their transport to the present final position. The generated data were compared with wave height decay curves of strongest storm that has hit the Gujarat coastline (May 2001 storm). It was concluded that even the strongest storm ever recorded in Arabian Sea (Gonu 2007) cannot detach and initiate the transport of these boulders to theirs final position. However, a tsunami wave of 3.5-m wave height can easily detach and mobilize these boulders to their final position. Using optical dating technique, the age of deposition of dune on which these boulders were scattered, estimated to be 3.4 ± 0.23 ka, which implies that this tsunami event took place sometime during the last 3.4 ka.

GEOMORPHOLOGICAL EVIDENCES INDICATING ACTIVE SEISMICITY ALONG THE BELA ISLAND, KACHCHH, GUJARAT

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In tectonically active settings, it is of crucial importance to distinguish tectonically induced river incision from river downcutting resulting from nontectonic causes. The presence of bedrock rivers in the tectonically active Kachchh region in western part of Indian peninsula provides an opportunity to decipher fluvial response to structural discontinuities. The evolution of Kachchh peninsula has been subjected to changes in stress regimes which is also reflected in the landform characteristics. The landform characteristics of Bela island (part of island belt fault zone constituting the northernmost part of Kachchh) is least investigated. In view of this, the present study is an attempt to address fluvial response to tectonics with the help of different geomorphic indices (stream-length gradient index, sinuosity, drainage basin asymmetry and asymmetric factor), steepness index estimation and sedimentology. In addition to this, recent earthquake epicenters have been plotted in order to identify seismically active parts of the Belaisland.

On the basis of the present study, it can be suggested that the eastern part of the Bela is undergoing domalupwarping, manifested in the Sharan river basin which shows abrupt deviation towards north. This is also reflected in the higher values of steepness index. Drainage Basin Asymmetry (values ranging from 0.01 to 0.94) and Asymmetry Factor (with values ranging > 50 and <50) suggest highly asymmetric river basins with lateral tilting. Sinuosity index close to 1 (1to 1.1), variable values of stream length gradient index and steepness index suggest differential uplift along the island.

Analysis of relocated seismicity data during 2006-2013 suggests that the E-W striking south dipping Gedi fault located in south of Bela island is playing a prominent role in the neo tectonic activity of the island. Most of the seismic events are highly concentrated in southern part of the study area at shallow depths with very less events in the northern part

ASSESSMENT OF GROUNDWATER POLLUTION IN KOLHAR INDUSTRIAL AREA, BIDAR DISTRICT, KARNATAKA, INDIA

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Kolhar industrial area is one of the oldest industrial areas of Karnataka state, situated in Bidar district covering an area of 1054 acres. It was established during 1980's and currently 205 industries of small, medium and large scale sectorsare working in this area. The present study is aimed to assess the impact of industrial pollutants on the ground water regime in and around Kolhar industrial area. Electrical Resistivitysurvey was carried out at 45 locations in and around the industrial area, to have an overall evaluation of groundwater potential . Pre and post monsoon monitoring of 66 ground water samples was done to evaluate major ions and heavy metal concentrations.Geologically Kolhar industrial area consists of Deccan Basalts covered with lateritic capping of thickness varying from 20 m to 30 m. The interpretation of VES has indicated presence of 3 to 5 geo-electric layers, which correspond to top soil, weathered, semi weathered lateritic formation, jointed/Fractured rock and basement comprising massive basalt rock. The layer resistivities (Ωm) from top to bottom vary from 4-145, 193-480, 665-1206, 39-170and 646-1400Ωm, while the layers thickness (m) range from 0.7-13.2, 0.7-22.6, 1.4-12.5, 1.4-21.7 and 0.5-7.1 m.These values have been arrived at by analyzing resistivity data acquired at VES No's: 10, 22, 26, 34 and 45 .Chemical The ground water analysis of 66 ground water samples reveals that TDS ranges from>500mg/l to 10506 mg/l; Cl >650 mg/l to 5570 mg/l; Na > 200 mg/l to 2174 mg/l; NO^3> 57 to 2174 mg/l and Total Hardness> 500mg/l to 3600 mg/l. High concentrations of Fe (13660 μg/l), Mn (7961 μg/l),Cu (27.04 μg/l) andZn (51 μg/l) observed in the industrial area are above the permissible limit. Integration of resistivity signatures with hydrochemical data indicates groundwater pollution in the Kolharindustrial area. The information provided by the study would be of use in formulating needed strategies and taking up appropriate measures in treating industrial wastes and safe disposal of the treated wastes to upgrade environmental quality.

NUMERICAL MODELING OF GEOTHERMS IN CONTINENTAL CRUST MELTING

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In a typical geothermal system, heat is transferred from the interior to the Earth's surface by the means of conduction, convection, advection or advection-diffusion. The variation of the magnitude of conductive heat transfer is heavily related to the subsurface temperature distribution and variation in the distribution of rock's thermal conductivity values. Therefore, the information about subsurface temperature distribution may provide an insight for the interpretation of the geothermal structure in the subsurface in particular. The present study investigates the thermal history using numerical

modeling. We solve heat conduction as well as convection-diffusion equation with proper initial and boundary condition using a combination of different schemes of finite difference methods. We apply these algorithms for modeling crustal heat production problems using radioactive sources in the subsurface. Further we couple advection phenomenon in the equation and model the continental crust melting process. The depth of the model is 350 km and we assume the thickness of Moho at 35km. With some model values of radioactive heat producing elements and for a typical distribution of rock conduction profile, we compute the geotherm variation over a significant amount of time. MATLAB codes have been developed for this model study, which can be used for modeling some real field situations.

HIGH RESOLUTION UPPER CRUSTAL STRUCTURE USING AMBIENT NOISE TOMOGRAPHY OF KUMAON-GARHWAL HIMALAYA

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We present high resolution Rayleigh wave group velocity map at periods from 2-18 sin Kumaon-Garhwal Himalaya bycross-correlating 3 years of continuous ambient noise data from 01/04/2005 to 31/06/2008 recorded by 50 broadband stations. Group velocity dispersion curves for Rayleigh waves were measured for each cross-correlated wave form Green's Function by applying Frequency Time Analysis method. Tomographic in version is performed using Fast Marching Surface Tomography. At the periods 2 to 18 s, the distribution of Rayleigh wave velocities delineates several distinct low and high velocity zones separated mainly by geological boundaries, as well as by sediment thickness. Low velocity zone is located around region with sedimentary and high grade metamorphic rocks and high velocity zone is located around region with plutonic rocks. Group velocity data obtained from tomography were thaninverted to find the shearwave velocity structure of theregion. Shearwave inversion results show presence of sediments as low velocity formations up to a depth of 5km. At a depth of 10km a high velocity layer (Vs~3.68km/s) is present beneath MFT and MBT. Another high velocity layer(Vs~3.52)is noticed at 10 km,beneath MT and VT.

MORPHOMETRIC ANALYSIS OF KRISHNA RIVER BASIN, INDIA USING SHUTTLE RADAR TOPOGRAPHY MISSION (SRTM) DATA

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Krishna river is one of the major rivers of India having 2,58,791 Sq.km drainage area flowing across Maharashtra, Karnataka, Andhra Pradesh and Telangana states. It is ranked fourth in terms of catchment area among the Indian rivers. It is the largest river after Godavari in Southern India and originates from Western Ghats. In the present study, an attempt has been made to characterize the drainage morphometry of Krishna basin to understand the hydrological and geological characteristics, which are crucial inputs for Integrated Water Resource Management.

Morphometric analysis was carried out using Shuttle Radar Topography Mission (SRTM) 30 m resolution data and Hydrology tool of Arc-GIS environment to prepare digital elevation model

(DEM), flow accumulation, flow direction and flow length.This further helped in the evaluation of 42 morphometric parameters of linear, areal and relief aspects. Drainage pattern of the study area is dendritic with intermediate drainage texture and less elongated having 0.36 km/Sq.km drainage density. Krishna is an interstate river and is currently facing numerous water disputes. The demand and competition for water resources is constantly increasing in Krishna basin. As such, an integrated approach is needed for water management and planning. The outcome of present study will provide a functional base to understand the important morphometric features of the entire Krishna basin for initiating further detailed investigations on sub basin level water management and planning.

INTERPRETATION OF GRAVITY ANOMALY PROFILE USING SINGULAR VALUE DECOMPOSITION (SVD) ANALYSIS

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The gravity method may be used for the detection of subsurface voids, mapping of thickness of sedimentary basin, mapping of boundaries of landfills, estimation of excess mass, mapping of dipping contacts like faults.The gravity survey is also useful from the hydrological investigations and oil exploration. The gravity method provides the useful information rapidly and economically for a region, where proper geological information is not 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 have been reported in the geophysical literature for estimating the depth and amplitude coefficients of geological structure assuming simple source geometry like sphere, cylinder. These techniques include graphical as well as analytical methods.

The present study shows the application of a simple and efficient method to interpret the gravity anomaly profile to estimate the depth and amplitude coefficient of a spherical ore body. The method involves the solution of a system of algebraic linear equations. First the equations have represented as a matrix equation and then solve the same using SVD analysis. The SVD analysis involves the decomposition of a matrix into the product of three matrices. The fidelity of the method has been demonstrated for noise free synthetic data as well as synthetic data with noise. The method has been applied to field data for the estimation of depth and amplitude coefficient.

LANDSLIDE HAZARD ZONE MAPPING OF GARHWAL REGION USING REMOTE SENSING TECHNIQUES

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There is a necessity to carry out detailed study on landslides to know their effect on environment and impact on livelihood of those affected by these natural hazards. They are primarily triggered by earthquake, rainfall, or road construction and can cause enormous destruction to properties and lives in those areas. With the advent of Geotechnical properties of soil with Remote Sensing data and

Geographical Information System, the knowledge on landslides may be enhanced from regional to local perspective and help in identifying landslide prone areas and hence necessary preventive measures to mitigate the landslide disaster.

Our studies have been carried out to map factors responsible for landslide and hence arrive at landslide hazard zone map and its inventory correlation. The study area lies within Uttarakhand state. Geographically, the area is situated in the foothills of Siwaliks. The study area falls in the survey of India topographic sheet No. 53 N/2.The study area is located between the latitudes 30° 35" to 30° 45" N, and between longitudes 79° 00" to 79° 10"E.

Data used in study are LISS IV, Topographical Sheet, Geological Maps, Landsat Imagery. During the study following data were processed

- Cartosat-1 DEM and
- Thematic layer viz.,

1. Geology, 2. Land use and Land cover, 3. Slope, 4. Aspect, 5. Relief, 6. Soil, 7. Rainfall, 8. Drainage density, 9. NDVI,10. Lineament- density and 11. Distance to Roads

Compiling the above thematic maps, Landslide Inventory Map was prepared. Detailed analysis of this map is in progress.

EFFICIENT NUMERICAL MODELING STRATEGIES FOR TWO-PHASE FLOW IN POROUS MEDIA WITH CAPILLARY PRESSURE

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Conventionally, Univariate two-phase flow in porous media often falls under hyperbolic category of partial differential equations. In such formulations, however, the contribution due to capillary pressure is ignored. If one considers the effect of capillary pressure in the formulation, it is basically parabolic partial differential equation or diffusion equation to be more precise.

Such formulations are generally not self-similar unless the boundary flux is inversely proportional to square root of time. The well-known mathematical solutions for this are Buckley-Leverett equation and McWhorter and Sunada equation (MSE) the later including the effect of the capillary pressure. An alternative way to model this phenomena is to solve the equations using an efficient numerical technique.

Chebyshev Pseudospectral methods are well known for their simplicity and high spectral accuracy. We model two-phase flow in porous media accounting the capillary pressure. Further we perform different iterative methods for solving linear systems arising due to such discretization and perform a series of numerical tests for the convergence analysis.

We also discuss the stability of the differential operator constructed using Pseudospectral method with polynomial interpolation used in above numerical experiments, which demonstrates that

Pseudospectral methods are viable tools for modeling fluid flow in porous media. The Pseudospectral methods work well in univariate case and further extension requires the use of tensor grid products.

APPLICATION OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM FOR LAND USE / LAND COVER MAPPING AND CHANGE DETECTION IN THE DHANBAD CITY, JHARKHAND.

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Remote Sensing is the most common approach, nowadays, to monitor the substantial changes of land pattern in a particular area. The current study focuses on the changes occurred in Dhanbad City due to unexpected growth of manmade activities. The study explores the changes in the city over the period 2004 - 2014 using Remote Sensing and Geographical Information System methods. Software, Arc GIS 10.1 and Erdas Imagine 13.0 are used to develop the unsupervised classification using 15 m pan-sharpened resolution 'Landsat 8' Operational Land Imager (OLI)' image of the year 2014 and 30 m resolution 'Landsat 7' Enhanced Thematic Mapper (ETM+)' of the year 2004, all these are taken at 44N WGS 1984 datum. We, in our study come on a conclusion that most of the agriculture and reserve area got converted into mine area. Rapid mining activities in the region is changing the natural environment profoundly in terms of vegetation, water sheds and mainly in the built up areas or urbanization. Hence an attempt has been made to determine and identify the changes in land use of the area featuring from topographical study and satellite imagery.

Environmental and Socio-Economic Impacts of Increased Mining Activities: It is been studied that Dhanbad has been credited as the most "Critical City of India". Pollution level has increased sequentially contributing in the migration of local personnel to the nearby places. The conjoint impacts due to mining are Air Pollution and Water Pollution and its adverse effects on the health of people. Above study shows that there are very few aquifer in Dhanbad and these mining activities are in result of depletion of water quality of water regime present nearby and also contaminating ground water.

INFERENCES ON SHALLOW SUBSURFACE DRAINAGE REORGANIZATION IN THE NW (PALAEO) YAMUNA PLAINS, HARYANA USING GEO-ELECTRIC RESISTIVITY EVIDENCE

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Climate change and active neotectonic movements in the north-western plains of India during the Late Quaternary have led to the migration and abandonment of drainage systems and formation of a large number of palaeochannels. It has been postulated by previous workers that prior to 120 Ka ,Yamuna was flowing along the present-day dry palaeochannels of Ghaggar/Hakra riverbed and later relocated to its current position during Late Quaternary. The prevailing opinion is that the palaeo-Ghaggar (Saraswati?) River, originally fed by the Yamuna and Sutlej Rivers, dried due to a combination of tectonic activity and river capture. This avulsion of Yamuna River has also been linked to the disappearance of the Harappan Civilization (5500-3300 BP or 3500-1300 BCE).

However, till date, no conclusive evidence has been provided as to when and why the Yamuna avulsion occurred. Afew conceptual models and limited geophysical data hinted at the presence of a number of subsurface palaeochannels,but these hypotheses are yet to be proven asno geophysical data on the size anddimension of these sand bodies have been carried out. The present study aims to establish subsurface existence of buried channels of palaeo-Yamuna, which might have acted as possible source of the palaeo-Ghaggar River. Our goal is to reconstruct the subsurface stratigraphy and alluvialarchitecture (upper 100 m) of the interfluvial formations between the modern Yamuna and Sutlej Rivers,based on electrical resistivity soundings and borehole data. Vertical Electrical resistivity soundings were carried outalong two NW-SE trending transects in Karnal and Kaithal districts of Haryana .Data from 9 and 13 VES respectively along the two profiles were used to map the subsurface large-scale geometry and architecture of the palaeochannel system. The presence of thick and extensive subsurface sand bodiesin parts of north-western Haryana plains, identified in this study, imply that these are the deposits of a large river system and suggest that Yamuna was flowing into Ghaggar River as hypothesizedin earlier works based on remote sensing techniques. However, we opine detailed sedimentalogicaland chronological constraints are required to establishsuch links,unequivocally.

EARTHQUAKE HAZARD PARAMETERS IN NORTH-WEST HIMALAYA AND ADJOINING REGIONS

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The return periods and occurrence probabilities ranging from medium to large earthquakes (Mw 4.0- 7.0) in North-West Himalayan region have been estimated using well-known extreme value theory given by Gumbel and Gutterberg-Richter methods. In the present analysis, the return periods, the most probable maximum magnitude in a specified time period and probabilities of occurrences of earthquakes of magnitude M >= 4.4 have been computed using earthquake catalogue for the period between 1973 and 2014. The estimated *b*-value is 0.81 using Richter-Guttenberg and that for the Gumbel's method is 0.84. Return period of earthquakes M> 4.4 is also evaluated. Probabilities of occurrence of earthquakes of different magnitudes have also been estimated for both of the methods. The median magnitude is estimated to be 6.18 for period of 50 years by Gumbel's method. However, the maximum magnitude of7.39 and 7.61 have been arrived at byGumbel and G-R methods, respectively.

PROBABILITIES FOR THE OCCURRENCES OF LARGE EARTHQUAKES IN NEPAL HIMALAYAN REGION

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The return periods and occurrence probabilities related to great earthquakes (Mw 8.0) in Nepal Himalayan region (26°–32°N and 79°–90°E) have been estimated using well-known extreme value theory given by Gumbel and Gutterberg-Richter methods. In the present analysis, the return periods, the most probable maximum magnitude in a specified time period and probabilities of occurrences of earthquakes of magnitude M >= 4.0 have been computed using a earthquake catalogue for the period between 1973 and 2014. The estimated *b*-value is 0.74 using Richter-Guttenberg and that for the Gumbel's method is 0.84. The most probable largest earthquakes that may occur within different

time periods have been also estimated and reported. The study reveals that the estimated mean return period for the earthquake of magnitude Mw 8.0 is about 50 years and its probability of occurrence is about 63%.

STUDY OF DEFORMATION OF THE CONVERGING INDIAN LITHOSPHERE AGAINST THE INDO-MYANMARRANGES USING GRAVITY AND EARTHQUAKE DATA

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The present study area comprises the Indo-Myanmar subduction margin, and extends between latitude 17 and 30°N and longitude 90 and 100°E with a lateral extension of ~ 200 km. Two-dimensional gravity model of the subduction Indian lithosphere along a profile at 23°N, cutting all through the main geological features across the Indo-Myanmar Rangeshave been reconstructed based on Bouguer gravity anomaly data to understand the long-wavelength features. One of the most common problems encountered in geophysical studies pertains to selection of appropriate data acquisition geometry to effectively map geological contacts at different depth-levels. Models based on gravity and seismic data suggest that the long-wavelength gravity anomalies arise due to Moho-depth variations caused by flexing of the Indian lithosphere. Mohovićić (Moho) boundary is thus calculated from gravity and topography data and constrained by spectral analysis results. Topographic data are used in the computation of base of the crust based on Airy isostatic compensation model. The estimated Moho-depth is used as an initial parameterforthe two-dimension forward gravity model. Through iteration, the geometries of different crustal blocks have been computed. The estimated Moho-depth varied from ~ 33 to 50km between Bengal Basin and Central Myanmar Basin. This is in agreement with the results obtained fromAiry isostatic model. Dip angle varies from 10 to 15° near Bay of Bengal through 20 to 25°near Indo-Myanmar Rangesto 30 to 50°in the Central Myanmar Basin. The projection of hypocentres of earthquake activity in this area shows their preferential association with the bending zone of the penetrating lithosphere. It may be stated that the maximum deformation is occurring within this bending zone, and little deformation is also noted along the Sagaing fault.

ASSESSMENT OF HYDROCHEMISTRY AND GROUNDWATER SUITABILITY FOR DRINKING AND IRRIGATIONAL USES IN THE COASTAL STRETCH BETWEEN MOONUPEEDIKA TO KODUNGALLUR OF KERALA, INDIA

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An attempt has been madeto evaluate the ground water quality in the coastal area of Kerala. A total of 30 groundwater samples were taken for the baseline study. The groundwater samples collected in the field were analyzed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), major cations like Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}) and major anions like Bicarbonate (HCO_3^{-}), Chloride (Cl^{-}) and Sulphate (SO_4^{2-}). Besides irrigation quality parameters like Sodium Adsorption Ratio (SAR), percentage Sodium, Residual Sodium Bicarbonate (RSBC), Permeability Index (PI), Magnesium Hazard(MH), Kelly Index (KI), are used to characterize the groundwater quality and its suitability for drinking and irrigational uses. The results were evaluated

in accordance with the drinking water standards given by the World Health Organization (WHO) and Bureau Indian Standards (BIS). Piper diagram, Wilcox, Gibb's diagram, Doneen's plot were generated and discussed. The statistical approach like Spearman's correlation analysis and principal component analysis (PCA) was used to distinguish the statistical relation between different ions and contaminant source in the study area. It indicates that in these regions, groundwater quality is significantly influenced by weathering, seawater intrusion and anthropogenic activities like industrial waste water and irrigational return flow.

ATTENUATION CHARACTERISTICS OF HIGH FREQUENCY SEISMIC BODY WAVES IN SOUTHERN INDIA

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We present a study of seismic attenuation and Q_P, Q_S structure derived from the spectral analysis of *P-*, and*S-* waves in the southern Indian region in the frequency range 1–20 Hz. The amplitudes of the seismic waves areaffected by the physical properties or quality of the crust and upper mantle, at different distances, by a combination of elastic and anelastic processes.We characterize the seismic attenuation quality factor, 'Q'using about 45 earthquakes with magnitudes (M_L) varying from 1.6 to 4.5, and hypocentral distances up to 350 km. Also the variation of the seismic quality factors, Q_P, Q_S, for the three geological units EDC (Eastern DharwarCraton), WDC (Western DharwarCraton) and SGT (Southern Granulite Terrain) is investigated. We use the single station spectral ratio technique (Tsujiura, 1966; Frankel, 1982; Patane, 1994, Giampiccolo, 2007) to estimate the relations for Q_P and Q_S. The estimated values of Q_P, Q_S are observed to be increasing in general with frequency, and fitting to the power law form of $Q=Q_0 f^n$. The power law relations are obtained as $Q_P = (95\pm1.12)\ f^{(1.32\pm0.01)}$; $Q_S = (128\pm1.84)\ f^{(1.49\pm0.01)}$. To document the differences, if any, of the attenuation properties of the major geological blocks within southern Indian region, like EDC, WDC, and SGT, we provide separate estimates. The separate power law estimates are obtained as: $Q_P = (97\pm5)\ f^{(1.40\pm0.03)}$, $Q_S = (116\pm1.5)\ f^{(1.48\pm0.01)}$ for EDC region; $Q_P = (130\pm7)\ f^{(1.20\pm0.03)}$, $Q_S = (103\pm3)\ f\ ^{(1.49\pm0.02)}$ for WDC region; $Q_P = (68\pm2)\ f^{(1.4\pm0.02)}$, $Q_S = (152\pm6)\ f^{(1.48\pm0.02)}$ for SGT region. Based on the high value of the ratio Q_S/Q_P (>1), it is indicated that high degree of heterogeneity exists for SGT and EDC, and somewhat less for WDC. The heterogeneities causing seismic attenuation are in the form of fluids, temperature anomalies and varying fracture densities in the region. It is suggested that for south Indian region, the seismic attenuation might result as a consequence to intrinsic mechanisms. The results of body wave attenuation studies will be indispensable for regional hazard analysis, especially for the estimation of source parameters of earthquakes and simulation of strong ground motions in southern India.

WATER QUALITY MONITORING OF HUSSAIN SAGAR LAKE, TELANGANA STATE, INDIA

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Hussain Sagar is major lake in Telangana state and it has great cultural and ecological importance in the Hyderabad city. We have carried out water quality monitoring of Hussain Sagar Lake (HSL) in the month of January 2014. The water samples have been collected from four nallas entering into the HSL

and two samples from two surface areas of HSL. The samples have been analyzed for physicochemical parameters (pH, Dissolved oxygen, Acidity, Alkalinity, Hardness, Sulphates, Chemical oxygen demand, Chlorides) by following American Public Health Association (APHA) standard methods. The pH of HSL is 8.0. It shows that the water is alkaline in nature. The Dissolved Oxygen (DO) is 0.1 mg/L. It indicates that the value of DO in the lake is below the tolerance limit (5 mg/L), as per Beaurau of Indian Standards (BIS). The acidity in HSL ranges between 1300 mg/L and 450 mg/L, which is high in nature. The alkalinity of HSL is 254 mg/L, which is also high as per BIS. This is due to the presence of bicarbonates, carbonates, and hydroxides, which combine with H^+ ions from the water thereby raising the pH (more basic) of the water. The hardness is 240 mg/L, which is below permissible level as per BIS. The COD (Chemical oxygen demand) observed in HSL is 3000 mg/L which is very high. The sulphates and chloride concentrations are 100 mg/L and 248 mg/L, respectively. The presence of high chlorides is driven by domestic and industrial discharges into the lake. All physicochemical parameters reveal that the pollution of HSL is high. It is evident from the study that pollution is caused by different pollutant sources. As such, appropriate remedial measures are to be taken on priority to protect this important water body. The study concludes that lake reclamation like preventing pollutants entering into the lake, both from point and non-point sources, should be taken in order to counter act or reduce the toxic load posed by the industrial, chemical, sewage and idol immersion.

GROUND MOTION AMPLIFICATIONS IN THE 2D AND 3D BASINS CAUSED BY THE BASIN GENERATED SURFACE WAVES

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This paper presents the comparative scenario of ground motion amplifications in the 2D (SC: semi-cylindrical) and 3D (SS: semi-spherical) basins caused by the basin-generated surface (BGS) waves and the associated spatial variations of average spectral amplification (ASA) and differential ground motion (DGM) in the basins. Seismic responses were computed using a recently developed 3D fourth-order spatial-accurate time-domain staggered-grid finite-difference (FD) algorithm based on GMB-EK rheological model. An analysis of the computed responses of the 2D and 3D basins on the various linear arrays for different polarization of the incident S-wave revealed the focusing of the BGS-wave in the 3D basin, a prime factor for tremendous increase of ASA and DGM towards the centre of the 3D basin as compared to the 2D basin.

VOLUMETRIC ATTRIBUTE ANALYSIS FOR FAULT INTERPRETATION: A CASE STUDY FROM SE PART OF OFFSHORE TARANAKI BASIN, NEW ZEALAND

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The ability of volumetric seismic attributes in demarcating structural discontinuities and lateral extents make this as an important element of structural interpretation of the seismic data. An integrated analysis of volumetric seismic attributes like dip, curvature and similarity is carried out over Opunake block in the SE part of offshore Taranaki basin to provide an improved and detailed map of subsurface

structures / discontinuities making it as an essential framework for the 3D structural interpretation of seismic data. 3D pre-stack time migrated seismic volume covering an area of approximately 215 sq.km has been subjected to detailed investigation to generate the attributes, after several post stack processing steps to bring data to the certain level to enhance quality of images of discontinuous feature like, faults, folds, fault scraps etc. The acquired volume of data was subjected to dip-steered median filtering technique for reducing the randomly distributed noise and enhancing the quality of lateral continuity detail of the seismic events along the structural dip. The pre-calculated dip field was used to compute volumetric attributes. These results were integrated with that of obtained from similarity attribute for detailed delineation of these structural features. The attributes study brought out major NNE-SSW trend relating to fault signatures, resulting increased confidence in structural interpretation.

NEW MAGNETOTELLURIC STUDIES IN THE EASTERN SEGMENT OF CENTRAL INDIAN TECTONIC ZONE.

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Central Indian Tectonic Zone (CITZ) is one of the most important tectonic boundaries that separate the Indian subcontinent into two halves. The CITZ has differential crustal movement and also acted as a zone of crustal weakness, which facilitated eruption of basalts. The Narmada-Son Lineament (NSL) marks the northern boundary of the CITZ; while the Central Indian Shear zone is considered to be the southern limit. The Narmada North Fault (NNF) and Narmada South Fault (NSF) are identified as the boundary faults that define the NSL. The NSL believed to be a weak feature is the most conspicuous tectonic feature that cuts across the Indian shield from west to east. It also forms between the Gondwana (Mesozoic) sediments towards south and Proterozoic Vindhyan sediments towards north. A number of geophysical studies of the CITZ region have been undertaken to investigate its crustal structure and tectonic evolution. Previous magnetotelluric (MT) studies have investigated individual sections of the western and central segments CITZ, and no one yet studied eastern segment of CITZ. A key question that remains to be addressed is what controls the continued weakness of this region over geological time. In the present study, the geoelectric structure of the CITZ is investigated using MT imaging along a 264 km long profile from Jamanpani (Chhattisgarh) to Rewa (Madhya Pradesh).

In this region we acquired MT data at 74 locations with station spacing 0.5 to 5 km, during 2014 field session. Near the Rewa city at some stations MT data was highly contaminated with noise and we could not improve the data even after applying various processing methods. So, we re-acquired the data at these stations during 2015 field campaign. From the acquired data, we got clear signature of Narmada-Son south fault zone. In the Southern segment of the profile, during 2015 field campaign we adopted EMAP with station spacing 0.5 km interval to get high resolution subsurface structure. In the south, we observed anomalous phase, going beyond 90^0 at 10 locations. Such behavior could be due to the signature of CITZ or could be due to localized 3D structure.

BIOSTIMULATED TREATMENT OF FLUORIDE CONTAMINATION IN AQUATIC SYSTEMS

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Fluoride contamination in the groundwater and wastewaters is a serious health hazard. It is established this contamination is responsible for various health problems such as dental fluorosis, brain and kidney damage. This paper is focused on developing fast and cost-effective techniques for treatment of fluoride waters. In the present experiment, zeolite is used as the source of cations and the sodium fluoride as the source of fluoride contamination. The geochemical capability of natural zeolite is catalyzed by inoculating bacteria in experiment column for remediating fluoride concentrations. Bacteria are known for enhancing water rock interaction as they grow and proliferate and create slightly acidic micro-environments. As a result micro-organisms may enhance cation-anion exchange activity leading to the formation of insoluble fluorides. Physico-chemical parameters pH, redox potential, total dissolved solids and conductivity were monitored every 10^{th} day to understand the variations in biogeochemical environments within the column. Anion, cation and microbiological analyses were conducted in fluid samples at various stages of the experiment for understanding biomineralization process. Preliminary results indicate sharp decrease in fluoride concentration from 452 ppm to 120 ppm within 23 days and further decreased to 41.5 ppm after 60 days. Additionally, nitrate and sulphate introduced by the zeolite in the experiment column were also completely remediated by microbial process. Decrease in concentration of aluminum ion with decrease in fluoride concentration implies the possibility of formation of insoluble aluminum fluoride as the dominant biogeochemical process during first 30 days of the experiment. Furthermore, decrease in total dissolved solids and conductivity indicates the biogeochemical precipitation of metals. Geomicrobiological and geochemical analysis of water samples and sediments collected after day 30 onwards will be helpful in understating geomicrobiological processes involving in bioremediation of fluoride contaminants. Additionally, our experimental study demonstrates that the proposed methodology has the potential for treating fluoride contamination. Results thus obtained will provide vital information in development of cost-effective biogeophysical monitoring techniques and refining the remediation strategies for treating fluoride contamination in natural and wastewaters.

IDENTIFICATION OF AQUIFER CHARACTERIZATION, BY USING RESISTIVITYMETHOD OF MICRO WATERSHED NEAR KOMARTHY,SRIKAKULAM, ANDHRA PRADESH.

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An attempt has been made to identify the Aquifer characterization and subsurface lithologyby using electrical method of micro watershed near Komarthy village. The study area bounded by Polakigedda and Mabhagamgedda is about 6 sq.km. We have acquired 18 vertical electrical sounding data in the watershed region, using the Schlumberger configuration.The collected data were analyzedusing both quantitative and qualitative interpretation. We havegenerated 3 to 4 subsurface layers and

Pseudo cross sections with the help of IPI2Win Software. Apparent resistivity(ρ_a), Total thickness(H), Longitudinal conductance(S), Transverse resistance (T), Anisotropy (λ) contour maps were prepared with the help of surfer software.The apparent resistivity of the study area varies from 2.48Ωm to 237.28Ωmat VES-12 and VES-5,revealing A-typeand H-type curves,respectively .The total thickness of the aquifer varies from 1.34m at VES-6 and 37.25m at VES-18. The interpretation exposed that watershed area indicates mostly H-type curves, with second layer low resistivity.Thissuggests probable presence of groundwater, with varied quantities depending on thickness of low resistive second layer..

A 3D MOHO DEPTH MODEL FOR THE HIMALAYA-TIBET FROM EIGEN-6C4 SATELLITE GRAVITY DATA

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The collision of the Indian and Eurasian plates, which began in Paleogene and continues today (at a rate of about 5 cm/year), has been forming the Himalayan and Tibetan Orogenic belt. The deep structure of the Himalayas and the Tibetan Plateau has been a subject of debate for a long time. Due to the high topography and active compressional forces, it is expected that Tibet should have an extraordinarily thick crust and its Moho should be buckled.

Numerous geophysical studies faced the problem of recovering the shape of the Moho beneath the Tibetan Plateau and the Himalayas: in particular the crustal structure was investigated by several seismic exploration campaigns and from studies based on gravimetric inversion. However, all these models based on seismic or gravity ground data, are inevitably limited in the Tibetan Plateau and the Himalayas, due to insufficient data coverage. The inadequacy is due to inhospitable environment coupled with severe logistic constraints imposed by the extreme topography.

In the present study, we present a new 3D Moho model beneath the Himalaya and Tibetan Plateau region obtained from an inversion of EIGEN-6C4 gravity data. In order to guarantee the uniqueness of the solution a two-layer model is assumed. Although the actual crust–mantle boundary can be locally much more complicated than this simplified model, for instance showing doubling, fragmentation or a broad transition,the resulting Moho is found to be generally consistent with existing models.

The Moho undulation model is found to be consistent with the geometry obtained from other geophysical methods. EIGEN-6C4 model is found to be useful, with reasonable resolution capability, to map the Moho configuration beneath the Himalaya and Tibet. The distinctive undulations of the Himalaya- Tibetan Moho have been formed by buckling in a compressional environment, superimposed on the regional increase in crustal thickness.

SHEAR-WAVE VELOCITY STRUCTURE OF THE EASTERN INDIAN CRATON USING AMBIENT NOISE CROSS-CORRELATION METHOD

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Both phase and group velocity dispersion curves for Rayleigh waves are computed by applying the ambient noise method to broad-band data of ambient noise from the temporary seismic network of 15 seismographs. The network is being deployed in the Eastern Indian Craton (EIC) by NGRI (CSIR-National Geophysical Research Institute, Hyderabad). Interstation cross correlations of ambient seismic noise from one year of continuous data at periods between 2 to 28 s are used to compute Rayleigh wave group and phase velocity dispersion curves for the EIC covering Eastern Ghat Mobile Belt, Singhbhumcraton and Chotanagpur Granite-Gneiss Complex (CGGC). Vertical-component ambient noise data during 2013-2014 have been cross-correlated for station-pairs to estimate fundamental mode Rayleigh wave Green's functions. Cross-correlations are calculated in 1-hour segments, stacked over periods varying from 5 to 11 months. We use the multiple-filter analysis technique to calculate group and phase velocity dispersion curves at 2-28 s for Rayleigh waves. Finally, these dispersion curves are inverted to delineate 1-D shear velocity crustal structure for the region. A sensitivity kernel of Rayleigh wave group velocities corresponding to the shear velocity model is being computed. Results of inversion modeling reveal that average upper crustal (at 0 - 5.1 km depth)velocity varies from 3.45 to 3.55 km/s,suggesting a felsic upper granitic crust while velocity in the middle crust (at 5-19.7 km depth) varies from3.62 to 3.7 km/s, suggesting an intermediate crust (Christensen and Mooney, 1995; Rudnik and Fountain, 1995). The velocity oflower crust (at 20 - 44 km depth) varies from 4.0 to 4.47 km/s, indicating presence of a mafic underplated layer. Average Conrad discontinuity for the study region is modeled at 19.7 km depth. The inversion of dispersion curves obtained from different station pairs is also being done individually. And, we notice a marked variation in shear velocity structures across the study area, which shows a good correlation with the known geological features in the region.

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BIOGEOPHYSICAL SIGNALS ASSOCIATED WITH BIOREMEDIATION OF FLUORIDE CONTAMINATION

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A biogeophysical laboratory study is conducted for understanding the biogeochemical processes associated with remediation of fluoride contamination in aquatic environments. The main objective of this study is to investigate the possibility of use of natural zeolite in treating fluoride contaminated water and wastewaters, and in catalyzing the geochemical remediation of fluoride by biostimulation of experiment column. To achieve the preset objectives, an experimental setup is designed and constructed which consists of three columns, first one is filled with 1 gm/L sodium fluoride dissolved

in deionized water, second is filled with zeolite and fluorided solution, and third is filled with zeolite, fluoride contaminated water and bacterial seed. Electrical potentials were monitored everyday on each of the columns. However, geochemical and microbiological analysis were conducted at regular intervals for understanding variations in biogeochemical conditions within the columns. The first and second column were poisoned with 2 ppm sodium azide for not allowing growth of micro-organism within them for comparative study of geochemical and biological remediation of fluoride. Non-invasive electrical potential signals in conjunction with geochemical and geomicrobiological analysis of solid and liquid samples obtained from second and third columns were corrected with reference to first column. Dramatic variations in electrical potentials monitored at third column after thirty days indicate the possibility of domination of anaerobic microbial activities within it. Findings of this experiment suggest that geochemical remediation of fluoride is faster than bioremediation until thirty days, and thereafter elevated concentrations of fluoride, sulfate and nitrate indicates the possibility of induction of these contaminants into the water from zeolite. However, after a period of one month, exponential reduction in fluoride concentration, and complete removal of sulfate and nitrate were noticed in anionic analysis of water samples. Thus, this study clearly indicates that bioremediation is very effective in treatment of fluoride and other contaminants in wastewater and groundwater. Furthermore, electrical potentials of the order of -45±5 mV associated with biostimulated fluoride remediation indicate the possibility of non-invasive biogeophysical monitoring techniques for development of cost-effective and sustainable treatment technologies for wastewaters and groundwater.

PARTICLE SWARM OPTIMIZATION FOR GRAVITY INVERSION OF SEDIMENTARY BASIN WITH PARABOLIC DENSITY CONTRAST

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Particle Swarm Optimization is a global optimization tool which is based on the Swarm intelligence. Kennedy and Eberhart (1995) first implemented the PSO by using social behaviour of birds. PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. PSO has a memory component for each particle in the swarm so that both the cognitive knowledge and social behaviour of the particles are used simultaneously in deciding the excursion of the solution in model space. . Sedimentary rocks are associated with negative gravity anomaly due to low density rocks. Rama Rao and Murthy (1978) opined that the ambiguity in gravity anomalies can be overcome by assigning a mathematical geometry to the anomaly causing body with a known density contrast. The cross-section of the basin is described by the stacked prism model of Bott (1960). PSO is used for the inversion of gravity anomaly of sedimentary basin. A Matlab code based on PSO is used to find the depth to the bottom of the sedimentary basin where density contrast varies parabolically with depth. Initially PSO is applied on synthetic anomaly and then its validity is tested by calculating the basement depths of the Tucson basin, Southern Arizona.The Marquardt inversion by Chakravarthi and Sundararajan (2007) solved the structure of a sedimentary basin along with estimating regional background from observed gravity anomalies. The PSO results are better than local optimization methods and are correlated well with borehole information. Particle Swarm Optimization is very simple algorithm based on only velocity updating and consequently position updating. Range of the parameters should be known in PSO. Computational time is more in PSO in comparison to local optimization methods. PSO can search through a large number of solutions and make few assumptions about the problem.

ANALYSIS OF SOURCE PARAMETERS OF LOCAL EARTHQUAKES OCCURRED IN THE EASTERN PART OF INDIAN SHIELD

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In the present study, the source parameters of 30 local earthquakes with magnitudeMw 2.0–3.6 have been estimated. The earthquake data, recorded between 2007 and 2015 by the broadband seismic station running at the premises of Indian School of Mines, Dhanbad, have been used. The station is located at latitude 23.87°N and longitude 86.44°E on the Archaean basement (hard rock terrain) of the Eastern Indian Shield.The waveform data extracted from the horizontal-component of S-waves has been usedfor the analysis, using the Levenberg–Marquardt nonlinear inversion technique. The inversion scheme is formulated based on the ω-square source spectral model. The estimated seismic moment (Mo) and source radius (r) vary from $9.98\times 10^{11}$to 3.55×10^{14}N-m and 161.30 to 389.35 m, respectively. The stress drops ($\Delta\sigma$) values range from 0.049 to 8.535MPa. The corner frequencies are found to be ranging from 4.25 to 8.49 Hz. Our estimated stress drop values are marginally large compared to other similar size Indian intraplate earthquakes. This can be attributed to the presence of crustal mafic intrusives and aqueous fluids in the crustal part of the region.

HYDROCHEMICAL AND HYDROGEOPHYSICAL STUDIES TO PROVIDE SAFE DRINKING WATER, DANTEWADA DISTRICT, CHHATTISGARH

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Kirandul and Bacheli are situated in the Bailadila hill ragnes, Dantewada District, Chhattisgarh. The general lithology in the area is lateritic soil in the top followed by phyllaticclay.It is underline by quartzites and Gneiss with poor to moderate well yields. The drinking water needs of the region are met from perennial nalas and springs, through central water distributary systems. It is reported that low mineral content in supplied drinking water can have major nagative health impacts on local population. In addressing this problem, we have carried out hydrochemicalstudies to ascertain mineral content.Based on the results we have suggested scientific methodologies for increasing mineral content in drinking water.

Electrical Resistivity Tomography (ERT) has beencarried out to assess the groundwater potential in both Kirandul and Bacheli to locate potential groundwater resources.The mineral content in all drinking water sources that include both surface water and groundwater has been monitored by analyzing water samplesfor pH, TDS and major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, F^{-}, HCO_3^{2-} Cl^{-}, SO_4^{2-} NO_3^{-}) and heavy metals (Al, As, Mn, Cr, Cd, Co, Ni, Cu, Pb and Zn),druing December 2014 and April 2015. The salient water quality features revealed that raw water and treated water supplied from filter house in Kiranduland BacheliTownships possess low TDS and low mineral content(Ca^{2+} and Mg^{2+}),below the desirable limits set by BIS: IS10500, 2012.Such a low percentage of minerals will have major health impacts, unlesssuplimented by other dietary intakes. The concentration of heavy metals (Al, As, Mn, Cr, Cd, Co, Ni, Cu, Pband Zn)is within permissible limits of BIS:IS10500/WHO drinking water standards. The experimental resutls indicated that mineral content in drinking water

can be increased by adding food grade salts ($MgSO_4 \cdot 7H_2O$, $CaCl_2$, $KHCO_3$ and $NaHCO_3$). But long term health related issues after consumption of mineral water should be well studied.

Four bore wellsare drilled to meet the future needs of Kirandul and 3 bore wells in Baheli,based on ERT investigations.Yields from these wells range from 2.2-220m^3/day.It is suggested thatartificial recharge mechanism has to be implemented for augmenting the limited groundwater potential in the area, through construction of appropriate water harvesting structures.

NEW INSIGHTSON THE EVOLUTION OF THE BUNDELKHANDCRATON, CENTRAL INDIA FROMRADIOELEMENTAL, PETROLOGICAL AND GEOCHEMICAL STUDIES

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The Bundelkhandcraton, central India is one of the most important Archaean nuclei in the Indian shield where Neo–Archaeangranitoids and Meso–Archaean gneisses are extensively exposed covering an area more than 30,000 km^2. We have carried out radioelemental (^{232}Th, ^{238}U, ^{40}K), petrological and geochemical studies on these granitoids and gneisses. Data from the present study reveal that above characteristics are distinct between these two rock formations. Among the granitoids, pink granitoid is K–feldspar rich and meta–aluminous to per–aluminous in character and have highest radioelements; biotitegranitoid is meta–aluminous in character and have intermediate radioelements; and grey granitoid is rich in Na–feldspar and mafic minerals, granodiorite to diorite in composition and meta–aluminous in character and have lowest radioelements. Among gneisses, potassic type gneisses have twice radioelements than the sodic type gneisses. Moreover, gneisses have much lower radioelemental abundances compared to the granitoids, indicating lowest radioelemental abundances in the craton.The Bundelkhandcraton, thus, can be broadly divided into three distinct radioelemental zones, which are related with evolution of the craton in time and space. The central tectonic zone, where gneissic rocks associated with metavolcanics of greenstone belt, has least radioelemental abundances and is the zone of oldest lithounits of the craton. North of this central zone, dominated by grey and biotitegranitoid, is characterized by moderate radioelemental abundances whereas south of this tectonic zone, dominated by pink granitoid. It is characterized by high radioelemental abundances. Integrated petrological, geochemical and radioelemental studies further indicate that two distinct granitoid suites were developed in Neo–Archaean, i.e., the Na–rich calc–alkaline granitoidmagmatism (grey and biotitegranitoids) in the northern part and the K–rich calc–alkaline granitoid (pink granitoid) in the southern part. The variations in the radioelemental abundances of major lithounits in the Bundelkhandcraton along with their geochemical and petrological characteristics are the first documentary evidences on the crustal scale, which can be attributed to the compositionally different magma sources from which these granitoids have evolved.

ANALYSIS OF TIME DOMAIN ELECTROMAGNETIC DATA FOR MAPPING CONTACT BETWEEN YOUNGER AND OLDER SEDIMENTARY SEQUENCE OVER CENTRAL PART OF KACHCHH REGION, GUJARAT

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Time Domain Electromagnetic (TDEM) methods have proven to be most efficacious, producing better results in the area of Ground water exploitation, identification of major stratigraphic seqeuences, mineral exploration and geothermal studies than traditional galvanic techniques like DC electrical methods. The major advantage of these methods are that deeper soundings can be performed in a relatively short time. We present the results of TDEM investigations carried out between Anjar and Bhuj, Kachchh district, Gujarat. This tectonically active intraplate region comrprises of thick sedimentary formations of Mesozoic to Cenozoic. TDEM soundings at five locations in the study area have been carried out using 100 m sided transmitter loop to map the vertical and horizontal contact between these two sedimentary formations in terms of resistivity distribution. The measured transient decay curves have been used to model the depth and subsurface resistivity of the underlying structure. The resistivity section after combining the all 1-D models gives information down to the depth of 250 m. The section shows a good lateral resistivity contrast between the Tertiary (<5 Ω.m) and Mesozoic (≥ 10 Ω.m) sediments between Anjar and Bhuj. Near Anjar, we infer that 90 to 100 m thick Tertiary sediments overlie the Mesozoics. We also infer the presence of clays/clay rich sand at eastern sites (close to Anjar) and sandstone (might be saturated with moderate quality ground water) at western sites (towards Bhuj).

ONE DIMENSIONAL CRUSTAL VELOCITY MODEL FOR HIMACHAL PRADESH, INDIA

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A preliminary 1 D velocity model for Himachal Pradesh, India has been developed by utilizing the P and S-wave travel time data. A very steady and narrow velocity model was obtained with travel time inversion, and a range of velocity models were tested with earthquake locations to derive the best-fit velocity model. The 1 D velocity model proposed for the study region has seven uniform layers with interfaces at depths of 0, 5, 10, 15, 20, 25 and 30 km with P-wave velocity of 5.219 km/s, 5.314 km/s, 5.391 km/s, 5.392 km/s, 5.964 km/s, 6.071 km/s, 6.073 km/s and S-wave velocity of 2.998 km/s, 3.015 km/s, 3.134 km/s, 3.135 km/s, 3.441 km/s, 3.482 km/s and 3.647 km/s, respectively. According to the proposed model, the Moho in this part of the Himalaya lies at 60 km depth on an average. For P and S-waves the station correction ranges from -0.88 to 1.50 and -0.58 to 3.59 sec, respectively. This low variation in station residuals indicates small lateral velocity changes that confirm the accuracy and stability of the proposed 1 D velocity model. Using the new derived 1 D velocity model the earthquake epicentres were relocated and we observe a shallow seismic activity in the region at < 30 km depth that clearly describes the ongoing convergence of the India-Eurasia plates in the study region. This study also infers a new, highly active seismicwindow in the latitude

range of 31.8 °N to 32.8 °N and longitude range of 76.8 °E to 78.8 °E in the study region across the KaurikChango fault, a causative fault for the 1975 Kinnaur earthquake.

NOISE ANALYSIS AND ATTENUATIONOF 2D SEISMIC DATA OF CAMBAY BASIN

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The seismic method has been successful in providing images of the subsurface. The seismic reflection method has been extensively used to delineate near-surface geology for the purpose of hydrocarbon exploration. Data processing provides the interpreter a seismic section, which represents the geological section. Seismic Data Processing is an important link between Seismic Data Acquisition and Interpretation. The success of any Seismic campaign to a large extent depends upon the quality of Seismic Data Processing. The study is based on the real land raw data of Cambayfor normal sequence of Seismic data processing. The Cambay basin is an Intra-carbonic basin, which came into existence at the close of Mesozoic period.The entire Cambay basin is divided into five tectonic blocks based on transverse fault system, which is subsequent of longitudinal fault originating within the basin itself.The used software for attenuation of noise was GEOCLUSTER, provided by CGG- Veritas. The Input SEGD data was converted to CGG format and subsequently mergedwith navigation data in SPS format supplied by the field crew. Field statics provided by the party were used for processing. There are three main steps in seismic data processing viz. Deconvolution, stacking, and migration. Before Deconvolution there are some essential steps, which must be followed at the time of data processing. The term 'Signal 'denote any event on the seismic record from which we obtain information. Everything else is 'Noise', including coherent events that interfere with the observation and measurement of signals. The 'signal-to-noise ratio', abbreviated S/N ratio is the ratio of signal in a specified portion of record to the total noise in the same portion. For noise attenuation various filtering techniques are used. DSPIKE stands for high amplitude noise burst removal. FDNAT (Mono-Frequency Noise Attenuation) program attenuates mono-frequency or near mono-frequency noise in a seismic trace. FILTR (Signal Processing Convolution and frequency filtering) applies the filter operators stored in filter libraries and performs time-variant filtering. SPASM (Spatial amplitude smoothing) equalizes an input seismic trace with respect to its neighbouring traces. After preconditioning of data, a stack section known as brute stack has been prepared toview the subsurface geology with the help of some reference velocity function.

The above techniques are used to get noise free section i.e. high amplitude spike is eliminated by using DSPIKE module and so on. Therefore above modules enhance signal to noise ratio which is the prime objective of seismic data processing. Removal of such types of noises helps in better interpretation of seismic section.

SOURCE PARAMETERS AND SCALING RELATIONS FOR SMALL EARTHQUAKES IN NATIONAL CAPITAL (DELHI) REGION

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The National Capital Region (NCR) of India lies in the geological realm of the Peninsular India and is about 200 km from the India plate boundary (Himalaya). The seismotectonic set up of NCR and its position in the neighbourhood of Himalaya makes it vulnerable to high seismic hazards. Since historical past, the NCR has experienced earthquakes of magnitude 6.0 and above.They can cause severe damages in the Delhi region and collapse the physical systems and loss of life. The occurrence of even such moderately high seismic event in densely populated Delhi, with several old and weak structures, can be devastating.

The locally recorded accelerograms carry rich information about the source parameters, which may be used for testing models of sources and develop scaling relations.They are useful for the evaluation of seismic hazard in the region. For the analysis of the source parameters in the region, we have used the accelerograms of 15 events with the magnitude range of 2.3-4.7, recorded by the network set up by IIT, Roorkee. The source spectra obtained from the accelerograms have been modeled in terms of Brune Spectra to estimate source parameters (moment, magnitude, stress drop, source dimension) and attenuation parameter Q. A grid search procedure has been adopted for this purpose. The estimated moment magnitude of the earthquakes lies in the range 2.46-4.47.Seismic moment ranges from 5.708 x 10^{19} to 6.134x10^{22} N-m, and the source radius varies from 0.14 to 0.5 km. The scaling relations have been developed using the estimated source parameters.

USING CERTIFIED REFERENCE MATERIALS (CRM'S) FROM MONGOLIA; STEP 1: CALIBRATION OF ED-XRF FOR RARE EARTH ELEMENT ANALYSIS.

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One of the most sophisticated non-destructive analytical techniques for trace element analysis is Energy Dispersive X-Ray Fluorescence. Here, we describe the calibration of REE analyses using Energy Dispersive X-Ray Fluorescence Spectrometer (ED-XRF) and different precautionary steps required during calibration.The Certified Reference Materials (CRM's) chosen are produced from Central Geological Lab, Mongolia. The ED-X-Ray fluorescence has become the instrument of choice with several advantages: a) high spectral resolution; b) low detection limit; c) nondestructive and less time consuming analytical techniques for wide range elements (LILE, HFSE,REE and HSE) in comparison with other *in situ* based techniques.

The instrument used for the analysis of the REE, CRM's is Epsilon-5, a high powered ED-XRF spectrometer. This spectrometer has a polarized optics system that produces least background intensities and thus gives better limit of detection than other conventional XRF. It has 100 KV excitation potential. It can measure 'K' and 'L' shell X-Ray photons of the elements ranging from Na-U in the periodic table. Important feature of this instrument is the use of Crompton lines originating from the secondary targets available in the instrument. Instrument doesthe correction using Crompton ratio

method ,as the intensity of the scatter peak is directly related to the matrix composition. Epsilon-5 also uses a deconvolution algorithm to analyze the sample spectrum and determine the net intensities for the element peaks. In case of the overlap of these intensity peaks, mathematical algorithms are used to correct them. To establish the precision and accuracy of the calibration by Epsilon-5 for REE, CRMs produced by CGL, Mongolia were analyzed as unknown samples and results were compared with the reported values.

TSUNAMI FORCES ACTING ON ANY GIVEN DAM STRUCTURE: A SYNTHETIC STUDY

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This paper attempts to calculate the lateral forces due to tsunami acting on any proposed dam constructed near an ocean or sea. Firstly, a hypothetical dam is considered and the lateral forces (due to surges and bores) acting on it are calculated. The dam is divided into 5 sections and calculations are made separately for each section for a better understanding of forces acting. Secondly, same forces are calculated for similar dam structures of different lengths. And lastly, change in forces with time is plotted for both surges and bores. A possibly large tsunamigenic earthquake in the Makransubduction zone is considered. For a hypothetical dam structure the impact of the tsunami on it is computed. Forces due to tsunami induced hydraulic bores are larger than tsunami surge forces.

ANALYSIS OF FRACTURE PARAMETERS FROM WELL-LOG DATAOF MAHANADI BASIN, INDIA

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Fracture plays an important role in hydrocarbon exploration; it increases the possible pathways and enhances formation permeability. Apparently tight and non-porous reservoirs are shown as productive due to presence of fractures. However the accurate identification of fracture is critical in many reservoir. Fractures have significant effect on both the mechanical and hydraulic properties of rock mass. In this paper natural fracture system have been identified by well log analysis using conventional log data. The identification of fractures is based on the observation of a resistivity contrast with the host rock for electric tools (either conductive or resistive fractures), or on the combination of transit time and amplitude contrasts for ultrasonic tools as well as caliperlog(C1, C2). We have assumed that fracture medium is transversely isotropic with horizontal axis of symmetry (HTI) and these causes azimuthal travel time variation. The P-wave velocities, i.e. vertical and background isotropic P-wave velocity are considered as same. Fracture parameters are calculated by constructing HTI Stiffness matrix. Three dimensionless parameters $\varepsilon^{(v)}$, $\gamma^{(v)}$, $\delta^{(v)}$called "Thomsen Style" parameters(the superscript (v) denotes that the vertical velocities are used as reference velocities)are calculated including V_p/V_S ratio. These parameters deviate from zero characterises the relative strength of anisotropy. The "Thomsen Style" parameters, $\varepsilon^{(v)}$ is the fractional difference in fast and slow velocity for P-wave travelling horizontally through the HTI zone, $\gamma^{(v)}$ represents fractional difference in fast and slow S-wave velocities, and $\delta^{(v)}$ describes the P-wave travelling obliquely through the medium. Thefracture density iscomputed at the

well location within the depth of interval. Some problems and limitations are encountered in the well by approximating the vertical P- wave velocity same as the background isotropic P- wave velocity are studied. Fracture zones are identified from overlay technique using various plots:density vsdepth, $V_p$vsdepth, $V_s$vsdepth, $\varepsilon^{(v)}$vsdepth, $\gamma^{(v)}$vsdepth, $\delta^{(v)}$vsdepth, fracture density vsdepth.

SUBMARINE GROUNDWATER DISCHARGE (SGD) ZONE DELINEATION BY GROUND PENETRATING RADAR (GPR) AT A TIDAL FLAT OF BAY OF BENGAL

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Submarine groundwater discharge (SGD) may be defined as the discharging groundwater across the seafloor. To map the pattern of this discharge zone in tidal flat adjacent to the Bay of Bengal, Ground Penetrating Radar (GPR) survey has been used along several transects. The study site is located in the Chandipur area, Balasore district of Odisha, India. Previous study clearly demarcated presence of the two different geomorphic terrains that existin the study area, which are uniform lowland zone and seaward zone bounded by a line of shore-parallel coastal dune. Tidal flat of the area has two distinct features, a shoreward fine sand zone of 30 m width with an average slope of 6°and a 1.5 km wide silty tidal flat zone with ripples. In order to identify the seawater-groundwater interaction zone, GPR surveys were carried out by employing 200MHz antenna along the perpendicular direction of the shoreline with a profile length of 85 m. After processing of the acquired data, it was possible to locate the interaction zone as demarcated by high amplitude reflection. The boundary between the seawater and freshwater deepens towards the land. The section of many profiles extending below the high tidewater line on ocean-facing beach is affected by saltwater intrusions ,which are often reflection-free.In spite of the presence of clay rich sediment and coastal sedimentary facies, maximum depth of signal penetration was 3.9m. Near the sand dunes, the contact zone is located at a depth of 2.6 m with a magnitude of about 30° extended up to 21.3m towards offshore, where the interaction zone lies at a depth of 1.7m. After this point, huge salt-water intrusion has taken place and a steep slope of the discharge zone is observed up to 25.7 m, where freshwater existsalmost at the surface (contact zone is at a depth of 0.4 m). A reflection free zone due to the presence of salt-water is also observed,which prominently starts after 21.3m. GPR helps to establish the conceptual model of groundwater existence of the subsurface of the studied coastal area.

PRE AND POST EXCAVATION CROSS HOLE SEISMIC STUDIES FOR FOUNDATION DESIGN OF A NUCLEAR POWER PROJECT

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The potential effect of vibratory motion induced by 'design-basis-earthquake' has to be taken into consideration while designing the foundation of a heavy civil structure such as a nuclear power reactor. The transmission of vibratory motion due to an earthquake is governed by dynamic elastic moduli of the subsurface layers at the site and these can be best evaluated from measurement of in situ compressional (P-) and Shear (S-) wave velocities by cross hole seismic method. The velocity measurements include a larger volume of subsurface mass between two boreholes and are better representative of the nature of the strata than from sample measurements. Cross borehole seismic

wave velocities were measured in five sets of three boreholes each at 1.5 m intervals up to a depth of 30 m from the surface. The measurements were made in four mutually perpendicular directions so as to check variations in velocity with direction (anisotropy) at the site of Kaiga atomic power project 3 & 4 units. The site was then excavated up to a depth of 15 m and cross hole seismic studies were conducted again at the reactor buildings 3 and 4 sites in four mutually perpendicular directions to check the condition of the strata and rock after excavation. Granite gneiss, the bed rock encountered at the site is deeply weathered resulting in a four layered geological section of soil, laterite, weathered rock and fresh rock. The studies were conducted in rotary drilled NX sized boreholes (internal diameter 76 mm) employing Signal enhancement seismograph, borehole hammer (energy source) and triaxial borehole geophones. The P-wave velocities in the pre excavation stage with depth for overburden varied from 1030 to 2320 m/sec, for weathered rock between 2320 to 3800 m/sec and for granite gneiss 3800 to 5400 m/sec. Whereas S-wave velocities for the same strata varied between 520-1300 m/sec, 1300-2100 m/sec and 2100-3050 m/sec respectively. In the post excavation stage, P- and S-wave velocities for the rock varied from 4900 to 5900 m/sec and 2600 to 3300 m/sec respectively. P- and S-wave velocities at any depth in all the four directions were of the similar order confirming that inhomogeneities have no preferential direction of orientation at this site.

ESTIMATION OF EARTHQUAKE SOURCE PARAMETERS IN THE KACHCHH SEISMIC ZONE, GUJARAT, INDIA, USING THREE COMPONENT S- WAVE SPECTRA

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Earthquake source parameters and crustal Q values are computed through inversion modeling of S- wave spectra from three component broadband data of 138 selected local events (Mw: 2.5 to 4.4) of the 2001 Bhuj earthquake sequence. These local events, which were recorded at three or more stations, are located using the SEISAN software and existing 1-D velocity model. First, we estimate velocity and displacement spectra of S-waves from 3-component broadband data, using the SAC (Seismic Analysis Code) software. Then, the 3-component displacement spectra are inverted through the Levenberg –Marquardt non-linear inversion technique wherein the inversion scheme is formulated based on ω^{-2} source model. The best fit displacement spectrum provides the model parameters viz. corner frequency (f_c, in Hz) and long period spectral level ($\prod_o$, in nm-s). Finally, the estimated $\prod_o$ and f_c are used to compute other source parameters (viz. stress drops, seismic moments, source radius and moment magnitudes), through some well-established empirical relations.The estimated seismic Moment (M_o) and source radius (r) range from 7.03E+12 to 5.36E+15 N-m and 178.56 to 565.21m, respectively. The corner frequencies vary from 3.025 to 7.425 Hz. We also estimate the radiated energy (E_s), which is varying from 2.76E+06 to 4.07E+11 Joules. The estimated apparent stress drop and static stress drop values range from 0.01 to 2.56 MPa and 0.53 to 36.79 MPa, respectively. Our study also reveals that estimated Q_s values vary from 119.0 to 7229.5 with an average Q value of 701. We also calculate the error in source parameters by estimating standard deviation for corner frequency (f_c), seismic moment (M_o), source radius(r) and stress drop. The estimated multiplicative factor and standard deviation of stress drop values range from 0.524 to 1.934 and 0.008 to 5.415 MPa, respectively. The standard deviation of corner frequency and source radius values are varying from 0.004 to 0.378 (Hz) and 0.46 to 37.77(m), respectively. We also estimate Zuniga parameter, which can be used to identify the earthquake rapture process.It suggests that most of the studiedKachchh events follow the frictional overshoot model. Also we found that our estimated static stress drop values are higher than the apparent stress drop values.

STANDARDIZATION OF AQUIFER RESISTIVITYCOUPLING WITH BORE HOLE ELECTRICAL LOGS FOR DEDUCING MULTI-LAYERED AQUIFER SYSTEM IN A PART OF MIDDLE GANGA PLAINS, PATNA, BIHAR

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Multi-layered aquifer system commonly exists in the Middle Ganga Plains (MGP) in Northern India. It is the challenging task to delineate precisely the multi-layered aquifers which are separated by very thin conductive layers (clays). Thus this article deals with the analysis of vertical electrical soundings (VES) coupling with the existing bore hole electrical logs for deducing the multi-layered aquifer system from the AQBHR area, Patna, Bihar. Initially 5 VES data with the help of Schlumberger configuration (current electrode spacings AB/2, min.= 235m & max= 1500m) were collected at nearby existing bore holes, where the electrical logs along with the lithologsare available.These e-logs were digitized for getting layer resistivity values andthicknessesin conjunction with the lithologs at a certain depth ranges. The synthetic data weredevelopedwith the help of IX1-D Interpex software using these parameters, which were checked with the nearby the collected VES data. Then both thefield and synthetic data were subjected to inversion for arrivingthe geoelectrical attributes at the bore hole sites. It was more or less matching with the lithologs and the RMS values vary from 1.02% to 5.30% for the field data whereas for the synthetic data, 1.5% to 4.05%. Due to the sparse of lithologs in the study area, 72 VES data were given more weitages for attributing aquifer resistivity.The results show that the resistivities of clay, sandy clay/silt, fine sand, medium sand, coarse sand and gravel mixed with sand are <15, 5-37, 25-45, 45-60, 60-80 and >80 Ω-m, respectively. The near surface aquifer (unconfined) occurs within the depth ranges of 3.2 to 5.8 m (bgl) having resistivity range of 22-122 Ω-m. The aquifers at depths known as first and second principal aquifers could be also delineated along with shallow aquifers up to explored depth of ~324m. The first principal aquifer (depth range: 21.6 -66.2 m, bgl) is characterized by resistivity in the range of 51 to 76 Ω-m with an average resistivity of 61 Ω-m. The aquifer resistivity changes spatially implying a higher degree of aquifer granularity and hence comparatively more aquifer potentiality. The second principal aquifer commences at an average depth of 135 m (bgl) and its depth varies from 99.2 to 173.0 m (bgl). Resistivity of this aquifer varies from 40 to 51 Ω-m with an average of 46 Ω-m.The analysis of the disposition of 'a clay bed' separating the first principal aquifer from the underlying second principal aquifer is quite significant. The depth of this clay bed varies in general from 71.2 to 150.6 m, bgl with an average resistivity of 26 Ω-m.

LIQUEFACTION SUSCEPTIBILITY OF KOLKATA THROUGH NEAR SURFACE GEOPHYSICAL AND GEOTECHNICAL INVESTIGATION

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Soil liquefaction is a secondary phenomenon triggered by a large earthquake in an alluvium filled terrain like Kolkata, which causes increase in pore pressure resulting in the reduction of shear strength of soil when monotonic, cyclic or shock loading is applied. The subsurface stratigraphic sequence underlying the city of Kolkata is composed of potentially liquefiable alluvial fan deposits of Ganga-Brahmaputra river system containing varying amounts of clay, silt, sand, and gravel interbedded with

decomposed wood and peat. Considering the favorable geological, geomorphological & hydrological conditions, an attempt has been made to create liquefaction hazard scenario for the 1934 Bihar-Nepal Earthquake of M_w 8.1, which has induced an MM intensity of VI-VII in the city. 1D shear wave velocity (V_s) at each of the 654 sites has been achieved by generating site and depth specific, lithology dependent empirical relations between V_s and corrected SPT 'N' value, estimating effective V_s in the range of 145-356m/s in urban Kolkata. Stochastically synthesized ground motion of the considered earthquake convolved with local site effects generates peak ground acceleration (PGA), depicting a variation of 0.04-0.16g at surface level. The triggered soil liquefaction is measured in terms of Factor of Safety (FOS) and Probability of Liquefaction (P_L), for each lithostartigraphy. Using these inputs the Liquefaction Potential Index (LPI) and Liquefaction Risk Index (I_R) are assessed for the entire soil column. The liquefaction susceptibility and risk distribution classifies the city into Severe (LPI>15), High (5<LPI<15) and Low (LPI<5) susceptibility zones. The areas that have experienced damages due to 1934 Bihar-Nepal earthquake were found to exist within the severe and high susceptibility zones. Further, surface consistent deterministic liquefaction susceptibility scenario of the city has been created with 10% probability of exceedence in 50 years ,which expectedly generated a high liquefaction hazard zone in the depth range of 5-10m due to the presence of coarse grained sediments viz. sand, silty sand, clayey silty sand and shallow ground water conditions. The results of the present study will help the structural engineers and geoscientists in better understanding the soil vulnerability and the related hazard conditions in the city of Kolkata and in similar lithostratigraphic terrains present elsewhere.

DELINEATION OF GROUNDWATER POTENTIAL ZONES IN CHITTARBASIN, TAMIL NADU USING REMOTE SENSING, GIS AND ANALYTIC HIERARCHY PROCESS (AHP) TECHNIQUE

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Groundwater occurrence in India is highly uneven due to diversified geological formations with considerable lithological and chronological variations, complex tectonic frame work and also climatological variations. Major parts of Tamil Nadu are underlain by hard rocks and presence of ground water is subject to availability of secondary porosity i.e. joints, fractures, fissures and weathered residuum. In these rocks, the groundwater mostly occurs in shallow unconfined aquifers in the weathered residuum and under semi-confined conditions in deeper fractures and joints. Remote sensing and GIS technology have opened new paths in groundwater resource studies. With the development of remote-sensing technology and its spatially accurate performance in georeference processes, the factors influential to groundwater potential zonation can be more easily identified on a broad scale. The present study has been conducted to demarcate the groundwater potential zones within Chittar basin using multi-criteria decision analysis technique. Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by Prof. Thomas L. Saaty in the 1970s for organizing and analyzing complex decisions. Eight thematic layers, viz., Geology, Geomorphology, Drainage density, Lineament Density,Slope, Average annual rainfall,Soil type andLand use /Land cover were considered in this study. All these themes and theirindividual features were then assigned weights according to their relative importance ingroundwater occurrence and the corresponding normalized weights were obtained based on the Saaty's analytical hierarchy process. The assigned weights of the thematic layers and their features were then normalized by using AHP. The thematic layers are finally integrated using overlay analysis in GIS environment to yield a groundwater potential zone map of the

study area. Thus, different groundwater potential zones are identified in the area, namely 'Very good', 'good', 'moderate' and 'poor'. The result depicts the favourable groundwater potential zones in the study area and can be helpful inbetter planning and managing of groundwater resources, particularly in hard rock terrains.

SEISMIC HAZARD ASSESSMENT IN GUJARAT – A PROBABILISTIC APPROACH

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Gujarat is one of the most seismically active regions in India and falls under all four seismic zones V, IV, III and II of the seismic zoning map of India. Zone V expects the highest level of seismicity, whereas zone two is associated with the lowest level of seismicity. Each zone indicates the effect of an earthquake at particular place based on the observation of the affected areas and can be described using a descriptive scale like Modified Mercalli Intensity Scale. Two major earthquakes struck Gujarat, one of magnitude M_w 7.8 in 1819 and other earthquake of magnitude M_w 7.7 in 2001. Physiographically, Gujarat comprises three distinct zones: Kachchh, Saurashtra and Mainland Gujarat. Gujarat is located in the 'Himalayan Collision Zone', where Indo-Australian tectonic plate slides under Eurasian plate causing active fault lines beneath.Active faults are source for large magnitude earthquakes in seismically active regions. Their proper identification and distribution significantly help in knowing the seismic potential and associated hazard in the region. The major faults in Kachchh region are Nagar Parkar fault (NPF), Allah Bund fault (ABF), Island Belt fault (IBF), South Wagad Fault (SWF), Kachchh Mainland fault (KMF) and Katrol Hill fault (KHF).For seismic hazard study of a particular region the following five parameters can be studied: geology of the region, past earthquake history, active fault in the region, focal mechanism and Gutenberg Richter curve for the region. In the probabilistic approach we first have to define earthquake sources, which can be small fault or large seismotectonic province. In this study the sources are taken as faults in source zone that probably associated with past earthquake activity. Then we define seismicity recurrence characteristic for each seismic source. Each source is characterized by recurrence relationship. Recurrence relationship gives the relation between log of cumulative number of earthquake of given size and magnitude, given by the Gutenberg-Richter formula Log N=a-bM.The constants,a and b are computed for the various source zones of the region. The parameters like Peak Ground Acceleration (PGA) and Spectral Acceleration (SA) are calculated and the scenario hazard maps showing their spatial distribution are prepared.Thus, from this study it is observed that the seismic hazard of Kachchh region is more in comparison to Saurashtra and Mainland.

STRUCTURAL ANALYSIS AND PETROGRAPHY OF HIGH GRADE GNEISSIC ROCKS OF ELURPATTI AREA WITH SPECIAL REFERENCE TO THE EVOLUTION OF NORTHERN MARGIN OF CAUVERY SHEAR ZONE, SOUTHERN INDIA

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The high-grade terrain occurring at the southern tip of India, popularly known as the Southern Granulite Terrain (SGT), comprises a group of fragmented and imbricate crustal blocks separated

by crustal-scale Cauvery Shear Zone system (CSZ) and the Achankovil Shear Zone. The CSZ is demarcated as the interface between the Dharwarcraton and the SGT, which has been interpreted as a zone of Palaeoproterozoic and Neoproterozoic re-working of Archaean crust. The CSZ constitutes high-angle thrust represented by the Moyar-

Bhavani-Mettur Shear Zone at the northern margin and many sub-parallel shear zones to the south representing back thrusts, which are together visualized as a crustal-scale 'flower structure'. TheCSZconsists mainly of late Archaeancharnockites, migmatitic mafic gneisses,quartzo-feldspathic gneisses, high-grade supracrustals and a variety of younger intrusions such as alkaline-anorthositic rocks and granitoids. At present, some part of CSZ remains unmapped, for example Elurpatti area in the district Tiruchiraplli, South India. Therefore, it is necessary to understand the structural and tectonic evolution of the southern margin of CSZ, which helps us to correlate with regional geological model. In the present work, we have collected the rock samples from the study area and also demarcated the geometric characteristics of ductile shear zones. The structural and petrographicalstudy on the rocks of the study area highlights the finite strain geometry, pattern of deformation and grade of metamorphism. The reconnaissance structural analysis has revealed pattern of tectonic evolution, regional as well as mesoscopic kinematic indicators along all the shear zones consistent with predominance of dextral movements along the CSZ system.Variety of structures found in the region show the intense shearing such as Riedal Shearing pattern, type 2 interference pattern of fold (Hook pattern).These patterns enumerate two generations of folding. The structural cross section of the area exhibiting thrust surfaces fits to the 'flower structure'.Petrographical studies suggest that there is an increase in metamorphic grade when we move from north to south. The results from the present study in conjunction with the available geological, geochemical and geochronological data, suggests a subduction and accretion tectonics of Gondawana tectonics.

GLOBAL MESHLESS COLLOCATION FOR TWO DIMENSIONAL ADVECTION-DIFFUSION PROBLEMS

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The advection–diffusion equation is a combination of the diffusion and convection (advection) describing physical phenomena where particles, energy, or other physical quantities are transferred inside a physical system. Many conventional mesh-based numerical methods have been proposed to solve this equation for precise modelingof the interaction between advective and diffusive processes. In recent years, meshless methods have attracted the attention in numerical modelling due to their ability to solve problems without using a predefined interconnection between the scattered nodes in the mesh. Radial basis collocation is one such method where a shape function is interpolated over a set of scattered nodes and the field is approximated using combination of this shape functions and some unknown coefficients,which are determined depending upon type of the problem . Radial basis meshless methods are easy-to-program and extendable to higher dimensions without significant changes. Since radial basis functions are infinitely differentiable, the approximate solution obtained can be upscaled to any degree. Here, we present a global radial basis collocation algorithm for two dimensional advection-diffusion equation. The efficacy of the algorithm has been discussed in terms of condition, elapsed computational time and error. A Matlab code has been developed for this purpose, which can incorporate the source term, general initial condition as well as Dirichelet and Neumann

boundary conditions. The algorithm can be used to model many geodynamic processes involving diffusion, advection or convection, and advection-diffusion simultaneously.

INTERPRETATION OF BOUGUER GRAVITY DATA BY SPECTRAL ANALYSIS AND DOWNWARD CONTINUATION, OVER PARTS OF RAJMAHAL TRAP AREA

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Rajmahal traps forming low lying hills in eastern Jharkhand and western West Bengal, Indiabounded by SinghbhumCraton in the west and Bengal basin in the east. These traps are believed to be the result of Kerguelen Hotspot activity and appeared around 117Ma ago when earth opened up along paleocontinental margin of eastern India and large amount of basaltic lava with high temperature and low viscosity gradient spread almost laterally blanketing an area of about 4100 Km^2.Study area is characterised by at least 28 number of basaltic lava flows separated by inter-trappean sediments. It has also been suggested that Gondawana sediments are partly covered by the traps. Several basalt and coal mines located in the area around Birbhum district makes the area potential target for exploration for further estimation of Trap/basalt thickness and finding the depth of Gondawana sediments which have been reported to contain coal. We have also tried to find the depth of basement in the area.

Knowing the fact that there is considerable density difference between basalts and inter-trappean sediment, in this study we have taken this challenge to handle with gravity data interpretation and to estimate total thickness of basalts. Two dimensional potential fieldas gravity field may be considered as the superposition of fields due to density distribution in the subsurface. The present study deals with the interpretation of gravity data in frequency domain by the spectral analysis method. Bouguer gravity data of the area has been used for analysis. 2-D Fourier transformation and calculate Radially Averaged Power Spectrum (RAPS) of data is calculated. Now this RAPS is used to find the depths of different sources contributing to total gravity field of the area. Downward continuation technique also applied to find the depths of causative sources and compare the results of both applied methods.

DELINEATION OF SUB-TRAPPEAN SEDIMENTS USING MAGNETOTELLURIC METHOD ALONG INDORE-JALGAON TRAVERSE IN CENTRAL INDIA

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A wide band magnetotelluric study was carried out to delineate the sediments buried below the volcanic rock cover – Deccan traps. A 190 km long traverse from Indore to Jalgaon, oriented nearly in NS direction (covering the well-known Narmada-Son lineament zone) was covered. In total 42 sites have been investigated. The shallow geoelectric section along Indore-Jalgaon traverse indicates basement depth of less than 1 km towards north.It steeply increases to about 3-4 km coinciding with Narmada South Fault (NSF) and gradually decreases to 2 km further south of the traverse near Jalgaon. Deccan trap thickness is less than a km towards north and increases to about a km south of NSF. Like basement, an increasing trend is noticed towards south, near Jalgaon. The Deccan trap layer is overlain by alluvium cover towards south, i.e. north of Jalgaon with a maximum thickness of 500 m. Thickness of sediments to the tune of about 2.5 km is observed in the southern part of

NSF. It gradually reduces to about 1 km near Gaviligarh fault (GF). From deep (0-50 km) geoelectric section, anomalous high conductive zones are also observed south of NSF, near Barwani-Sukta Fault (BSF) and Tapti North Fault (TNF). The deep high conductive zones are spatially co-relatable with high heat flow region indicating that the region has hot thermal fluids at deep crustal depths. Spatial correlation of these zones with regional gravity high indicates that the rocks at mid-crustal depths might have close association with mafic material. Such a correlation with high heat flow might be a favourable factor for generation of hydrocarbons in the upper crust close to the region. The presence of large thickness of sediments south of NSF , with thickness varying between 1-4 km can be considered as an additional favourable factor for the generation of hydrocarbons. Additionally, the near surface Deccan trap cover might be acting as a cap rock for maturation of hydrocarbons.

MAPPING AND ASSESSMENT OF AQUIFERS THROUGHGIS, SEISMIC &ELECTRICAL IMAGINGIN HARD ROCK TERRAIN OF KHORDA DISTRICT, ODISHA

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In this study, we apply techniques such as GIS,2-D Seismic and Resistivity Imaging to understand groundwater prospects in hard rock terrain of Khorda district of Odisha.GIS technique, and resistivity imaging were used to locate and quantify aquifer thickness whilehydrochemical analysis was used to delineate water quality and its usability for domestic purpose. The area is a metamorphosed terrain dominated by litho units like laterite, khondalite and charnockite rocks. Multicriteria analysis in GIStechnique marked the area as moderately potential groundwater zone. 2D Resistivity imaging was carried in the region upto a depth of 70m. Western part was prospected as poor potential zone while adequate groundwater is expected in the eastern part of the region.Bore well drilled in the central part supports the resistivity imaging results. The integrated analysis of thesetechniquessuggests that the area has some deep seated fracture zones but may not sustain for long-time.

CRUSTAL STRUCTURE BENEATH THE CLOSEPET GRANITE BATHOLITH, DHARWARCRATON: A GRAVITY PERSPECTIVE

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The formation and evolution of granitic provinces and batholiths are being increasingly studied, because of their importance in understanding thecrustal evolution. The Dharwarcraton in South India is intruded by several elongated bodies of Late Archaean (2.5 Ga) granites. Among these, the Closepet granite batholith is the largest (400 x 30km) linear feature elongated along N-S to NW-SE and exposed from shallower crustal levels (greenschistfacies) in the north to the deeper levels (amphibolite & granulite facies) in the south due to differential erosion. Emplacement mechanism and evolution of this important tectonic domain is still debated.

In order to delineate the subsurface disposition and crustal structure beneath the Closepet granite batholith, gravity data acquired over Dharwarcraton is utilized. The Bouguer anomaly (BA) map of

the study area shows a prominent gravity high of regional nature superposed on short wavelength linear highs and lows. To decompose the gravity field due to shallow and deep seated sources, radially averaged power spectrum is calculated to estimate the cutoff wavelength (CW) of LP and HP filters for regional and residual anomalyseparation. The regional anomalymap obtained from LP filter with CW of 120km shows a prominent linear gravity high over the Closepet granite suggesting a deeper high density magmatic source. Residual anomalies obtained from HP filter with CW of 120 km show number of N-S trending linear highs and lows in the region. It is observed that, no distinct gravity anomaly persist over the entire length of the Closepet granite. It may be partially due to large variation in density (2.58- 2.72 g/cm^3) of Closepet granites. However, further analysis of residual anomaly map reveals that in the southern part, the western contact of granite-basement shows high whereas the eastern contact is associated with gravity low.It probably suggests that western contact is migamitizedresulting in higher density of the basement rocks.It is interesting to note that minimum of gravity low at the eastern contact falls away from the exposed contact indicating that in the subsurface the Closepet granite dips towards the east. Presences of greenschist belts in the northern part of the batholith obliterate the gravity signature due to Closepet granite. Therefore, disposition of subsurface geometry from gravity alone is not unique. However, regional gravity high coinciding with the NW-SE trending Closepet granite suggests deep seated mafic magmatic source for the origin of Closepet granite.

EULER DEPTH SOLUTIONS USING ANALYTICAL SIGNAL OF SP DATA: AN EXAMPLE OVER VMS DEPOSIT

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North Singhbhum Mobile Belt (NSMB)has evidences of metallogeny. NSMB consists of Singhbhum Group of Metapelites (SGM), DalmaVolcanics (DVs) and Singhbhum Group Quartzite and Pelites (SGQP). Proterozoic age DVs has played a major role for the evolution ofmetallogenic belts in its northern fringes.Most of the gold occurrences of the NSMB are present in the meta-sedimentary belt lying north of the DVs. The auriferous mineralisation of the study area is mostly found in form of sulfide minerals viz. Arsenopyrite, pyrite, and some pyrrhotites as disseminations, specks, streaks, fracture fillings etc. in quartzitic rocks.

To study the nature, size, location and depth of already identified Volcanogenic Massive Sulfide (VMS) mineralization, Self Potential (SP) surveys were carried along 13 lines with a line spacing of ~ 50m and station spacing of ~ 10m. Initially, SP data were corrected for drift i.e., correction applied for variation in SP readings with time. Subsequently, regional-residual separation was carried out using the code of Agarwal and Srivastava (2010). Horizontal derivatives as well vertical derivatives and its total gradient measured i.e., analytical signal of SP residual anomaly are computed from a code developed byAgarwal and Srivastava (2008). Finally, Euler depth solutions were obtained using Geosoft Euler 3D module to determine the depth of causative source anomaly. The analytical signal map was used as an input to Euler 3D module of Geosoft to obtain Euler Depth Solutions. This procedure makes it equivalent to located Euler method unlike standard Euler method as analytical signals are used as an input in place of residual anomalies. The depth solutions were computed for varying Structural index,

SI, (i.e., 1.0, 2.0, and 3.0.) for two window size (10m and 15m) for a fixed grid cell (10m X 10 m). Each solution is plotted at its plan position (x, y) using a symbol size proportional to depth z. They show roughly the same trend at all three structural indices but with different degree of clustering and different depths.The best/tightest cluster of solution was obtained for a grid cell size of 10m X 10m and window size of 15 m for structural index of 3.0 corresponding to spherical body. The probable plan positions of three major best clusters of Euler depth solutions are also drawn on map. The corresponding Euler depth solutions depicts the depth of sulfide mineralization is in between 40-60m.

NUMERICAL MODELLING FOR SUBSURFACE CAVITY DETECTION ASSOCIATED WITH OLD COAL WORKING

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Detection of shallow subsurface mine galleries/cavities is very important for land use and coal mining at deeper seams. Subsidence occurred due to void mine galleries is one of the reasons for environmental hazard. So, it is very essential to stabilize those void mine galleries. The use of a suitable geophysical prospecting procedure is concentrated for the identification and characterization of these underground cavities.It is unnecessary to use destructive methods, such as drilling boreholes, that are much more expensive and environmentally damaging. In general, geophysical prospecting involves a number of different techniques that help to identify mine galleries in the physical and chemical properties of the subsoil, including the propagation of electromagnetic, gravity, acoustic, electrical, or magnetic signals. Electrical resistivity tomography is one of them which concentrate on the subsurface electrical resistivity distribution. This is done by taking a very large number of readings either from the surface or from perforations. The depth of information may vary from a few meters to hundreds of meters in depth. This technique has numerous possible applications in complex subsurface geology. Now a days, it has used in environmental studies, hydrogeology and geotechnics among other fields. This technique has also been used for detection of natural crevice-type caves and manmade mining cavities/galleries. Synthetic models have been designed on the basis of board and pillar mining method. The forward modeling has been computed using RES2DMOD software utilizing the finite difference calculations, which divides the subsurface into number of rectangular blocks with specific resistivity values. Threemodel have been considered. For all model resistivity responses have been computed using three electrode array as Wenner, Schlumberger and Dipole-Dipole. After that a Gaussian distributed random noise of 3 mV/A peak-to-peak amplitude has added with the synthetic data for field environment simulation in ordered to make the models more realistic.After that RES2DINV software has used for inversion. For every model, a multi electrode configuration of different electrode spacing has been considered. For each case dipole-dipole array shows better result for shallow subsurface cavity detection.

SEISMICITY VARIATION ACROSS THE HIMALAYA AS INDICATED BY SPATIAL VARIATION OF B-VALUE USING MAXIMUM LIKELIHOOD ESTIMATION (MLE)

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The Gutenberg-Richter (1944) relation (G-R relation) is commonly used for earthquake precursor and probabilistic seismic hazard assessment and it defines the magnitude-frequency relation of earthquakes. In any seismically active region, the spatial variation of the parameter 'b-value' that is derived from the G-R relation indicates locally effective stress. In this study we have computed the spatial variation of b-value in the Himalayan region. Earthquake catalogues were collected from different data sources; i.e. USGS-NEIC, ISC, NCEDC and IMD to extract needed information about earthquakes with magnitude above 4. Event with magnitude scales in mb, ms and M_L have been converted to corresponding Mw to achieve homogenisation of data base, using the equation proposed by Kolthayar (2012). De-clustering of the events has been done by using Gardner-Knopoff windows method. The spatial distribution of the de-clustered catalogue shows that the epicentres are clustered in the zone between MCT and MBT.Catalogue completeness (Mc) is the next important step for calculation of b-values. Using Woessner and Wiemer catalogue based method, Mc has been estimated (4.5). The entire Himalaya has been divided into four regions from west to east i.e. Western, Central-I, Central-II and Eastern, following NDMA (2011). Spatial distribution of b-value has been estimated by Maximum Likelihood Estimation (MLE) method as proposed by Aki (1965) using 100km grid, and interpolated using Inverse Distance Weight (IDW) method for no-data cells. The b-value has been found to vary between 0.65-1.5 across all the zones. The zones dominated by lower b-values are those with historical recordsof higher magnitude earthquakes. Lowest b-value (0.65) has been found in Western region near to Sunder Nagar fault and MCT and highest value (1.5) is found in Central-I region. Because of higher magnitude earthquakes in the Central-II region the gird-values are varying between0.68 and 0.90 and indicate high stress accumulation, whereas in the Eastern region the values are varying from 0.67 to 1.12. Incidentally, the Nepal earthquake (25th April 2015) occurred in Central-II region.The structural heterogeneityof the terrain causes the different types of stress accumulation in the zones indicated by varying b-values.

FREQUENCY CHARACTERISTICS OF GEOMAGNETIC INDUCTION ANOMALIES IN SAURASHTRA REGION

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Magnetovariational studies were carried out along four different EW profiles in Saurashtra region in different phases,during January 2007-March 2012. Transient geomagnetic field variations recorded along theseprofiles are analyzed to infer theelectrical conductivity distribution of the region. The vertical field transfer functions which depict the characteristics of electrical conductivitydistribution are presented in the form of induction arrows. From the spatial distribution of these arrows, it isinferred that the sediments filling the offshore basins are more conductingthan those basins in Saurashtra region. The contact zone between Jasdan basin and Saurashtra region is marked by the reduction in the amplitude of induction arrows.

Z/H pseudo sections along the four profiles in conjunction with tectonics/and other geophysical methods permit to infer thatthe conductivity anomaly in the eastern part of the profiles is associated with the crustal/lithosphere thinning. The possible cause for these anomalies may be explained in terms of partial melts associated with mafic intrusions, related to Deccan and pre-Deccan volcanism. The frequency and polarization characteristics of the induction response of theseanomalies are discussed in this paper.

SEISMIC HAZARD ASSESSMENT IN TWO MAJOR SEISMIC ZONES OF THE N-W HIMALAYA REGION

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The seismic hazard assessment of any region is of great importance to minimize the seismic risk. The seismic hazard due to an earthquake can be minimized by implementing the building codes in developing countries like India. The seismic hazard can be evaluated from the statistical analysis of the seismic history of a region by estimating the probabilities of occurrences of an earthquake in a given region within a certain time period.

Interplate boundary in subducting zone is the most vulnerable zone in term of seismic hazards. The region in present study lies in the subduction zone of two boundaries: Indian and Eurasian plates. The whole region is subdivided in two zones, Zone-I (Kashmir region) and Zone-II (Uttarkashi-Chamoli region). Seismic risk for the two zones has been estimated using both Gumbel's extreme value theory and the theory proposed by Knopoff and Kagan. In present study, the most probable maximum magnitude in a specified time period, the mean return period and probabilities of occurrences of earthquakes of magnitude M≥5.5 have been estimated using a homogeneous and complete earthquake catalogue prepared for period 1968-2008 for zone-I and zone-II. The results show that the largest probable annual earthquakes are 5.0 for zone-I and 5.2for zone-II. The estimated most probable largest earthquake that may occur within different time periods for two zones shows that zone-I has low probabilities and larger mean return periods for higher magnitude as compare to Zone-II. It is observed that Zone-II has probability ›85% of occurrence of an earthquake of magnitude 6.9-7.0 in upcoming 200 years.

COSEISMIC OFFSET DUE TO THE APRIL 25, 2015 GORKHA, NEPAL EARTHQUAKE

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The April 25, 2015 Gorkha Earthquake (Mw 7.8) was one of the largest earthquakes of recent time in the active Himalayan thrust belt. We have observed significant coseismic offsets at sites in the adjoining Indo-Gangetic plains, the largest being about 7 mm towards north at Patna, Bihar. In this presentation we have compared various available slip models of this earthquake derived from seismic back projection, GPS data, InSAR data etc. We have estimated the coseismic displacement at various sites of Indian GPS networks and those of Nepal , for spherical layered earth due to the available five

slip models (USGS, 2015; Avouac, 2015; Yagi, 2015; Wang, 2015; and Galetzka, 2015). We found that the slip model of USGS and Yagi have large inconsistency with observed coseismic displacement at the nearby GPS stations (KKN4, CHLM, SNDL, and NAST, in Nepal) and have good consistency at far field GPS stations. The average root mean square error of coseismic displacement is less for slip model derived by Galetzka et al., (2015) from the inversion of GPS and InSAR data, as compared to the other slip models. We have used a linear inversion scheme to derive the slip distribution on the finite fault in layered earth (CRUST2.0) using coseismic offsets at the GPS stations of Nepal and India. We have found reduced root mean square error as compared to the other available slip models of the earthquake. The estimated moment magnitude is consistent with that reported by other authors. The ruptured segment is about 130 Km and majority of the slip occurred between the epicenter of the main shock (Mw 7.8) and its largest aftershock (Mw 7.3).

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DETECTION OF COAL FIRE ZONE IN PATHERDIH COLLIERY, DHANBAD USING MAGNETIC MODELING

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Magnetic survey was carried out to the segment of the coal fire zone of Patherdih area, Dhanbad district, Jharkhand. Patherdih region is located to the southwest of the Jharia coal-field. The work is divided into three steps. The first step is related to data acquisition, second step is to detect areas of coal fires by feature extraction through data processing, and the third one is the interpretation part involving the mapped magnetic anomalies for finding the depth-extension of coal fire zone using Enhanced Local Wave Number (ELW) Technique. The data have been collected by Proton precision magnetometer along 5-profiles with station spacing of 10m and profile spacing of 50m. The analysis shows that the coal fire region is mainly confined between Latitude 23.6655 and 23.6654°N and Longitude 86.4334 and 86.4345°E, and the depth of its continuity is ~ 7m.

INTERPRETATION OF GRAVITY ANOMALIES USING PARTICLE SWARM OPTIMIZATION TECHNIQUE CAUSED BY MANGANESE ORE BODY, NAGPUR, INDIA.

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Particle Swarm Optimization (PSO) is a global optimization inversion technique inspired by natural social behaviour of flock (swarm) of birds.While searching for food each bird continuously

optimizes its position and velocity with respect to whole group so that it, as a part of whole group can find the best possible wayin reaching the food. In Swarm Intelligence technique, birds are regarded as particle /models inside the room (search space) searching exit door (optimum solution).The algorithms of PSO areefficient, robust and simple to implement on gravity anomalies data .This method has been applied to the inversion of gravity anomalies data caused by buried bodies with simple geometry like sphere, horizontal cylinder and vertical cylinder. The inversion parameters are the depth of the body, gravity anomalies, amplitude coefficient, and shape factor of the bodies. The method has been applied to the synthetic noise free data with white Gaussian noise. The applicability of the PSO algorithms has been seen on manganese ore body, Nagpur area, India. Theresults have been compared with the previous results obtained by different methods showing a significantly good agreement. The main advantages of the PSO method is that it is a fast method, does not require an assumption about the shape of the source of the gravity anomalies and considerable computation time. **Poster**

RADIAL ANISOTROPY BENEATH SOUTH INDIAN CRUST INFERRED FROM SEISMIC AMBIENT NOISE TOMOGRAPHY

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Most of the studies of continental crust are made by assuming it to be isotropic. The analysis of the Rayleigh and Love wave empirical Green's Functions derived from cross-correlation of seismic ambient noise give an opportunity to better constrain the crust of south India by calculating the shear wave velocity structure and radial anisotropy. The negative anisotropy ($V_{SV} > V_{SH}$) is mainly associated with the surface geology and the positive anisotropy ($V_{SV} < V_{SH}$) is mainly associated with the material property of the rocks present in the mid to lower crust. In EDC there exists very low magnitude of anisotropy because of the batholiths. The higher magnitude of anisotropy in the southernmost part of WDC implies the existence of Peridotite in the lower crust. In SGT also we can see a large variation of anisotropy, where the south east part with high grade metamorphism have a higher magnitude of mid to lower crustal anisotropy, whereas the khondalite part with metasedimentation has a lesser amount of anisotropy. The study will provide a priori information for the further study of mantle structure beneath South Indian crust.

PRELIMINARY PALAEOMAGNETICRESULTS FROM MAFIC DYKES IN EASTERN DHARWARCRATON, INDIA: IMPLICATIONS RELATED TO THE AGE OF DYKE EMPLACEMENT

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Oriented samples were collected from 15 sites covering surrounding places of Warangal district (17°65′N; 79°80′E)in the eastern Dharwarcraton for palaeomagnetic and Rock magnetic studies to determine the dyke emplacement age. There is no direct age information available for these Dykes

in this region. Here we present preliminary results from palaeomagnetic and rock magnetic study of the mafic dykes fromWarangal region. Rock magnetic studies (IRM and SIRM) indicate that main remanence carrier resides in multi domain Magnetite. The Natural Remanent Magnetization (NRM) Intensity values range from 0.7 to 5.24 A/m and the Susceptibilty values range from $2.58x10^{-2}$ to $1.01x10^{-1}$ SI Units. Selected samples were subjected to Thermal and AF demagnetization to remove the secondary magnetization and to isolate the Characteristic Remanent Magnetization (ChRM) directions. The final statistics infer mean declination (Dm) =288° and mean inclination (Im) = 8° (N=8, α_{95}= 11.1 and k=13.8) and yield a palaeopole at lat.18.4°N; 348.14°E. This new poleposition indicates an emplacement age of ~2.1Ga for Warangal region dykes of eastern Dharwarcraton. This pole is in conformity with the easterly shallow ChRM poles determined for dykes ofCuddapahbasin, Southern Granulite terrain (SGT) and those in the peninsular India.

FABRIC ANALYSIS OF THE 2.61GA GRANITES IN THE CHITRADURGA REGION – PRELIMINARY RESULTS FROM ANISOTROPY OF MAGNETIC SUSCEPTIBILITY (AMS) STUDIES

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The NW-SE trending Chitradurga Schist belt represents the Archean age greenstone belts of the western Dharwar craton, South India (Chakrabarty et al., 2006; Mondal and Mamtani, 2014). It represents a thick volcano sedimentary unit which is metamorphosed up to greenschist to lower amphibolite facies. Previous geological investigations revealed the presence of various granites (~2.61Ga) associated with the schist belt in the region. In the present investigation the fabric of these granites are analyzed in light of regional deformation. In general the granites are devoid of mesoscopic field fabric. To determine orientation of fabric elements in these massive granitic rocks, Anisotropy of magnetic Susceptibility (AMS) has been performed in field oriented rock samples using KLY-4S Kappabridge (AGICO, Czech Republic). The susceptibility (K_m) value ranges from 13.7 x 10^{-6} SI unit to 2560 x 10^{-6} SI unit; however most of the samples show K_m value below 500 x 10^{-6} SI unit which suggest the rocks are mostly paramagnetic rocks (Bouchez, 1997). The mean orientation of the magnetic foliation (K_1K_2) is NW-SE oriented with an easterly dip which is sub-parallel to the regional trend of the Chitradurga schist belt. The magnetic lineation (K_1) show subvertical plunging due NW to SE. Chadwick et al., (2003) has concluded that the early NE-SW and late NW-SE directed far field stresses controlled the regional tectonics of the area. In light of the discussion, the present authors believe that the AMS data helps in providing more information about deformation and regional tectonics of the area. According to the authors, the fact that the magnetic foliation is NW-SE oriented and the magnetic lineation plunges due NW to SE, may be an indication of early NE-SW and late NW-SE far field stresses respectively. Further studies on the granites of the WDC with a detailed sampling along with field-based kinematic analysis are in progress to ascertain these preliminary conclusions and to work out the regional tectonics.

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3-D VELOCITY STRUCTURE FROM LOCAL EARTHQUAKE TOMOGRAPHY IN THE KOYNA-WARNA REGION

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The seismic activity in the Koyna-Warnaregion, Maharashtra state, has persisted for more than 50 years. It beganafter the impounding of Koyna reservoir in 1962.The largest reservoir induced earthquake occurred on 10 December 1967 (M 6.3), located near to Koyna reservoir. About 30 km south of the Koyna reservoir, impoundment of another reservoir (Warna Reservoir) started in 1985 and the reservoir was filled to a depth of 60m by 1993.In this paper, first we determine the appropriate 1-D P-wave velocity model using VELEST program (Kissling, 1994), which is used as a reference model for routine earthquake locations and for 3-D seismic tomography in the study area. Second,to describe source zone behavior and to better characterize the seismogenicupper crust,we generate three dimensional (3-D) Vpand Vp/Vs models of16 km wide and 22 km long area that largely cover the highest density of epicenters near the Warna reservoir. We implement the SIMULPS12tomography codeto first arrivals data of 350 local earthquakes ($M_L \leq 4$) that were recordedby a dense network of 97 temporary seismic stationsoperated during the period from January 2010 to May 2010. It was observed that an area rich in seismicity to be associated with sharp velocity contrast southwest ofWarna reservoir. Resulting 3-D tomographymodel shows undulating structure beneath the study area, with apparently varying zone of high and low velocity. Anomalous zonesof relatively highVp(~6.5 km/s)tolow Vp(~5.9 km/s) and relatively low to highVp/Vs ratio (1.65-1.75) extends nearly vertical to at least 8 km depth and laterally northward at least 15 km,suggesting that earthquake occurrence is closely related to structural heterogeneities of the fault zone.

GEOENVIRONMENTALAND TECTONIC STUDIES IN THE MIDDLE REACHES OF SABARMATI RIVER, GUJARAT: IMPLICATION TOWARDS PAST MONSOON VARIABILITY AND TECTONICS

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The influence of climatic fluctuations on fluvial activity can be understood by investigation of sedimentation and erosion processes (Baartman et al., 2011).The response of large river systems to climatic shifts and prevailing tectonics is very complex because of the variety of geotectonic settings of the drainage basins .Rivers in arid zones like Sabarmati River respond in a complex manner to climatic change. The present study is focused on the middle alluvial segment of ephemeral Sabarmati River in western India. According to Merh and Chamyal (1997) and Juyal et al. (2006), the region experienced major tectonic activity that shifted the river to its present course and also caused incision

of the sediments. In order to reconstruct the paleoenvironmental condition, we have used facies architectureand sedimentology, which allow us to discern two broad depositional environments viz. the lower fluvial sequences and the upper aeolian sand sheet. The facies architecture and sediment textures indicate temporal variability in the paleo-hydrological condition. Considering that the Sabarmati River is fed by the Indian Summer Monsoon (ISM), we ascribe these changes to the temporal changes in ISM. In order to ascertain the time domain of the above events, we used the existing chronology from the stratigraphically equivalent succession located ~30 km upstream of the study area (Tandon et al., 1997; Srivastava et al., 2001).

Broadly four major palaeo-hydrological/palaeo-environmental events have been identified during the deposition of fluvial sequences. These are the event-I dominated by braided-meandering fluvial systemwhich is assigned >50 ka, suggesting high sediment water ratio (during the weak ISM). Event-II constitutes laterally avulsive channel deposit, implying deposition under consistent flow regime between 50 ka and 30 ka (during strengthened ISM corresponding to the Marine Isotopic Stage-3). The event-III is identified as a mixed fluvio-aeolian sedimentation suggesting fluctuating hydrological condition after 30 ka and <12 ka (during declining ISM corresponding to the MIS-2). Finally, the event-IV, which marks the termination of sediment succession at the study area represents dwindling hydrological condition and onset of desert condition. It is assigned 12 ka (onset of Holocene climatic optimum; MIS-1).

Comparing our results obtained from the middle alluvial plain with that of the existing palaeoenvironmental data from monsoon, ISM record from Arabian sea suggests that sedimentation pattern and its variability was governed by the temporal changes in ISM during the last >50 ka. However, it can be suggested that the incision following 12 ka was mainly governed by tectonics supplemented by climatic condition.

GROUNDWATER QUALITY INDEX FORECASTING USING AUTOMATIC RELEVANCE DETERMINATION MODEL

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Groundwater is the most important natural resource used for drinking, irrigation and other domestic purposes around the world. While the sources of groundwater are limited, the demand for safe groundwater is increasing owing to the rapid growth of industrialization, urbanization and human population. Moreover, groundwater quality index forecasting is of topical interest because the quality of groundwater is influenced to a considerable extent by the chemical composition of rocks and soil mass through which it moves under various physical and chemical conditions. We employ an automatic relevance determination-based Bayesian neural network (ARD-BNN) approach to evaluate the relative impact of individual water quality parameters for forecasting groundwater quality index (GQI) of coastal Maharashtra, India. The unsupervised classification using cluster analysis (K-means and hierarchical) and principal component analysis (PCA) were also performed to obtain information about the data dimensionality and the number of class that supports the classification scheme. Upon successful parameterization of geochemical and geophysical water quality parameter for training the

ARD-BNN model, the model was tested in both validation and test data set in presence of different levels of correlated red noise to evaluate its generalization capacity. Prior to actual data analysis of acquired water quality data, the stability of the hyper-parameters of ARD-BNN modelling for all geochemical and geophysical water quality parameters were examined with different sets of input parameters. Furthermore, ARD-BNN model enables to calculation of the ranking of input variables for the forecasting according to their relative importance to the output variable i.e., groundwater quality. The pH and sulphate (SO_4) were found to be more relevant input water quality variables for assessment of groundwater of coastal Maharashtra, India. The novel ARD-based BNN approach offers automatic means to estimate the rank/weightage of the input variables, which were used to calculate the relative importance of each input parameter for calculation of GQI of coastal Maharashtra. The GQI result will provide appropriate guide lines for management of groundwater resources in the coastal Maharashtra region of India.

A COMPARISON OF TWO TECHNIQUES FOR THE ESTIMATION OF CODA-Q (QC)

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The attenuation properties of the Earth are among the inherent elements governing the amplitudes of seismic waves at various distances from an earthquake source. The overall attenuation is composed of several factors like geometrical spreading, scattering due to inhomogeneities in the medium and anelasticity. The attenuation of seismic waves due to anelasticity is characterized by the quality factor – Q. The frequency dependent Q can be estimated using the different parts of a seismogram including P-waves, S –waves, surface waves and coda waves. The continuous slowly dying wave trains observed at the tail of seismograms after the passage of primary waves are termed as coda waves. These waves are the result of the scattering of seismic waves by random heterogeneities present in the crust of the Earth. The coda waves are widely used to estimate the attenuation of the seismic waves in a region. The frequency dependent attenuation relation for Q is also important from seismic hazard point of view.

A number of studies have been done to compute the quality factor for coda waves (Qc) using the single back scattering model of Aki and Chouet (1975). Many techniques to compute coda-Q using the single back scattering model have been developed. The present study deals with the comparison of two of the techniques developed by Aki and Chouet (1975) and Sato (1977). The back scattering model considers the coda at single back scattered waves with the source and receiver in the same location. The single isotropic-scattering model allows the separation between source and receiver. Due to this, Aki and Chouet model is valid only for coda waves arriving twice the S-wave travel time. Sato's model after a correction is valid even for coda waves arriving immediately after the direct S-waves.

The resolution of Qc extraction techniques have been compared and tested in the present. The recorded accelerograms for the Himalayan earthquakes have been used for this study purpose.

MAGNETO-MINERALOGYAND INTERPRETATION OF AMS FABRICS IN THE BALUGAONANORTHOSITE MASSIF, EASTERN GHATS BELT, INDIA

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Massif-type Anorthosites were emplaced in the granulite faciesrocks present in almost all the Proterozoic mobile belts of the world (Ashwal, 1993). In India they are found within the poly-metamorphic, multi-phase deformed high grade rocks of Grenvillian age (1.1-0.95 Ga) in the Eastern Ghats Belt or EGB (Dobmeier and Raith, 2003). Important among these is BalugaonAnorthositemassif ,which is our present study area and has an outcrop of about 295 km^2. The region has suffered three phases of events D_1, D_2, D_3 and D_4leading to the development of the S_1, S_2 and S_3 foliation planes. The S_0 foliation plane is completely obliterated and the S_1 foliation plane is only visible in the microscopic scale (Das. K., et al.,2012). Field evidences suggest that the dominant structural fabric is the S_2foliation. The S_2 foliation shows a steadyattitude of NE-SW/ 50°→NW. The objective of the present study is to determine the magneto-mineralogical characteristics of the rock and to interpret the AMS fabrics by correlating the magneto-mineralogical characteristics with tectonic fabric.Petrographic study suggests that the rock is not pure Anorthosite, rather it can be termed as Pyroxene bearing Meta-Anorthosite, containing70-80% Plagioclase and about 20-30% Clinopyroxene,which shows recrystallized textures. Ore-petrographic studies unravelled thepresence of both primary and secondary generation Fe-Ti oxides (mainly Magnetite and Ilmenite) ; although primary oxides are dominant. Among the primary, evidences of both high temperature (>600°C) and low temperature oxidations (<350°C) wereobserved. The high temperature oxides are constituted by host grains of titanomagnetites with exsolvedlamellae of ilmenite. Changing density and thickness of the lamellae, within the host grain, points towards increasing temperatures of oxidation(Haggerty, 1976). Low temperature oxidations are evidentfromtitano-magnetite grains having cracks developed at periphery. The cracks migrate from periphery to centre of the grains andfinally develop "droplet" like structure of Titanomagnetites within the host grain,which is being replaced by silicatesthat occur due to increasing degree of the low temperature oxidation(Johnson and Hall, 1978). For AMS study about 15 suitable locations were selected from where 6-8 oriented cores were collectedfrom each in-situ rock exposureusing portable drill machine. The magnitude and direction of susceptibility and related parameters (Magnetic Foliation, Magnetic Lineation etc.) were obtained using the Bartington Susceptibility Meter (MS-2) and AMS-BAR software and plotted on Lower Hemisphere Circular Diagram to obtain the attitude of the magnetic foliation. The magnetic foliation was found to have an extremely variable attitude form NE-SW to NW-SE, with dip amount of 20-40^0 towards SE and SW, respectively. Thus, although locally there is some parity between the tectonic (S_2) and the AMS fabrics, overall poor correlation persists between the two. From these, it can be concluded that the AMS fabric mimics any deformation ,which is post D_2, i.e D_3 or D_4. Also post deformational accumulation of strain, increase of metamorphic grade and heterogeneous deformation pattern are potentialfactors triggering such deviation of the fabrics.

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ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT) STUDIES IN DELINEATING PALAEOCHANNELS OF GHAGGAR PLAINS

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Most of the world ancient civilization has been sustained on the banks of rivers. Indus valley civilization flourished around Ghaggar plains. The most proposed reason of downfall of Indus valley civilization was caused by excessive rains and resultant extreme floods that frequently altered the rivers direction. The objective of this study is to reconstruct the nearsubsurface architecture of palaeochannel(s) system of Ghaggar plains, which is probable signature of ancient river system and hence useful for mapping of distribution of fluvial aquifers in this water stressed region.Surface resistivity measurements have extensive capability to delineate major boundaries in alluvial deposits with contrasting resistivity values that depend on variable combination of properties like grain size, water saturation and soil salinity.In the present study 2D electrical resistivity tomography (ERT) datasets acquired along closely spaced survey lines, across the trace of palaeochannelsidentified on the basis of surface signature of satellite imageries, using multi-electrode equipment with Wenner and Gradient configurations have been used. Resistivity data was processed and inverted to generate resistivity sections showing the variation of resistivity with depth. The interpretation of resistivity results was done in combination of lithology and geoelectric well logs acquired during a drilling (~150m; 5 sites) and coring (~50m; 10 sites) at nearby resistivity survey lines, which has given significant information on the geological and hydrogeological characteristics.The interpreted range of resistivity values for different lithological units at all the ERT sections are as; top soil (4 - 40 Ωm), saturated sand with silt (10 - 30 Ωm), unsaturated sand (150 - 800 Ωm), unsaturated sand with kanker(> 800 Ωm), sand with freshwater (35 - 180 Ωm) ,sand with saline water (<1 Ωm) and minor clay fills (1 - 5 Ωm).A thick and extensive unsaturated sand layer is omnipresent in the near subsurface in most of the ERT sections. They are interpreted as buried palaeochannels. Below the unsaturated sand layer, presence of saturated sand is noticed. This layer is confirmed as good aquifer system holding huge amount of fresh groundwater.

VELOCITY ESTIMATES OF GANGOTRI GLACIER: TREND OVER THE LAST 20 YEARS

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Glaciers are important indicators of climate change as well as a major source of freshwater. Variations in the extent, mass and velocity of Glaciers have a direct impact on some of the key

components of the global water cycle, including sea level rise and freshwater availability. Apart from being one of the largest Himalayan glaciers, Gangotri is an important contributorto flow of Ganges, which has a considerable influence on the socioeconomic structure of a largely over-populated catchment area accounting for approximately 26% of India's landmass. Glacier velocity is connected to the mass balance of glaciers and is an important indicator of its overall health and stability . Consequently, monitoring velocity changes over time can contribute in predicting possible hazards that may arise from unstable glaciers.

In this study velocity estimates of Gangotri Glacier were computed using sub pixel correlation of multispectral Landsat imagery(Band 4). For this purpose 5 pairs of Landsat images over the period of 1993-2014 were acquired. The methodology used here involves determination of correlation between pixels of an image pair obtained from two consecutive years using frequency correlation window with step size 2 and window size 32. Consequently three maps (North-South; East-West; SNR) were obtained for each of the pairs, which were then filtered for poorly correlated pixels using the condition SNR>0.9 .Final Band math of the two filtered component images (viz. N-S and E-W) yielded ice surface displacement within the one year period, which is used as the velocity field.

The results obtained showed an irregular variation in annual mean velocities. The mean velocity in the 1993-94 season was around 34.15 m/yr ,which decreased to 26.12 m/yr in 1997-98 and again increased in 2001-02 season up to 37.58 m/yr. The velocities in the next two study periods decreased considerably to 27 m/yr. Similar trends were observed in the accumulation and ablation regions. The average velocity estimates in the ablation region are generally higher than those in the accumulation, except for the 2001-02 period. In general, the velocity in most parts of the Gangotri is seen to be decreasing over the years, except for the period of 2001-2002, which is in concurrence with the trend observed in other major Himalayan Glaciers. The increase in velocity during 2001-2002 may be attributed to glacial surge as a result of increased basal sliding. This study has important implications for monitoring temporal variations in ice thickness and mass budget of the Gangotri region. Further, our methodology has the potential to produce accurate estimates of velocity fields over mountainous glaciers with a high degree of efficiency.

SOME INSIGHTS ON TIME-LAPSE SEISMIC MONITORING OF CO_2 FORPOTENTIAL EOR AND STORAGE AT CAMBAY BASIN, INDIA

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Time-lapse seismic monitoring is one of the significant aspects for successful CO_2-enhanced oil recovery (EOR) and sequestration project.Time lapse seismic images can identify bypassed oil to be targeted for infill drilling by monitoring the small-scale subsurface physical property changes such as velocity and density due to CO_2 injection in a reservoir. In general, surface seismic data quality embedded with CO_2 response is influenced by numerous factors such as subsurface heterogeneities, CO_2 properties at subsurface conditions, results in poor monitoring of the injected CO_2.

In the present work, we report the development of a numerical seismic forward model mimicking a mature oil reservoir from Cambay Basin, India to simulate the response of seismic wave propagation for feasible CO_2-EOR and storage. The main aim of this study was to ensure that the changes in the

elastic properties of the reservoir due to the injected CO_2 would be detectable in the surface seismic response. In this regard, we developed a geological 2D model based on the available well logs from four well drilled through the reservoir formation. In addition to this, we incorporated the rock physics model that developed to get insight on the response of the reservoir elastic properties in the presence of CO_2. Both, pre- and post-CO_2 injection scenarios at 20 % CO_2 saturation (*Uniform* and *Patchy*) were realized to map the time lapse seismic changes within the reservoir due to CO_2 injection.

We identified that even in the case of patchy saturation, the seismic response of CO_2 should be observable in surface seismic data. Time-lapse analysis shows a dramatic decrease in seismic amplitude as a result of CO_2 injection in the reservoir formation, and the decrease in amplitude in case of uniform saturation is significantly larger than in the case of patchy saturation. Also, we assessed the two-way delay time is 1.53 ms within the most productive reservoir formation of the oil field under study.

2D MODELING OF MAGNETOTELLURIC DATA: UNDERSTANDING THE 2D FINITE DIFFERENCE MODEL MESH.

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This poster is based on 2D modeling of magnetotelluric data using REBOCC program and WinGlink software package. REBOCC program inputs a startup file through which all the other files (data file, model file, sensitivity and distortion file) are accessed. We have developed the code for the generation of input model and data files using MATLAB. In the present study, we are basically trying to understand the generation of the 2D finite difference model mesh in a greater detail. The gridding of the model to be generated i.e., the distribution of x and y axis into grids by following certain criteria. The accuracy of the numerical solution to the 2D problem depends strongly on the level of discretization of the mesh. A properly discretized mesh is important to ensure accurate results.

PRINCIPAL COMPONENT ANALYSIS AND POWER SPECTRAL DENSITY ANALYSIS OF TOTAL MAGNETIC FIELD IN ASSOCIATION WITH EARTHQUAKES (M>3.8) DURING 2014, 2015 IN KACHCHCH, GUJARAT.

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In order to extract any ULF signature associated with earthquakes, the principal component analysis (PCA) and Power Spectral Density analysis (PSD) have been performed to investigate the possibility of discrimination of signals from different sources (geomagnetic variation, artificial noise, and the other sources (earthquake-related ULF emissions)).The data recorded by Overhauser Magnetometer with a sampling interval of 1sec for the period of 2014 and 2015 have been used for this analysis.We first calculated the daily averages of the TotalMagnetic Flux for theentire study period. Power Spectral Density(PSD) at 1Hz frequency have been computedin fivefrequency bandsi.e.,f1 (0.001-0.005Hz),f2 (0.005-0.01Hz), f3 (0.01-0.05Hz),f4 (0.05-0.1Hz),f5 (0.1-0.5Hz).We also performed the Principal Component Analysis (PCA) to investigate long-term variations due to different sources as mentioned

above. Five events on 9thMarch (M 4.1,depth(d) 36km), 29th April (M 3.8,d 13km),24th July(M4.0, d 22km),27th Sep 2014(M 3.8,d 10km) all during 2014,and 24thMarch 2015 (M 3.8 d 25km) within 100 km hypocentral distance of our observatory are considered for this analysis. There is not much variation found in Total Magnetic flux variations.However, we have seen 50-80% increase in PCA and PSD anomalies prior to the events. The relative Percentage difference of PCA is computed by (V1-V2)/ V1*100, V1 Precursory signal value, V2 event time. Detailed observed anomalies are mentioned below:

STATISTICAL ANALYSIS OF NEW ZEALAND EARTHQUAKE OF MAGNITUDE (MW-7.8)

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Earthquakes have been occurring in most complex manner and its in-depth understanding requires extensive research. Various researchers applied numerous methodologies to have the exact knowledge of earthquake mechanism. We apply here the statistical tool for understanding the large size earthquake occurred in New Zealand. The country experiences enormous earthquakes due to the collision between the Pacific and Australian plates. Fractal correlation dimension (Dc) of earthquakes distribution is determined to see the fluctuation nature of Dc value of large size earthquake that hit New Zealand. Dc value provides us the information about the seismicity of a region. A highly clustered events have been recorded before the main-shock. The event is followed by the decrease in Dc value. The study of New Zealand earthquake of magnitude (Mw-7.8) is observed with some anomalous change in Dc value before the event. A sudden change in Dc value is indicated as a precursory condition for this large size earthquake. Such study may be of great help in understanding the future large size earthquakes and hence to mitigate hazard."

EFFECT OF DE-NOISING STRATEGIES IN SEISMIC WAVELET ESTIMATION USING GENERALIZED INVERSION

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In exploration seismology, seismic wavelet estimation or source signature estimation plays a vital role in the processing and interpretation of seismic data. Seismic reflection data contaminated with the random and geologically incoherent noises create problems for accurate wavelet estimates and thereby mislead the processing, structural and stratigraphic interpretation. Several researchers in the past have proposed different deterministic and statistical approaches for wavelet estimation from such noisy data. A combined approach of Spatial Singular Spectrum Analysis (SSSA) and Multivariate Wavelet (MW) based de-noising accompanied with generalized inversion based wavelet estimation is proposed in this study to surmount the above problems. The algorithm was applied on a synthetic data set of three layer model contaminated with Gaussian white noise. In order to determine the influence of noise on wavelet and reflectivity estimation, a novel generalized inverse algorithm was tested on the above noisy-synthetic data. Iterative SSSA based data adaptive de-noising techniques was applied on the noisy synthetic data. The SSSA de-noised output was used to estimate wavelet via generalized inversion. Although, the reflectivity estimate from the de-noised output correlates well (correlation

coefficient of 0.72) with original reflectivity series, there are still some amount of noises present. Simultaneously, multivariate wavelet-based de-noising technique was also performed on same data, which resulted in no significant improvement in the original and the estimated reflectivity. In final approach, MW method was applied to suppress the remnant noise from SSSA de-noised output. The estimated reflectivity series has shown good correlation with correlation coefficient of 0.92 with the original reflectivity. The seismic wavelet and reflectivity series estimated from noisy synthetic data using the proposed methods are matching well with the original seismic wavelet and reflectivity series data. Hence, we conclude that the SSSA or combined usage of SSSA and MW de-noising methods are robust and promising pre filtering alternative to remove noise from seismic filed data for precise wavelet estimation via generalized inversion method.

ANALYZATION OF FLUCTUATIONS OF GROUND WATER LEVEL DUE TO CONTAMINATED HYDROCARBON USING REMOTE SENSING

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Ground water table has been depleting persistently leading severe damage to agriculturally and ecologically valuable areas. Satellite remote sensing provides a cost-effective methodology for identifying potential groundwater sources. In context of researches on different petroleum sites, we came to know that the Ground water storage is decreasing due to leaks in petroleum storage tanks and jet fuelling stations. The purpose of this article is to investigate the possibilities of using remote sensing for analyzing groundwater flow systems in various petroleum sites. We modeled our study on a military air force base (AFB) at Hradcany situated about 100 km northeast of outside Prague, Belgium. Due to the regional extension of the flow systems and the required spatial accuracy, huge quantities of distributed model input data are necessary. Many of the needed parameters like hydraulic conductivities and recharge rates are difficult to assess accurately in a distributed way. The remote sensing for groundwater systems helps in the translation of the remotely sensed two-dimensional surface, i.e., the type of soil, moisture condition, land use, vegetation type, etc. to the related 3-D groundwater flow pattern. Following steps were followed to extract the data: (a) map elevation data derived from the ASTER Global Digital Elevation Model (GDEM), (b) analyze land cover using Supervised Classification c) analyze lineaments and surface dips using Landsat 7 ETM+ Band7 data, and (d) analyze soil and rock type using Landsat 7 ETM+ data. The data were processed in Arc Map 10.1, Erdas 14.0, RoltaGeomatica. Processed data were analyzed and examined to arrive at a conclusion-- Ground Water Level fluctuates approximately up to 1 m. The reason for this fluctuation has been discovered. It is noticed that magnetic concentration parameters increased towards the top of the GWTF (Groundwater Table Fluctuation) zone. From our results we conclude that the top of the fluctuation zone has the most intensive geo-microbiological activity probably responsible for magnetite formation.

HIGH PRECISION EARTHQUAKE LOCATION IN THE NW HIMALAYA, INDIA: TECTONIC IMPLICATIONS

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In the present study we have tried to understand the nucleation process and overall genetic mechanism of recent earthquakes occurring in the NW Himalaya, India and associated tectonics . For achieving the objective we have utilized the catalog P and S phase data of the 343 earthquakes recorded in the Kinnaur, NW Himalaya region by the digital network of Wadia Institute of Himalayan Geology, Dehradun. Further refinement in seismicity is achieved through the application of hypoDD relocation program that resulted in well- constrained 166 earthquake events having a focal depth distribution from 2 Km to 60 Km in the study region. Anotherconspicuous feature in this part of the Himalaya is shallow focal depth distribution up to 30 km.Very few earthquakes have focal depth up to 60 Km, which confirms the under thrusting of Indian plate beneath the Eurasian plate. The focal depth of earthquakes gradually increases from north to south, with focal depths reaching a depth of 60 Km.In this region maximum number earthquakes have a magnitude range of 2.0 (Ml) to 4.0 (ML) ,which confirms accumulation of strain in the region resulting in the higher concentration of seismicity. The maximum concentration of seismicity is also seen along the Kaurik- chango fault that was the causative fault for the 6.8 (Mb) magnitude Kinnaurearthquake of 1975. This also accounts for the occurrence ofneotectonic activity.

GRAVITY MODEL OF ANDAMAN-SUMATRA SUBDUCTION ZONE FOR A BETTER UNDERSTANDING OF GEODYNAMICS

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Gravity modelling is carried outalong two profiles at latitudes 6° and 10°N, cutting across the Andaman–Sumtra trench, for understanding the deformation of the converging Indian oceanic lithosphere. Satellite gravity and bathymetry data retrieved from Geosat and ERS-1 satellite altimetry have been used for the present analysis. Initially, the free air gravity anomaly data have been converted to Bouguer gravity anomaly for the entire study area.Mohorovičić (Moho) boundary is calculated from gravity and topography data, and is constrained by spectral analysis. Moho depth estimated from gravity and topography data is used as initialbasic parameter for modelling. Subsequent iteration has improved the model. The Moho depth is found to be varied between 4-10 km near the Ninety East Ridge, increasesto 20km near Andaman trench and becomes ~60km beneath the Andaman Nicobar Ridge. These results are in good agreement with spectral analysis result.The model also suggest thinner oceanic crust near Ninety East Ridge along 6°N profilecompared to that along 10°N profile. The thickness of oceanic crust has also decreased southward.The accretionary prism towards south is relatively thicker than the northern part of the area. The seismicity data projected on the model reveals most of the hypocenters are confined with the bending zone of the descending Indian oceanic lithosphere. The dip angle of the converging plate is 15-20° Andaman Nicobar Ridge and increases further beneath the eastern part of the area. This may be proposed that the maximum deformation has been occurring around the flexing zone of the penetrating lithosphere.

AN IMPROVED P-WAVE VELOCITY REFERENCE MODEL FOR DELHI REGION

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High-precision earthquake location is of importance in a seismically active region like Delhi where seismic database is prerequisites for tectonic interpretation and seismic hazard assessment. We have derived a P–wave 1D velocity model for Delhi region which may help in constraining earthquake locations and can be used as initial reference model for 3D seismic tomography. The inversion is carried out using 120 well located events together with 559 P wave observations and 279 S wave observations, during 2000-2015.The data was provided by national seismological network maintained and operated by National Seismological Centre (NCS). The program VELEST has been used to constrain final velocity model using P and S phases of the events located by a local network of 16 stations deployed in and around Delhi. VELEST uses an algorithm, which is based on damped least-squares method. The method helps in estimating the 1D velocity model along with revised hypocenter co-ordinates and station corrections. We have used initial velocity model published by Mahesh et al., 2013; Mukhopadhyay and Kayal 2003; Mukhopadhaya and Sharma, 2010 and Malick 2009 as a priori 1D velocity models to arrive at the final model of Delhi region. The P wave velocity ranges from 5 km/s to 8 km/s to a depth of 70 km. The Moho is located at around 30 km from the surface.

SEISMICITY ANALYSIS AND BVALUE DETERMINATION OF PAKISTAN EARTHQUAKES

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Earthquakes are mainly concentrated in the north and western sections of Pakistan, along the boundary of the Indian plate and the Iranian and Afghan micro-plates. The b value characterizes the release of energy due to stress accumulation in the rocks through an earthquake and is a direct indicator for the forecasting of aftershocks in the region. The b value analysis and determination is done here using ZMAP software. This method guarantees high accuracy results through a limited dataset. The objective of this work is to demonstrate an elegant method for the determination of the b value and predict the occurrence of aftershocks with high accuracy. Mainly the study is based on the Pakistan extending from 63^{o}-75^{o}E and 24^{o}-37^{o}N. Repeated earthquakes are analyzed between 1956 and 2014 in Pakistan and the b value is estimated for these earthquakes. These results give an indication that the b value of the mainshock and its aftershocks are different. In Awaran Earthquake the b value of mainshock was 0.73.The b value is related to the stability of the crust and when it is perturbed from its state of equilibrium it tends to go back to its original state by oscillating back and forth in terms of its b value. The correlation is established between the crustal areas with low *b*-values as well as fractal correlation dimension and the locations of the strongest earthquakes in the region. It is suggested that the three-dimensional mapping of the *b*-value can be helpful for estimating the location, depth, and maximal magnitude of the probable strong earthquakes in seismically active regions and can be used to assess seismic risks.

LITHOLOGICAL CHARACTERISTICS ANALYSIS OF RIDDERKERK AREA IN THE WESTERN NETHERLANDS USING WAVELET TRANSFORMS

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Identification of lithofacies accurately is of prime importance especially in geologic conditions pertaining to hydrocarbon reservoirs.Conventional core has been used extensively for obtaining detailed information of the well, but recovery of cores is an expensive and exhaustive process. An alternate to this is well log analysis, which is incongruous and interpreter dependent, and can lead to multiple interpretations and inferences. Various wavelet transform techniques have been used for delineating lithological boundaries and to provide subjective leads for reservoir characterization. Disparate wavelet-types on radioactivity logs of wells belonging to the Ridderkerk area in the western Netherlands, in the province of South Holland have been used for the present study. We have come up with an innovative approach using Continuous Wavelet Transform (CWT) and Discrete Wavelet Transform (DWT) to have lithological characterization, which is very crucial especially in the exploration of hydrocarbons.A multiscale analysis of the well log data was performed using CWT and DWT analysis.The gamma ray log was first DWT analysed using the Haar Wavelet and decomposed 7 times. The discrete coefficients pertaining to the 7^{th} level of decomposition were CWT analysed using the Haar Wavelet at various scales ranging from 2-10 m, 10-20 m, and 20-100 m and the results of the analysis are presented.The smaller scales (<10) detect the presence of high energy sedimentary deposits, while the high scales (20-100) detect low energy deposits like shale. The variations in the depositionary sequences suggest the variations in depositionary energy. The CWT analysis was performed with the d7 detail coefficients. It helped in identifying the largest number of facies found in the region, as inferred from the facies log. Each decomposition corresponds to dyadic decimation in terms of increase of powers of 2. The study demonstrated that wavelet transforms can effectively be used for bed boundary detection as a first approximation, as demonstrated through the comparision with the facies log presented.

BROADBAND MAGNETOTELLURIC DATA INTERPRETATION USING PHASE TENSOR

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In MT data processing the galvanic effect, which is produced by near surface inhomogeneity is a serious problem. Phase tensor is not affected by galvanic distortion. In the present work, we computed the Phase Tensor elements of abroadband magnetotelluric data and interpreted them.At very short periods 10^{-3} sec to 10^{-2} sec the phase tensor are more or less shaped as circles with different radii. It is only possible if the structure is 1D and also the conductivity varies with depth and the radius of the circles are decreasing with increasing period i.e. the conductivity is decreasing with increasing depth as conductivity is proportional to tangent of the principal value. Also the value of skew angle is exactly 0°. So it can be concluded that at very short period the conductivity structure is 1D. For the period range 10^{-2} to 10^{-1} the phase tensors are pure ellipses and the phase split between principal values is clear and it is large enough to be consistent with 1D. The skew angles at this period range are also 0° so it can be concluded that at the period range 10^{-2} sec to 10^{-1} sec the conductivity structure is 2D.The behaviour of phase tensor ellipses at the period range 10^{-1}sec to 10sec is too complicated. In this range

the value of skew angle is neither 0° nor too much large to be interpreted as 3D structure. In reality in this range the value of β(skew angle) varies from 3° to 5°,which is too large to be consistent with 2D. So, it can be concluded that at this range the conductivity structure is quasi-2D or nearer to 3D.For the rest of the period 10 sec to 10^3 sec the difference between the principal phases is too large. The skew angle appears to increase drastically from 3° to 20°, which is extremely high to be consistent with 2D. So, in this range 10 sec to 10^3 sec the phase tensor shows 3D conductivity structure.

The apparent resistivity and phase angles have been plotted with time period which shows phase splitting at 10^{-2} sec. The phase splitting is more prominent in the range of time period 10^{-1} sec to 10^3 sec. This observation is in agreement with the Phase Tensor analysis.

MAFIC INTRUSIONS RELATED HETEROGENEITY AND HYBRIDIZATION IN GRANITOIDSFROM THENALGONDAREGION OF EDC

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DharwarCraton is one of the largest cratonic masses of the Indian Shield. It is made of TTG suite of rocks that forms the basement, two generations of volcano-sedimentary greenstone sequences (> 3.2 GaSargur Group and 2.9-2.6 GaDharwar Super Group) and late calc-alkaline to potassic granites (2.62 and 2.56-2.52 Ga). The Craton is divided into two principal terrains i.e. the Eastern DharwarCraton (EDC) and the Western DharwarCraton (WDC), but based on the nature of crust; the WDC is further sub-divided into the Central DharwarCraton (CDC) (Peucat et al., 2013). The WDC is relatively older (3.3-2.7 Ga), whereas the EDC is predominately Neoarchaean (2.7-2.5 Ga).

The earliere studies demonstrated that Neoarchaeangranitoids of EDC are primarily juvenile, but also subordinate heterogeneous; derived due to the partial melting of the older crust and the mantle at variable proportions. Though geochemical and isotopic studies yield key constraints on such aspects, careful field observations, followed by detailed petrographic characterization provide important clues on the magma chamber processes, those responsible for the variability of granitoids. An excellent display of magma chamber processes are documented from the granitoids along the NE part of EDC at the Amanabole village, in the vicinity of Nalgonda,Telangana state and examined to unravel the processes of hybrid magma generation and the intrusion mechanisms. Various megascopic and microscopic features, typically representing the magma mixing, mingling and hybridization processes resulting in the formation of hybrid magmas are noticed. Such processes can take place at any stage in the life span of magma (Perugini and Poli, 2012), and can occur at different depths. The degree of mixing, mingling and hybridization leads to the heterogeneity of host granitoids.

Hybrid magma encloses the Mafic Microgranular Enclaves (MMEs) of various shapes and sizes, and such variations embrace the sequence of magmatic activities in a magma chamber. There is thermal, mechanical, chemical and physical exchange between the MMEs and host rocks. The thermal contrast between the magmas can induce various deformations (e.g. shearing, folding and fissures). Mantling of K-Feldspar, transfer of xenocrysts, poikilitic texture of the host rock and MMEs support the physical and chemical exchanges. Such exchange processes, coupled with thermal contrasts define the contact relationship(s) between the MME and host granitoids. MMEs, syn-plutonic dykes, schlieren structures and magmatic flow structures are various evidences for magma mixing processes in the study area.

CROSS CORRELATION TECHNIQUES FOR AMBIENT NOISE INTERFEROMETRY

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Ambient noise tomography is a rapidly emerging field of seismological research. Stacks of ambient noise cross-correlations are more and more routinely used to extract empirical Green's functions between stations pair. The success of the cross-correlations is due to waves,which are recorded by both stations and that constructively sum at lag times that equal their propagation time between the station pairs. The ambient noise data processing procedure is divided into four phases : (A) Single Station data Preparation, (B) cross-correlation and temporal stacking, (C) measurement of dispersion curves (by frequency-time analysis for both group and phase velocities) and (D) Quality control . Stacking cross-correlograms corresponding to different time spans improves the azimuthal noise coverage and further enhance the signal . We show that our processing tools canimprove the signal extraction from ambient noise data. The phase cross correlation (PCC)is based on the phase coherence,which we obtain from the phase of the analytic signals. Signals are therefore detected by their phase coherence while with the classical cross-correlations (CCGN) signals are identified by the largest sum of amplitude products, thus energy. If the signals should be detected by their waveform coherence then PCC is the better approach since it is the more sensitive measure. Conversely, CCGN is amplitude biased and may not discriminate between closely similar waveforms. Another important aspect of our analysis is the amplitude bias of the classical approach. In contrast to CCGN, PCC is not amplitudebiased and therefore no special pre-processing is required to remove large amplitude events. The main advantage is using as little as possible processed/altered waveforms for signal identification.It is shown that under these conditions PCC provides the better results, thus being less sensitive to the frequency range than CCGN.Other important processing step in the analysis of ambient noise data is the stacking of cross-correlograms. The incoherent noise attenuation during the stacking becomes, therefore, an attractive property. We use the tf-PWS, which is a time-frequency domain extension of PWS. tf-Phase Weightage Stacking (PWS) has also been used to show their benefits in the noise monitoring and signal extraction based on a non-redundant *S*-transform for the time-frequency representation.

SPATIAL VARIATION OF STRUCTURAL ELEMENTS OF GRANITIC ROCKS FROM WESTERN PART OF DELHI FOLD BELT AND ITS IMPLICATIONS

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Detailed studies of structures in granite provide valuable information related to its emplacement and evolution. In the present study the granite is porphyritic in nature and located along the western margin of the South Delhi Fold Belt, Pali district, Rajasthan. Systematic studies of the porphyritic granite from center towards the margin of the granite body were carried out to understand the deformation pattern. The granites show prominent development of foliation (10°/70°E) and sub-horizontal lineation with sinistral sense of movement on the XZ section. The intensity of development of foliation and lineation of the porphyritic granite increases outward with gradual development of protomylonite-mylonite followed by ultramylonite towards the margin of the body. On XZ section presence of both forward and backward rotating porphyroclasts suggests that the deformation was not only by simple shear but there was a component of pure shear. This implies that the deformation was

transpressional in nature. Kinematic vorticity value was measured using oblique grain shape foliations from center towards margin of the granite. This value gradually changes from Wk= 0.59 to Wk = 0.89 from less deformed porphyritic variety outwards i.e. the utlramylonite variety. This demonstrates that the non-coaxiality i.e. the simple shear component increases towards the ultramylonitic variety of the porphyritic granite. Microstructural study shows evidence of intracrystalline deformation with formation of sweeping to patchy undulose extinction, deformation lamellae and deformation twinning. Development of bulging, subgrain rotation indicates dynamic recrystallization. Formation of chessboard subgrain, indicating recovery, is common towards the center of the granite body. The granites show dominance of dynamic recrystallization towards the margin and static recrystallization and recovery towards the center. Presence of cuspate lobate grain boundary between quartz and feldspar, grain boundary migration, chessboard subgrain suggest the temperature was quite high (> 600˚C). Proportion of mica content drastically increases in the mylonite / ultramylonite variety i.e. towards margin depicting the evidence of strain softening. Present study suggests that the porphyritic granite was emplaced in a transpressional regime with degree of non-coaxiality increases towards the ultramylonite i.e. towards the margin.

FLUID SATURATION AND PRESSURE ESTIMATION FROM TIME-LAPSE SEISMIC DATA

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Variation of pressure with fluid-saturation creates anomalous seismic responses. It is generally difficult to discriminate between these two effects from seismic data. In most time-lapse studies, seismic differences between a baseline and monitor surveys are analyzed and interpreted as either a pressure change effect or a fluid saturation change effect. Seismic amplitude depends upon velocity contrast and density contrast across the interface; it also varies with the angle of incidence. Rock physics models establish the relations between seismic parameters (P-wave velocity, S-wave velocity and Density) with effective pressure and fluid saturation. Seismic parameters for a particular formation can be calculated for given fluid saturation and pressure using rock physics theory. Thus seismic amplitude variation with angle (AVO/AVA) can be predicted for changes in effective pressure and saturation. Landro (2001)** used Biot-Gassmann and Hertz-Mindlin theory for rock physics modeling and demonstrated an algorithm for pressure and saturation estimation from time lapse seismic data.

In this paper, we revisit Landro's approach to carry out more detailed investigation including anisotropy that is affected by pressure. We employ third order elasticity to investigate this. In forward modelling part, we considered a two-layer model and assumed no change in effective pressure and saturation in the upper layer (cap-rock layer i.e. Shale layer) between the two time-lapse scenarios. All the changes are taking place in the second layer i.e. reservoir layer. Seismic parameters for the first layer were assumed to be fixed for both pre-production and post-production models. For the lower layer i.e. reservoir layer, seismic parameters for both pre-production and post-production were calculated using rock physics theories. Synthetic PP-reflection data were generated for both the models. Using least square inversion, changes in intercept and gradient were calculated. Fractional change in P-wave velocity, S-wave velocity, anisotropy parameters and density were plotted with change in effective pressure and saturation. After fitting appropriate curves to those plots, rock physics constants were

computed to relate changes in intercept and gradient with changes in pressure and saturation. Changes in pressure and saturation were computed using obtained relations. Though saturation change was computed correctly but estimated pressure shows larger uncertainty. We also note that use of PP-PS reflection coefficients for computing changes in pressure and saturation for the same model improves the results. Detailed investigation of the effects of anisotropy is currently being investigated.

DEVELOPMENT OF AN EFFICIENT FILTER FOR TRANSFORMATION OF VLF ANOMALY INTO APPARENT RESISTIVITY AND PHASE DATA

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The Very Low Frequency (VLF) method is a useful technique for delineating the water saturated conductive fractures in hard rock area, mineral exploration and reconnaissance surveying purposes. In VLF method, the localized changes in electrical conductivity contrast governs the ratio between the vertical and the horizontal magnetic fields. The VLF transmitter is a vertical electric dipole which emits electromagnetic wave in the frequency range 15-30 kHz(horizontal magnetic field,H_y and vertical electric field,E_z). At great distances from the source, VLF fieldmay be considered as vertically incident plane EM wave. When H_y encounters the local conductivity of the earth, it generates horizontal electric field component E_x in the direction of propagation. Thus, a conductive body, whose strike is in the direction of propagation, generates secondary vertical magnetic field H_z either inductively or galvanically, and theconductive body whose strike lies in the perpendicular direction of propagation, does not generate the secondary magnetic field. The quantity $H_z/H_{y,}$ known as the tipper is the essence of the VLF-EM prospecting. The tipper shows a peak at lateral contacts of different resistivities and shows a cross over when it encounters a thin conductive target. In present study, an attempt is made to develop atransformation filter which can transformthe VLF-EM data into the apparent resistivity and phase data. The filter is developed on the basis of two assumptions. Infirst, the magnetic field is considered as constant along the surface, which leads to an approximate solution, where as in secondassumption, the magnetic field is considered not along the surface, which leads to a fullsolution of the problem. Full solution depends on secondary horizontal and vertical magnetic field which forms a Hilbert transform of VLF-EM data.The filter is tested on synthetic (noise free and added Gaussian noise) and real field data and results are compared with the data obtained from the D.C. resistivity surveying. Results are in good agreement with resistivity results and available well log information. The study would improve the quantitative interpretation capability of the VLF method, which conventionally are carried out qualitatively. Finally, this transformation filter would be applied to the real field VLF-EM data from a hard rock area for delineating water saturated fracture zones.

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SOURCE DEPTH ESTIMATIONS FROM GRAVITY ANOMALIES OF JHARIA COAL FIELD AND SURROUNDING REGIONS USING EULER DECONVOLUTION METHOD

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In the Indian coal scenario, Jharia coalfield occupies a special status as this is the only store house of prime coking coal and has been meeting the coking coal needs of the country for over a century. In order to find the new coal resources in this region different types of exploration methods have been tested. Euler deconvolution method is one of them. Presently this method is extensively used to determine the depth of the anomalous bodies and other geologic sources. Analytic signal maxima can occur directly over faults and contacts, regardless of structural dip .It is also independent of the direction of the induced or remanent body magnetizations. Mapped maxima (ridges and peaks) in the calculated analytic signal of a potential field anomaly map locate the anomalous source body edges and corners such as basement fault block boundaries, basement, lithology, contacts, faults or shear zones, igneous and salt diapirs, etc. The methodology adopted was useful in obtaining solutions by inverting Euler homogeneity equation, which relates the potential field and its gradient components to the location of the source of an anomaly, with the degree of homogeneity expressed as structural index. The structural index is a measure of the fall-off rate of the field with distance from the source. The choice of a proper structural index is a function of the geometry of causative bodies. Euler deconvolution process was carried out on the analytical grid of potential field data of the study area using a structural index of 1.0, 2.0 and 3.0, respectively. The choice of the structural indexes justified by trend of the body was estimated by locating the position of the anomalous sources. Thickness of the sediment near Kumardih and Mahuda and Barki region of Jharia coal field is about 2.2 km, as obtained from Euler method, Spectral analysis and 2-D density modeling. Depths obtained from Euler deconvolution method correlated with the true depth of the causative sources.

BIG DATA ANALYTICS FOR SEISMIC IMAGING

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Big Data technologies describe a new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high velocity capture, discovery and/or analysis while ensuring their veracity by an automatic quality control in order to obtain a big value. By employing big data analytics and precise subsurface imaging, hydrocarbon exploration and production is accelerated to enhance R/P ratio of a nation. Big Data is defined by following characteristics: Volume, Variety (structured and unstructured data), Velocity(high rate of changing), Variability, Veracity(uncertainty and incompleteness),viscosity, virility and value. Upstream petroleum sector is well-versed with Big Data. Oil & Gas companies use thousands of sensors installed in subsurface wells and surface facilities to provide continuous data-collecting, real-time monitoring of assets and environmental conditions. Seismic Hadoop combines Seismic Unix with Cloudera's distribution, including Apache Hadoop to make it easy to execute common seismic data processing tasks on a Hadoop(Pig) cluster. The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models.Python seismic unix is very efficient for seismic subsurface imaging.Big Data

and Extreme-scale Computing (BDEC) is emerging field of research for high performance computing regarding seismic imaging. There is an acute need for optimization in the oil and gas exploration and production stages.Big Data analytics can provide such optimization with span of exploration, development, production and rejuvenation of oil and gas assets. Statistical Analysis System (SAS), big data analytics software can boost exploration and production. Big Data and microseismic imaging accelerate the smart drilling and revolutionise oil and gas extraction. Seismic data is generated in exponential manners (exabytes to zettabytes) as the upstream exploration and production cutting edge technology accelerates hydrocarbon industry to enhance energy security of the world. Seismic data processing , imaging and interpretations ,modelling and simulation are integral part of subsurface structural imaging with high performance computing . Wavelet analysis of seismic signal is integral part of big data analytics for hydrocarbon exploration and production. Nano Imaging by third generation wavelet transform is prospective for digital rock physics. Discrete Signal Processing on Graphs (DSPG) and Sparse/graph Fourier Transform(SFT) are topics for creative research for Geophysical seismic signal processing.The use of pattern recognition has become more and more important in seismic oil exploration. Interpreting a large volume of seismic data is a challenging problem. Seismic reflection data in the one-shot seismogram and stacked seismogram may contain some structural information from the response of the subsurface. Syntactic/structural pattern recognition techniques can recognize the structural seismic patterns and improve seismic interpretations.

NEAR SURFACE CHARACTERIZATION USING MULTI MODES OF LOVE WAVE.

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Love wave is a type of surface wave in which particles move with a side-to-side motion perpendicular to the main propagation. The amplitude of this motion decreases with depth. Love waves cause the rocks they pass through change in shape. They travel faster than Rayleigh waves. Only first arrival information is used in the SH-wave refraction method. Most SH-wave data contain strong component of love wave energy. It is formed from constructive interference of multiple reflections of SH-waves in the shallow subsurface. The dispersive nature of love wave is independent of P-wave velocity. Love wave phase velocities of a layered earth model are a function of frequency and three groups of earth properties a) shear wave velocity, b) density, and c) thickness of layers. Phase velocity of love-wave may increases or decreases according to their direction of propagation along increasing or decreasing shear-wave velocity and rigidity of the layer.

Surface wave analysis is aproficient tool to obtain the vertical shear wave velocity profile. The large amplitude and low attenuation allow (surface wave energy attenuates to 1/r) an accurate reconstruction of the subsurface structure via inversion of the observed dispersion curve.We presuppose earth as a series of horizontal layers, a pure, plane, horizontally polarized shear (SH) wave refracts and reflects only SH waves and does not undergo wave type conversion as do incident P or SV(vertically polarized) waves. This is one reason the shallow SH-wave refraction method is popular. Love wave inversion for shear wave velocity profiles is more stable and reduces non-uniqueness.

The data has been taken using 4.5 Hz horizontal geophones by rolled along method. The acquired data are preprocessed like editing and filtering. Velocity spectrum has been generated by giving suitable parameters. Using velocity spectrum best suited model is prepared. Finally inversion is performed using Genetic Algorithm to get shear wave velocity profile.

ANALYSIS OF NATURAL SEISMICITY IN THE THRUST REGION OF CENTRAL AND NORTH-EAST HIMALAYAN

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The Central and North-East Himalayan region encounters seismicity because of two important factors i.e. due to collision of Indian and Eurasian plates (Himalayan seismic belt) and subduction of Indian plate into Burmese plate (a typical oblique subduction zone). The north east region of India is placed in Seismic Zone V.

There are two prominent seismic gaps in western to central Nepal and Sikkim to Arunachal Pradesh (Assam and Bhutan region).There is a need of detailed study to understand the behaviour of seismicity in and around the seismic gap regions i.e 80^0E to 88^0E in Nepal and 88^0E to 97^0E (Bhutan, Assam and Arunachal Pradesh). The analysis is splited in zones along the Himalayan thrust zones to classify stress regions.

We estimated the seismicity rate (b value) and overall seismicity (a value), the fractal dimensions and Shannon Entropy functions by inverting of Gutenburg- Richter relationship. We adopted different inversion techniques to obtain Mc (magnitude of completeness). We observed a sharp decrease in b value and sharp increase in randomness i.e. entropy in the span of 3 years which results in moderate to large magnitude earthquake i.e M > 5. We also concluded that spatial variation of b value ranges between 0.46 to 1.27 and mostly concentrated around 0.68, indicating high stress accumulation and the distribution of earthquakes near faults and lineaments could be prominent region of earthquake. Our observational analysis shows abnormalities in b-values during the years prior to the mainshock of Nepal earthquake which occurred on 25th April 2015. Thus we identify that Gutenberg Richter parameters can be one of the important tools to support the precursory studies in order to mitigate seismic risks.

SHALLOW AND DEEPER LITHOSPHERIC STRUCTURES BENEATH THE SON-MAHANADI GONDWANA BASIN OF INDIA-INSIGHT FROM GRAVITY AND MAGNETIC STUDIES

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During the recent years efforts are on for the exploration of hydrocarbons in the intracratonic Son-Mahanadi Gondwana basin in the eastern part of peninsular shield. The NW-SE elongated basin hosts a large thickness of Gondwana sediments ranging in age from Early Permian to Early Cretaceous which have been uplifted to more than one km above the mean sea level. In order to understand the lithospheric structures and evolution of the basin, gravity and magnetic data over the basin and the adjoining regions have been analyzed. The Bouguer gravity anomaly map of the region shows presence of short wavelength gravity lows and highs superposed on a long wavelength regional gravity low centered over the basin. The short wavelength lows and highs are caused due to presence of low density Gondwana sediments and basement up warps. On the other hand, regional gravity low which bears an inverse correlation with the regional topography suggests that the excess topographic load is

compensated at depth and the required buoyancy might be the consequence of deep seated low density heterogeneities formed due to thickening of the crust or thinning of the lithosphere. The proximity to the Deccan volcanic terrain and presence of large number of volcanic dykes and sills within the basin and adjoining regions, whose palaeomagnetic mean direction close to Deccan normal directions, suggest dyke emplacement during Deccan magmatism and therefore favors lithospheric thinning, due to impact of Deccan plume, as the preferred mechanism for the uplift of Gondwana sediments.

SEISMICITY AND FOCAL MECHANISM OF SOME RECENT EARTHQUAKES IN HINDU KUSH REGION AND THEIR TECTONIC IMPLICATIONS

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The paper investigates to study components of seismicity and prevailing tectonic stress regimes of the Hindu Kush region by analyzing the earthquake data that occurred during 2013 and 2014.Focal mechanism data obtained from the CMT global catalog for the given period has been plotted and discussed in the light of plate theory of global tectonics and geological faults.

It was found that the constant b in Gutenberg-Richter's frequency magnitude relationship was nearly 0.59 for the given period of observations of about 197 earthquake events. Very little seismicity was recorded in the crust from 0-70km depth. Earthquakes having depth up to 150km are distributed all over the region where the ones having depth more than 150km are concentrated at the center of the region. Plotting the focal mechanism data does not reveal a simple consistent pattern. Most of the fault plane solutions show Thrusting and a few show Strike Slip Rake. On the basis of plunging of P and T axes the fault plane solutions of the region can be divided into two parts. Fault planes with solutions that in the west have westward plunging T axes and in the east have eastward or vertically plunging T axes. Agglomerating all the results of our observations we infer that the configuration of the Hindu Kush seismic zone could possibly be the result of subduction of oceanic lithosphere from two separate, small basins in opposite directions.

ALONG THE STRIKEMAGNETOTELLURICPROFILE TO MAP ELECTRICAL STRUCTURE OF RADHANPUR-AJMERTRANSECT IN RAJASTHAN, INDIA.

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The delineation of intra crustal low velocity zone in the north-western part of India has necessitated application of a different approach, to better understand the tectonic implications. The primary objective of our study is delineation of the upper and mid crustal electrical structure of Radhanpur-Ajmer transect. The not so normal experiment was planned and conducted along the strike for the first time. Also this is the first reporting of magnetotelluric data along the profile in the area. After arigorous analysis, the crustal electrical structure along the profile is modeled. We covered16 stations and an additional station, with a 4-5 days recording at every station. The data quality is quite good at all the stations. To the northern end of the profile, geologically there are intrusions of Sendri-Amboji granite and gneissic rocks. There is an indication of batholithic type structure in

the conductivity section as well. After covering half of the profile, the high resistivity column from depth to surface supports presence of major rocks intruded by Malani plutonic suit and it is suspected that this high resistivity column might indicate the plutonic intrusions in this region. The tail-end stations are mostly represented by Alluvium and windblown sand deposits. The low resistivity up to 115 ohm-m, in this zone is representative of this consolidated sedimentary pile.However, the breaks in resistivity at depth of 15km may indicate a fault boundary, which also has disturbed the resistivity contours in high resistivity columnbetween Sirohi and Mount Abu. The hotspot trail has been reported to pass through the same. The electrical structure has come out with good indicators of the suspect of the plume tectonics. The low resistivity kink to the north of Sirohi,indicates the location of Banas Dislocation Zone. Our first set of results reveals the good possibility of relating them with new-tectonic activity.

REE AND TRACE ELEMENT GEOCHEMISTRY OF BANDED IRON FORMATIONS FROM HIGH-GRADE METAMORPHIC TERRAIN OF KARNATAKA, INDIA : EVIDENCE OF HYDROTHERMAL AS WELL AS HYDROGENOUS ORIGIN OF MESOARCHAEAN BIFS

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Study of banded Iron formations (BIFs) from Archaean terrains helps us evaluate the hydrothermal vs hydrogenous processes in giving rise to BIFs; they also help in understanding the Eh -pH conditions of the Archaean seas and their relation to contemporary biological processes. Geochemical studies on BIFs from>3000Myr Sargur Schist Belts of theWestern Dharwar Craton (WDC) were carried out to understand their origin.

Chondrite normalised REE plots for BIF samples from Motha Hill and Nugu Damareas near Sargur show slight LREE enrichment, flat HREE patterns with positive Eu anomalies. The interlayered amphibolites from Nugu Dam showstwo sets of REE patterns; slightly LREE depleted without Eu anomaly and light REE enriched with positive Eu anomaly.

The other set of BIF samples are from Thorekadanhalli and Shivasamudram areas. The Thorekadanahalli iron formations show LREE enchriched and HREE depleted patternswith a strong negative or positive Euanomalies.

When ΣREE *VS.* Ni+Cu+Co (i.e. incompatible/compatible elements)values were plotted for all BIFs and amphibolite samples, Motha Hill and Nugu Dam samples cluster together in the hydrothermal source field, whereas Thorekadanahalli and Shivasamudram BIFs plot between hydrothermal and hydrogenous fields and one sample of Shivasamudram plots in hydrogenous field. The Thorekadanahalli samples fall closer to the hydrothermal field compared to Shivasamudram samples.

Motha Hill and Nugu Dam samples show characteristics of iron derived from hydrothermal sources whereas Thorekadanhalli and Shivasamudram BIFs show more contribution from hydrogenous and continental sources.

Further Rb-Sr and Sm-Nd isotopic studies on these samples are in progress.

UNDERSTANDING THE LATE STAGE TECTONICS OF WESTERN DHARWAR CRATON, SOUTHERN INDIA-A STUDY BASED ON FAULT-SLIP ANALYSIS

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Fault-slip analysis of normal faults from Chitradurga granite, western Dharwar craton (WDC), southern India, is performed to decipher the late stage tectonics of the region. A total of 112 fault data are collected from the study area and analyzed in light of regional deformation. The Chitradurga granite (2.61Ga) is the part of younger granites of WDC and assumed to have emplaced during the regional D2 deformation (Chadwick et al., 1981). The Chitradurga granite is coarse grained and devoid of field fabrics, however foliations are observed particularly in the northern portion, close to Chitradurga shear zone (CSZ). Earlier studies in the region reveal that the area has undergone three phases of deformation (Chakrabarti et al., 2006). D1/D2 were coaxial with NW-SE striking vertical axial plane due to NE-SW directed compression, whereas D3 formed regional warping on account of late NW-SE directed compression (Chakrabarti et al., 2006, also see Mondal and Mamtani, *in-press*). Although the granite does not show any mesoscopic field fabrics, a large number of brittle structures (faults) are recorded. These faults are interpreted as oblique slip normal faults using slickenfibres and congruous steps. The fault planes show various orientations, however maxima lies in NW-SE direction. Most of the fault planes show moderate to high dip with the mean dip-amount being 53^{o} whereas pitch of the slickenfibres varies from 0^{o} to 90^{o} (mean=46^{o}). Initially the faults are classified into two groups based on slickenfibres orientation: (1) left lateral oblique-slip normal faults and (2) right lateral oblique-slip normal faults. The stress inversion (Gaussian) method is applied to analyze these normal faults using T-Tecto 3.0 computer program (http://www2.arnes.si/~jzaloh/t-tecto_homepage.htm). Paleostress analysis of these faults reveal that the faults have formed under NNE-SSW directed extension. Similar results are also obtained, while left lateral and right lateral oblique-slip normal faults are treated as separate entity. In light of the discussion, it is inferred that the normal faults in granite have formed as R, P, R′ and X shears of regional Riedel shear system developed due to sinistral movement along the CSZ. It is envisaged that the movement along CSZ was a consequence of WNW-ESE directed far field compression during late D3 deformation when the pluton achieved very shallow depth.

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MAGNETOTELLURIC RESOLUTION IN TERMS OF SKIN DEPTH AND ITS RELATION TO THE EVALUATION FREQUENCIES AND STATION SPACING

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Magnetotelluric (MT) is a diffusive Electromagnetic method which implies that MT is volumetric measurement method. Its depth of penetration is taken as the skin depth. So, this diffusive volumetric measurement at a particular frequency gives the information within a hemisphere whose radius is equal to the skin depth for that frequency. As a result, the resolution of MT measurement is frequency dependent. In the present study, an attempt has been made to find the optimal dimension of an object that can be resolved with a fixed set of measuring parameters (frequencies and station spacing) at certain depth on the basis of skin depth concept. Further we tried to establish optimal criteria (thumb rule) of selection of station spacing and evaluation frequency separation for resolution enhancement of that object. But to apply these resolution criteria we need prior information of the subsurface geology. So, to outline the approximate subsurface geology we have designed a systematic approach. The entire study was started from homogeneous earth and extended to 1D and 2D earth with calculation of correction terms. The validation of the proposed resolution criteria along with the proposed systematic approach was first tested with synthetic data starting from a simple model to a complex model stepwise. After getting success on synthetic data we finally applied this proposed idea to Koyna-Warna seismic zone for high resolution study.

FRACTAL BASED PETROPHYSICAL RESERVOIR CHARACTERIZATION USING WELL LOG DATA: A CASE STUDY

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Often the goal of reservoir characterization studies is to provide a 2D or 3D petrophysical model for reservoir performance simulation and for planning future production wells. In this study petrophysical reservoir characterization is carried out through estimation of porosity, permeability and lithology using well logs. A method of permeability estimation is proposed for a sandstone reservoir using fractal concepts.Sandstone reservoir is considered to be mono-dispersed medium because only macro porosity or useful-porosity porosityhas significant contribution to permeability. A Monte – Carlo algorithm for estimation of permeabilityfrom fractal distribution of pore diameters is developed. The method is applied on well log dataof Ankleshwar oil field, Cambay basin, India.

In Ankleshwar reservoir since oil production has declined, the operator planned for CO_2–EOR (Enhanced Oil Recovery) ina sand layer "S_C". Useful porosity and permeability distribution of S_C sand layer is modelled to understand the movement of CO_2.It is observed that high porosity and permeability trend is towards east. Thus, it is concluded that future production wells may have to be placed in the eastern side of the study area.Since there is significant lateral variation in permeabilityit is inferred that the present reservoir simulation models, which are based on constant permeability have to be replaced with variable permeability model.

UPPER MANTLE ANISOTROPY OF DHARWARCRATON USING SKS AND SKKS PHASES

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In the present study, we investigate the upper mantle anisotropy from west to east coast of Dharwarcraton, reveals significant lateral variations of anisotropy. The dharwarcraton consist of mainly Archean Western Dharwarcraton (WDC) of age 2.7–3.36 Ga and Eastern DharwarCraton (EDC) of age 2.5 Ga., Proterozoic basin and the passive continental margins along the west and east coast. We used high quality SKS and SKKS waveform from 180 teleseismic earthquakes, an east-west trending seismic array, which consists of 38 broadband seismographs during the period from April 2012 to February 2014. Along the profile, the fast polarization direction (ϕ) is consistently oriented to NW beneath WDC, while it is oriented to NE in the Cuddapah Basin (CB) and combined with Eastern Ghat (EG). Otherwise, in the EDC region it varies from NW-30^o to NE30^o. The delay time (δt) is not consistent across the region, varies from 0.4 to 2.0 s and is about 1 s in average, which is closed to the global average for continental shield, consistent with the earlier results. The evidence of two layer anisotropy manifest complex scenario of anisotropy beneath the region. The lower layer is almost consistent with absolute plate motion (APM) direction caused by asthenospheric flow. While the upper layer is significantly vary from west to east with respect to local geological features like shear zone, fault and continental rift. The source of anisotropy is around ~170 km estimated by non overlapped parts of the Fresnel zone at stations with different splitting parameter and which is correlating with the lithospheric thickness. Finally, we conclude that fast polarization direction beneath WDC is correlates with the strike of the regional shear zonewhile, the eastern part is greatly influenced by both present and past tectonic process. Also variability in the splitting measurements for single events recorded at various stations, suggest that anisotropy is located at shallow depth and it is none homogeneously distributed bellow the array at different depth.

SEISMIC HAZARD STUDY: SITE CHARACTERIZATION USING SHEAR-WAVE VELOCITY ESTIMATIONS OF AHMEDABAD SITES BY MASW METHOD AT AHMEDABAD, GUJARAT, INDIA

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The Ahmedabad region has earthquake hazard of destructive intensity of VIII,as it falls in Seismic zone III of Indian classification. The area is covered with soil, the top layers (up to 30 m depth) of which may cause 2-3 times amplification due to impedance contrast. This amplification is for seismic waves of 0.1 – 0.6 sec corresponding to 1 – 5 story building. If we know the depth and velocity of different layers, amplification of seismic waves can be worked out. Therefore, we have done site characterization using Shear-wave velocity (Vs) estimates of two sites in Ahmedabad by MASW technique. The sites are 700 m apart in Satellite area of western Ahmedabad. The average shear-wave velocities are estimated for top 5 m layer, for 5-20 m layer and for total ~30 m as given below:

Layer	Site 1	Site 2	% change
Top 5 m	166 m/s	183 m/s	16 %
5 – 20 m	278 m/s	320 m/s	17 %
Average Vs30	284 m/s	341 m/s	20 %

The change in Vs 16% - 20 % is not much. The second layer from depth of 5-30 m has strong soil. In view of these Vs values, the region can be classified as of class D type (stiff soil) according to NEHRP classification scheme. Foundations deeper than 5 m will be on firm ground.

SPECTRAL INDUCED POLARIZATION IN THE DETECTION OF HYDROCARBON CONTAMINATION IN SOIL USING PRBS SOURCE

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Spectral IP studies were carried out using an experimental Lab setup to study the influence of hydrocarbon contamination, such as diesel oil in a soil sample, by monitoring the complex resistivity in the Induced Polarization (IP) range of frequencies between 0.125HZ to 1000 HZ using Pseudo Random Binary Sequence (PRBS). Pseudo random excitation has been chosen to obtain the magnitude and relative phase response at one go over the entire IP spectrum (range) by using Lab VIEW soft ware. It is advantageous to use pseudo random binary sequence excitation, keeping in view of the limitations of both Time and Frequency domain IP measurements, which are required to observe the response at each and every frequency.

A constant PRBS current source was excited using Linear Shift Register (CD4015). Graphite Electrodes were used for current excitation. High quality Platinum tip electrodes were used for potential measurements in order to avoid oxidation and contact resistance, since soil sample is exposed to out side environments.

It was observed that while uncontaminated soil has a fairly constant resistivity of approx 20 ohm meters and the resistivity of diesel oil contaminated soil sample though initially became highly resistive to approximately 90 ohm meters, finally settled to 70 ohm meters after three months of maturation and to 60 ohm meters after 6 months of maturation. The phase response of uncontaminated soil sample over the frequencies from 0.2 Hz to 400Hz approx 90milliradians and phase shift was noted for contaminated diesel soil sample is approx 150milliradians.This method can be generally applied in real time/field to monitor for detection of soil contamination due to hydrocarbons at low cost, less time with high accuracy.

GEOTECHNICAL INVESTIGATIONS FORHAZARDOUS SOILS

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Soils are unconsolidated materials that are result of weathering and erosion process of rocks. When water content of some soils change, it makes problems to civil activities. The response of soil due

to change of water content producing significant amount of deformation or hazard has been one of the major concerns for geotechnical engineers working in hazardous soil. The problems include swelling, dispersing and collapse. Hazardous soils are formed in special geological conditions. These types of soils also play important role during earthquake leading to failure of civil structures like buildings, ports and other important facilities. Field observation and laboratory tests can be useful to identify such problematic soils.From geotechnical and engineering geology points of view, collapsible, expansive and dispersive soils are classified as problematic or Hazardous soils. The existence of problematic soil has been reported in all of the world continents. One of the most important problems found insuch soils is instability and considerable settlement due to minor changes in the water content, which can cause remarkable damages to overlying structures.Therefore, study of collapsibility potential, swelling and dispersion percentage are essential before construction of any structure. In this study, some empirical criteria are classified and implemented for Dahej (Kamboi) and Mandvi area on the coast of Gujarat. As a case study, ports in the regions were considered because they have high risk of failure due to collapsibility phenomena. After site investigation undisturbed samples have been collected for laboratory testsThe soil expansion and collapsibility potential was confirmed through comparison of selected criteria.

MACRO LEVEL LIQUEFACTION HAZARD MAPPING FOR COASTAL AREA OF GULF OF KACHCHH

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Liquefaction is a phenomenon wherein a mass of soil loses a large percentage of its shear resistance when subjected to monotonic, cyclic or sudden loading and flows in a manner resembling a liquid until the shear stresses acting on the mass area become as low as the reduced shear resistance (sladen et. al.1985). Macro level and Micro level study can be done for Liquefaction Hazard mapping. The macro level investigation is an overview to the Liquefaction Susceptibility and can be very helpful to know requirements of micro level study.This paper presents a macro level study of Liquefaction potential assessment for the coastal area, consisting big ports of Gujarat. The port structures are very essential and important for the transport of cargos. These structures are frequently exposed to seismic loading due to earthquake, for example, 1989 Loma prieta, 1995 Kobe, 1999 Kocaeli and 2001 Bhuj earthquakes. The geology of coastal region of Kachchh mainly comprises of Quaternary period sediments. Recent marine deposits are visible in these areas. The water table in the area is present at shallow depth upto 10m. In some areas it is found at slight depth of 1m. Moreover, the study area lies in high seismic zones IV & V and can feel the earthquake uptoModified Mercalli Intensity of X. It indicates the extreme severity of the earthquake. The Macro Level Liquefaction Hazard mapping for the coastal area of Kachchh is done based on Geology, Geomorphology, Age & type of deposit, water table and seismicity of the area.In this study, results indicate that almost all the study area is prone to liquefaction with moderate to high probability. The micro level analysis is also suggested for Liquefaction Potentiality before constructing any infrastructure facilities.

EFFECTOF DEPTH OF BASEMENT TOPOGRAPHY ON GROUND MOTIONCHARACTERISTICS

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The effects of basement topography (BT) on the characteristics of seismic waves have been receiving increasing interest after 1994 Northridge earthquake during which unique damage pattern in the cities of Santa Monica and Sherman Oaks was inferred. The effects of depth of BT on ground motion characteristics in both the quantitative and qualitative manners are recognized in this paper. Seismic responses of various BT models have been computed using a 2D fourth order accurate staggered-grid finite-difference algorithm for SH- wave propagation simulation in viscoelastic medium. In order to accurately quantify the depth of BT effects on the spectral amplification of ground motion, a frequency dependent damping in time-domain FD simulation is implemented based on rheology of generalised Maxwell body, widely known as GMB-EK rheological model. The analysis of simulated results revealed a drastic change in ground motion characteristics and generation of new seismic phases. The curves for average spectral amplification are not so smooth and symmetrical as was that of amplitude amplification of SH-wave because of presence of diffractions from the bottom and corners of the BT.Results of this study depict that consideration of BT effect is as much important as that of surface hills/ridges during seismic hazard assessment.

STRUCTURAL MAPPINGOVER SINGHBHUM-ORISSA CRATON, INDIA USING HIGH RESOLUTION EGM2008 GRAVITY DATAAND IN SITU GRAVITY DATA

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Singhbhum-Orissa Craton is one of the oldest parts made up of Archaean rocks in eastern Indian Shield, which is about 40,000 sq.km. in area forming a triangular crustal block. The area has a very complex Precambrian history dating as far back as 3200 m.y. and extending up to 850 m.y., during which time it experienced a number of orogenic cycles. Extensive studies have been done for geological appraisal, structural mapping and subsurface mapping by different methods in this area. But due to complexity of the geology and enormous mineralization new works are always being added for better understanding of the area.In this work, the subsurface structures and lineaments have been delineated by the interpretation of gravity data by using different edge detection and enhancement techniques. High resolution EGM2008 Bouguer gravity data of Singhbhum-Orissa Craton, India have been generated from the International Centre for Global Earth Models. Further, EGM2008 and in situ Bouguer gravity data have been enhanced using the 1st and 2nd VerticalDerivatives, Analytical Signal and Tilt Derivative techniques and corresponding lineament maps have been generated. Published geological and structural maps of the area have been correlated withgenerated lineament maps of the area. The lineament maps extracted using 1st and 2nd Vertical Derivatives, Analytical Signal and Tilt Derivative techniques provide better understanding of the geological setting of the Singhbhum-Orissa Craton.

APPLICATION OF SEISMIC REFRACTION TECHNIQUE TO MAP THE SUBSURFACE AND FIND STATIC CORRECTION

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Seismic refraction surveying is one of the most powerful methods used for detecting shallow subsurface structure. The method depends on the fact that seismic wave travels with different velocity in different soil and rock strata. Using the first wave arrivals in the recorded seismograms, we have plotted the T-X graph and delineated various layers present in the region. From this we have found the subsurface structure and its velocity profile.

In our present study we have used data from ITALY region and have processed the data and interpreted it using SMARTREFRACT® Software.

After processing the data and based upon our interpretation we have found that there are two velocity layers with average velocity V1=429 m/sec and V2= 2041 m/sec and the low velocity layer with varying depth from 4 meter to 20 meter ,which we have further utilized in finding out the static time correction for the seismic reflection survey.

ESTIMATION OF MODEL PARAMETERS FROM TRAVEL TIME AND AMPLITUDE INVERSION OF SEISMIC REFLECTION DATA: A THEORETICAL CASE STUDY

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Seismic reflection data contains information about the elastic parameters such as the P-wave velocity (V_p), S-wave velocity (V_s) and density (ρ) of different sub-surface layers. Here, we have taken a four-layered earth model, and compute the reflection travel times and reflection coefficients at different offsets/angles. By comparing the reflection coefficients based on three AVO approximations: Aki Richards, Shuey and Bortfeldwith the exact Zoeppritz equation.We find that the Shuey approximation matches best with the exact equation upto 30 degree angle. The reflection travel time data has been computed using the travel time expressions, which relate the layer parameters with offset and travel time.The Iteratively Reweighted Least Square (IRLS) approach has been used for the inversion of both travel time and reflection coefficient data. This weighting factor is a diagonal matrix also called as the resolution matrix. The inversions are performed on synthetic data added with 5% and 10% random noise. The maximum offset used is 3000 metres. We shall present the efficacy of the approach in estimating all the elastic parameters from the four-layered model.

AVO ATTRIBUTE ANALYSIS FOR DETECTION OF POSSIBLE HYDROCARBON IN MUMBAI OFFSHORE BASIN

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The variation in seismic energy with change in distance between shot point and receiver reflects differences in lithology and fluid content in strata. Amplitude Versus Offset (AVO) analysis is a technique by which geophysicists attempt to determine thickness, porosity, density, velocity and fluid content of strata. AVO analysis has gained lots of success both onshore and offshore oil and gas exploration. AVO analysis showed its broad prospects because the free gas can be distinguished effectively from the results. AVO and Lambda-Mu-Rho (LMR) analysis plays an important role in reducing risk in exploratory drilling. Simultaneous LMR and AVO analysis proved to be useful in reservoir characterization for hydrocarbon detection. Lambda-Rho ($\lambda\rho$) and Mu-Rho ($\mu\rho$) volumes obtained from calibrated well log data to derive accurate reservoir position which helps in reducing reservoir risk.AVO intercept and gradient attributes are obtained using well log data followed by fluid replacement modelling. In addition, fluid factor volume is also calculated to identify porous and permeable zone. This study is extended by applying LMR technique for finding correct position of suitable hydrocarbon zone. This present study is undertaken using Mumbai offshore basin data. The study demonstrates the effectiveness of using lambda-rho and mu-rho volumes along with AVO attribute volumes for performing stratigraphic interpretation and reservoir characterization. From this study at two way time 930-950 ms,a high porosity value is interpreted which is a potential hydrocarbon saturated zone.

SEISMIC ATTRIBUTES FOR THE DELINEATION OF GAS HYDRATES: A CASE STUDY IN THE MAHANADI OFFSHORE BASIN

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Gas hydrates have been found in shallow sediments along the continental margins of India where water depth exceed 500 m. Their presence can be indicated by observing an anomalous reflector known as the bottom simulating reflectors (BSR), on seismic section. BSR can be identified on seismic section based on its characteristic features like mimicking the shape of seafloor, opposite polarity with reference to the seafloor and cross-cutting dipping geological strata. The BSR is a boundary between high-velocity gas hydrate bearing sediments above and low-velocity free-gas or water saturated sediments below. Besides velocity anomaly, presence of gas hydrates causes 'blanking' or reduction in amplitude strength above the BSR due to cementation of pore spaces, whereas free-gas below the BSR exhibit high reflection strength and low instantaneous frequency domination. The BSRs have been delineated on seismic sections in the Mahanadi offshore basin, which is considered as a potential zone of gas hydrates in the eastern Indian margin. To confirm whether the BSR is related to gas hydrates, we have computed various attributes like reflection strength, instantaneous frequency, phase, sweetness, absorption, quality factor etc. The high reflection strength, low frequency anomaly, low seismic velocity and high attenuation are observed below the BSR, characterizing the gas-bearing sediments. The high velocity, blanking and low attenuation above the BSR indicate the presence of gas hydrates. An integrated seismic attribute analysis provides confidence in interpreting the zones of gas hydrates and free gas from seismic data in a study region.

EXPLORING THE INDIAN OCEAN GEOID LOW

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Long wavelength geoid anomalies are more responsive to density inhomogenities deep within the Earth, which can be well explained by the internal processes of the Earth that could lead to such large scale fluctuations. The Indian Ocean Geoid Low (IOGL) is the world's largest geoid low, centered near to south of Sri-Lanka and covers a large part of the northern and central Indian Ocean.The geoid fluctuation in the Indian Ocean region is of the order of -100m which is much significant as compared to other parts of the world. Our objectives are to explore possible reasons attributing to such extreme deficiencies in the geoid height of'Indian Ocean Geoid Low' and to understand the crustal influence to the origin of the IOGL.Earlier studies support that the source depths of IOGL ranges from crust to the core mantle boundary andthe influence of crust on the geoid height was significant (Spasojevic et al. 2010). An initial segregate study of contribution of these sources ofdifferent depths is important. Influence of crust on the geoid was found to be mainly due to the variation of the shape of crustal layers and variation of density inside the layers plays a secondary role (J.Kakkuri, 2003).

A detailed marine 2-D regional seismic survey has been conducted across IOGL area. The data is marked with complex geological features like long wave length folding, deep penetrating faults and unconformities. We have also acquired active Ocean Bottom Seismometer (OBS) data in IOGL region which reveals the Moho boundary at adepth of ~13 Km below sea-level which is large as compared

to other normal oceanic Moho boundaries. It is further planned to deploy passive OBS which would provide us deep earth structures. Elementary results of the study are presented in the poster.

PORE PRESSURE STUDY USING DOWNHOLE DATA OF INTEGRATED OCEAN DRILLING PROGRAM (IODP) EXPEDITION 323

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The Ocean Drilling Program (ODP) and the Integrated Ocean Drilling Program (IODP) are long term international scientific missions to explore ocean basin and oceanic crust by direct drilling. Pore pressure which refers to fluid pressures in the pore spaces varying from hydrostatic pressure to severe overpressure, is an important parameter for studying past sedimentation processes and environment over a region. Here, a method has been implemented for estimating pore pressure of well 1341B using downhole log data obtained during Integrated Ocean Drilling Program (IODP) Expedition 323 in the Bering Sea Slope region. Prior to applying the method to estimate the pore pressure, various cross-plot techniques were used in conjunction with rock physics model to study pores pressure boundary and its associated distribution supported by lithology. Log responses (porosity, resistivity, sonic velocity, gamma ray etc) were used to estimate the pore pressure distribution against depth using well known Eaton's method. The method involved rock physics and well established empirical formulas for abnormal pore pressure (when the pore pressure is different from the hydrostatic pressure /normal pore pressure), estimation of well 1341B in the Bering Sea basin of north pacific region. In order to examine the sources of over pressure zone created by disequilibrium compaction or not, Eaton's sonic method with an exponent 3.0 was then adapted for this purpose by using depth dependent normal compaction equations in subsurface formations. Hydrostatic pressure gradient and magnitude of vertical stress (Sv) are estimated as 10.2MPa/km and 13.5 MPa/km respectively. From the compressional velocity and porosity trend at this well, it is found that the top of over pressure generated at the depth of 388 m below seafloor (mbsf). The observed abnormal pore pressure gradient is estimated as 10.8MPa/km.

INTERNATIONAL OCEAN DISCOVERY PROGRAM (IODP) EXPEDITION 353: INDIAN MONSOON RAINFALL

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IODP Expedition 353 conducted drilling operations at six sites from 29thNovember, 2014 to 29th January, 2015 in the Mahanadi Basin off eastern India, in the Andaman Sea, and on the Ninetyeast Ridge. A total of 32 scientific participants representing 11 countries sailed on this expedition. IODP-India through the Ministry of Earth Sciences, Government of India sponsored three scientific participants from India.

The objectives of the expedition were: 1) to study the history and intensity of the Indian Monsoon in the Bay of Bengal and to capture erosion and run-off signals by reconstructing salinity gradients

across the Bay of Bengal; 2) to understand the physical mechanisms underlying changes in monsoonal precipitation, erosion and run-off across various time scales; 3) to provide verification targets for climate models; and on longer time scales to 4) understand the timing and conditions for the initiation of the Indian Monsoon and 5) the impact of global climate events on the Indian Monsoon.

Core recovery was very successful (97%), which was accomplished using piston, half-length piston and the extended core barrel rotary coring. A total of 4280 m of core was recovered during the expedition. Downholewireline logging was performed at one site (U1445). The sedimentation rates vary from 1-2 cm/kyr at the Ninetyeast ridge to 5-20 cm/kyr in the Mahanadi Basin and the Andaman Sea. Based on the sediments recovered, post-cruise research by the scientific participants will achieve all of the scientific objectives.

SEDIMENT DISTRIBUTION AND GEOMORPHOLOGY OF NORTH WESTERN CONTINENTAL MARGIN OF INDIA

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Evolution of passive continental margins is controlled by the mode of extension and thinning of continental lithosphere during its formation as well as associated sedimentation process. Many of the structures such as horst–graben features have been related to the rifting history which is masked beneath the thick accumulation of marginal sediments.Therefore, imaging of the continental margin using multi-channel seismic (MCS) reflection data provides significant overview with regard to the volcanism, sedimentation, and rift architecture of the margin. Interpretation along seismic sections from north western continental margin of India revealed five major sedimentary sequences and associated fault patterns. Seismic imaging mapped ~3.0s (TWT) thick sediment sequences with a steep scarp of seafloor at the shelf edge. A relief of ~4.0sTWT in seafloor is observed from the shelf to slope region. Within the continental slope, the sequences appeared to be faulted with anticlinal structure. Thin layer of sediments is observed in the shelf margin basin which appears to be intruded by several structural highs. The sedimentary layers pinch out suddenly at the lower wall of the highs. These stratigraphic sequences host detritus of syn- to post collisional events during rift-drift process. Presence of channel levee systems identified within the sedimentary sequences helped to understand its role in transporting the sediments further into the abyssal plain. Multichannel seismic data also confirmed the presence of an unconformity within the strata. The acoustic basement appeared to be faulted with intrusions in between. Hence the results from detailed analyses of multi-channel seismic reflection data in association with lithology data from drilled holes to understand the genetic link between tectonics, geomorphology and sedimentation of the region will be presented.

DEPTH ESTIMATION OF ARABIAN SEA ALONG WESTERN CONTINENTAL MARGIN OF INDIA USING SPECTRAL ANALYSIS OF MAGNETIC ANOMALY

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Spectral techniques provide excellent means of extracting magnetic field information contained in each of the magnetic field data. Spectral techniques (Power spectrum analysis of magnetic data)

estimate the mean depth of the interfaces considering the log of power of the magnetic spectrum as a function ofwave number/frequency assuming uncorrelated distribution of sources or scaling nature of sources. The spectrum of magnetic anomaly due to layered source is separated into multiple segments in frequency domain that can be interpreted in terms of mean depth of the interface. The theoretical power spectrum of a half space model of scaling sources explains the sources of observed power spectra of real potential field data very well. Minimizing the misfit between model and observed power spectrum yields an estimate for depth to top of the source.We applied the proposed algorithm to the total magnetic field anomaly from theArabian Sea along the western continental margin of India. The study arealies to the north of Chagos-Laccadive Ridge system. The magnetic field anomaly ispredominantly due to Precambrian basement faults.

The magnetic data was collectedalong several profiles oriented in NNW-SSE direction. The data are sampled atroughly 50 m along the profile direction, the distance between the profiles beingapproximately 3.7 km. The earlier solutions of Euler deconvolution suggestthat the magnetic anomalies are predominantly due to basement faulting and theirorientation is consistent with that obtained from regional magnetic interpretation.In the proposed method the radially averaged energy is computed with the help of 2-D FFT by transforming the data from space domain to wavenumber domain. The radially averaged energy spectrum is a function of wavenumber alone and is calculated by averaging the energy at all directions for the same wavenumber. Log spectrum of the data can be interpreted to determine the statistical depth to the top of the sources.

$$\text{Log } E(r) = 4\pi hr$$

The depth of the ensemble sources is easily determined by slope of the energy spectrum and divided by 4π. Spectral analysis of the magnetic anomaly shows different slopes. Slopes are generally affected by the depth and shape of the body. We took three AA′, BB′and CC′and calculated the depth with the help of spectral analysis technique.We prepared2D modeling along the three profile AA′,BB′, CC′. Inferred depthof modeling shows a good agreement with the depth found by spectral analysis. Along profile AA′ body having sphere like structure having depth nearly 2 km and along profile BB′ body having infinite dyke like structure with depth nearly 1 km have been delineated. Profile along CC′ body shape is like horizontal rod and depth is around 1.5 km.

PREDICTION OF POROSITY FROM 2D POST-STACK SEISMIC DATA

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Post-stack inversion of seismic data is routinely carried out to derive acoustic impedance (AI) to derive physical properties of sediment. Porosity is a very useful parameter for delineation of reservoir properties. Porosity inversion from AI is very common technique which can be easily done when correlation between porosity and AI is good. Due to variation in lithology and presence of dispersed shale porosity mapping by common method is not reliable. Here, we introduce an uncommon methodology of inverting post-stack seismic data into porosity from porosity log which improves the spatial distribution of porosity. In this method, relation between the acoustic and porosity reflectivity is used for porosity inversion. The post-stack inversion for estimation of porosity is performed by

model based inversion using initial low frequency model and wavelet extracted from log or seismic data. This methodology is implemented on the Krishna-Godavari (KG) and Mahanadi Basin data. The total porosity (ϕ) estimated from density log has been used as input for porosity inversion from the 2-D seismic stack data set having good and poor correlation between AI and porosity in the Mahanadi and KG offshore basins respectively. In Mahanadi basin, the porosity along the seismic line ranges from 53 to 65% within the gas hydrate bearing sediments with maximum value of 70% at the free gas filled unconsolidated sediment below the bottom simulating reflector (BSR). The water bearing silt/clay sediments indicates porosity of about 60-65% below the seafloor. In KG basin, the porosity in Raghavapuram shale varies from 13 to 30% with maximum value of 52%, which is observed in Paleocene sediments. The porosity sections show good correlation with the geological trends in both the Mahanadi and KG basins, and need to be validated with more number of wells or core porosity data.

AVO INVERSION USING SIMULATED ANNEALING WITH A CONSTRAINT FROM TIME TRAVEL INVERSION

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Gas hydrates can be identified on marine multichannel seismic reflection data by mapping an anomalous bottom simulating reflector (BSR), which marks the base of gas hydrates stability zone.The amplitude variation with offset (AVO) from a BSR contains useful information about the characteristics of overlying gas hydrates and underlying free-gas bearing sediments. The problem of extracting the p-wave (Vp) and s-wave (Vs)velocities, and densities (ρ) from AVO are non-unique in nature, as different combination of Vp, Vs and ρ may yield the same AVO response. This makes the AVO inversion quite intricate. If the data are inverted in a layer-by-layer fashion, any error in the upper layer gets cumulated in the lower layer. An attempt has been made to circumvent this non-unique problem by travel time inversion followed by AVO inversion of synthetic data using a global optimization method - simulating annealing.

First, we perform inversion of reflection travel time data from all layers together and derive the Vp and thickness of different layers. Then we carry out AVO inversion for the whole model and derive the Vs and ρ of different layers by constraining the Vp of different layers, obtained by travel time inversion. This provides a good strategy to estimate all the elastic parameters (Vp, Vs and ρ) for a multi-layered earth.

Methods based on local linearization fail if the starting model is too far from the true model. Whereas, the simulated annealing scheme (Very Fast Simulated Annealing), being a proficient in dealing with highly nonlinear problems, is used for inversion yielding robust results. The inversion scheme, applied on synthetic data with 0, 1 and 3% noise with maximum offsets of 3000 m shows very promising results, and we intend to apply the same to the field data in Krishna-Godavari offshore, where gas hydrates have been already recovered.

TURBIDITES FROM THE INDUS FAN AT IODP SITESU1456 AND U1457 IN THE LAXMI BASIN

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Submarine fans are the largest detrital accumulations on Earth and theIndus submarine fan deposits form the second largest submarine fan in the world. Two drilling sites, U1456 and U1457, weredrilled during International Ocean Discovery Program (IODP)Expedition 355 in the Eastern Arabian Sea. Atotal of about 1700 m of core, most of which is ~11 Ma and younger,were recovered from the two sites. Turbidites are common throughout much of the succession atboth drilling sites.However, they are thinner and represent more distal facies at Site U1457. Cyclical, stacked turbidites are particularly common in the upper Miocene to lower Pleistocene deposits, with the highest sedimentation rates occurring in the early Pleistocene based on the shipboard age model. The turbiditesare interpreted aslobes of the Indus Fan. The fan sediment recordincludes turbidites supplied from the Indus drainage, alternating with pelagicsedimentation.In addition, both sites encountered a thick sequence of mass transport deposit dated to ~11 Ma, which is interpreted to be sourcedfrom the Indian continental margin.

A COMPREHENSIVE GEOCHEMICAL AND SEDIMENTOLOGICALSTUDY OF DEEP SEA SEDIMENTS. LACCADIVE BASIN, ARABIAN SEA

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A high resolution study of a gravity core (ANS-08_GC-01), recovered from Arabian Sea was analyzed for their geochemical and sedimentological composition to study the impacts of their characteristics. The sediment core was predominantly constituted of clayey silt and silty clay sediments. The present study reveals strong shale normalized negative Ce anomaly in the investigated samples which suggests a very less oxidizing environment during their formation. The Shale normalized positive Eu anomaly in the sediment could be due to water affected by eolian input from horn of Africa and the Iran – Makran - Thar Desert regions. The rare earth elements and terrigenous elements show a significant strong correlation ($r=0.81$; $P<0.01$, 0.32; $P<0.02$, 0.39; $P<0.01$ for Al, Mg and Mn respectively and $n = 53$), indicating a unique source of their origin. A significant strong positive correlation ($r= 0.46$; $P<0.01$; $n = 53$) was observed between organic matter and carbonate content, which indicates that the carbonates were not diluted by organic matter, thus indicating a limited rain fall and which is also supported by the presence of smaller amount of sand in the analyzed sediment.

PRODUCTIVITY VARIABILITY BASED ON NITROGEN AND CARBON ISOTOPES IN SQUEEZE CAKE SAMPLES RECOVERED DURING IODP EXPEDITION 355

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The climate of the Arabian Sea is affected by the seasonal reversal of the southwest and northeast monsoon winds and associated oceanic circulation. Several external and internal forcing factors drive the variability of the monsoon in the Indian subcontinent. IODP Expedition 355 drilled two sites (U1456 and U1457)in the eastern Arabian Sea during April-May 2015 to primarily study the nature of the basement rocks and the tectonic-climate connection between Himalayan uplift and Indian monsoon. The sites drilled also provide an opportunity to document high-resolution palaeoceanographic changes during the Quaternary, which can then be related to millennial-scale monsoonal variability linked to various forcing factors. For the present study, squeeze cake samples collected from Site U1456 (16°37.28′N, 68°50.33′E; ~3640 m water depth; total depth of penetration ~1109 m) are being analyzed.The location of Site U1456 is approximately 475 km from the western coast of India and ~820 km south from the mouth of the Indus River, which is the dominant supplier of sediments to the area.The samples (5–15 cm long whole-round sections) were taken every ~20 m and were squeezed onboard the *JOIDES Resolution* using a modified titanium and steel squeezing device at ambient temperature with a hydraulic press at pressures of up to ~30,000 psi to collect the interstitial water. This squeezingresults in very compact sediment samples known as squeeze cakes. The squeeze cake samples have been processed and are being analyzed to determinedowncore variation ofcarbon and nitrogen isotope ratios ($\delta^{13}C$ and $\delta^{15}N$), total organic carbon, and total nitrogen content to study the denitrification intensity and productivity variability in the study region.The coupling of high productivity and moderate ventilation of the thermocline leads to the formation and maintenance of a strong and stable oxygen minima zone (OMZ) at water depths of 200–1200 m in the Arabian Sea. Denitrification is a significant process in the OMZ and $\delta^{15}N$ has proven to be a reliable proxy for studying denitrification variability and the strength of OMZ. The carbon isotopic compositionof the sedimentary organic matter will help to determine the provenance of the organic matter.

ESTIMATION OF POROSITY AND GAS HYDRATE SATURATION USING VERY FAST SIMULATED ANNEALING

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Porosity and water saturation are two important parameters for characterisation of hydrocarbon reservoir. We often assume constant porosity which gives erroneous estimation of water saturation or amount of hydrocarbon. Here, we use Very Fast Simulated Annealing (VFSA) coupled with rock physics theory to estimate porosity and saturation directly from observed impedance. Impedance is a function of bulk modulus (K), shear modulus (G) and density (ρ). These K, G and ρ are again dependent on the porosity, saturation and clay fraction. We have derived three equations for K, G and ρ in term of porosity and saturation (assuming constant clay fraction) and these equation are used for forward problem in our inversion. We have applied our technique to well log data in Krishna-Godavari (KG)

basin. VFSA is global search technique which is not trapped in the initial model like calculus based local search methods. We have used a prior range of porosity of 40-70% taken from observed log and water saturation of 60-100% of porosity taken from rock physics theory. Inverted results show well match with observed porosity and the amount of hydrate saturation estimated using the Three Phase Biot Equation. We have also correlated the hydrate saturation with available pressure core measurements, which shows close correspondence with our saturation estimates.

DELINEATION OF GAS HYDRATES FROM SEISMIC DATA IN KRISHNA-GODAVARI OFFSHORE BASIN

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Gas hydrates are formed in shallow sediments along the continental slope areas and permafrost regions under high pressure (>4MPa) and low temperature (<15^{0}C) conditions. Gas hydrates have attracted the global scientific community due to its widespread occurrences and a possible alternative non-conventional major energy resource. The Krishna-Godavari (KG) basin is a proven petroliferous basin located on the continental margin in the east coast of India. 2-D marine seismic data, acquired from the KG basin, was processed using the Paradigm processing software FOCUS (ECHOS). Length of the data was 4000 ms with sampling interval of 1ms, near offset 70 m and far offset 1545 m. The data was acquired with 120 channels with shot interval 25 m and receiver interval 25 m. The raw data was processed by applying a band-pass filter (5-8-80-100 Hz), muting, trace editing, deconvolution, velocity analysis, NMO correction, stacking modules of the software. Finally the migration was applied to collapse the diffraction hyperbola and to reduce the artifacts. As the geological structure was simple and lateral variation of velocity was less, post stack time migration was applied. The bottom simulating reflector (BSR), prime marker for gas-hydrates, was identified on the basis of its characteristic features of mimicking the shape of seafloor, cross-cutting the dipping strata and opposite polarity with respect to the seafloor. The BSR, which is a physical boundary between the gas-hydrates bearing sediments above and free-gas saturated sediments below, is also characterized by high seismic P-wave velocity for gas hydrates and low seismic velocity for free gas bearing sediments; seismic blanking due to gas hydrates and high reflection strength for the presence of gas. So, by identifying and characterizing BSR, we conclude that there exists gas hydrates in the study region.

MORPHOMETRIC ANALYSIS OF SUBMARINE CHANNELS IN THE UPPER INDUS FAN

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The upper Indus fan in the Arabian Sea is characterized by many linear and submarine channles, typically extending more than 100 kilometers in length and highly sinuous in nature. Submarine channels are significant networks for the transfer of terrestrial and shelf-derived sediments to the deepsea and form the distributive networks of submarine fans, the largest sedimentary deposits

in deepsea. High resolution multibeam bathymetric data were collected inthe upper Arabian Sea region, western offshore of India, to identify the submarine channels and quantify the morphometric parameters of channels.Bathymetric data were acquired using a hull mounted SeaBat-7150RESON-AS multibeam Echo sounderoperatingwith the frequency of 12kHz and swath width of 150°.The data sets were processedand Digital Elevation Model (DEM) generated to analyse the various features.The water depth in the surveyed region varies from -1564m to -3445m. Primarily, threemajor submarine sinuous channels identified.Similarly,Paleo channels, levee failure and Oxbow lakes have also been identified. The morphometric parameters analysed to understand the flow variation with in the channels include anumber of meandering belts with in channels, meandering length and Width, thalweg depth, meander amplitude andlength and meandering arc length. The 117km long Channel-A with five meandering belts moves from Northeast to southwest and finally turns west in water depthsvarying from 2329m to 2831m, sinuosity is 2.70 and thalweg varies from 2572m to 2704m. The 185.6 km long Channel-B with four meandering belts moves from Northeastto south in water depths varying from 2202m to 3019m, sinuosity is 1.61 and thalweg varies from 2467m to 2919m. The 444km long Channel-C with 18 meandering belts moves from Northeast to south in water depthsvarying from 2012m to 3395m, sinuosity is 2.55 and thalweg varies from 2366m to 2971m.In general, the channel depth varies from 50m to 160m, width from 800m to 3200 m and arc length from 450m-2200m. The results thus obtained shall improve our understanding of the seabed morphology and help to recognise key fan evolutionary trends.

CHARACTERISATION OF ORGANIC MATTERTO UNDERSTAND METHANOGENESIS IN BENGAL FAN SEDIMENTS

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Biogenic methaneis produced during bacterially-mediated anaerobic mineralisation (methanogenesis) of organic matter (OM)[1,2]. The shallow subsurface metabolism of microorganisms primarily produce methane with a small amount (<2%) of ethane, propane, butane and pentane[3]. Methanogenesis is the final stage of a series of biogeochemical reactions during post-depositional diagenesis of OM [3,4]. A number of factors including amount (>0.5%) and type (labile vs. recalcitrant) of OM, and biogeochemistry of the substrate control methanogenesis[6].Under normal depositional setting these processes occur at shallower burial environments and mostly within 1 m below seafloor. Moreover, methane is trapped in relatively shallow environments especially beneath the anaerobic sulphate-reducing zone[3,4,5]. However, elevated concentration of methane (1000-35000 ppmv) at greater depths (100-400 m below seafloor) in Lower Bengal Fan sediments has been observed during routine headspace methane analysis during IODP expedition 354. We will present the preliminary organic biogeochemical data to understand methanogenesisin the deep sea sediments, and address the limitations in our understanding of biogenic methane production in deep sea fan.

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FRACTAL ANALYSIS OF LUNAR GRAVITY ANOMALIES OVER THE BASINS OF LUNAR FAR SIDE

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Recent dedicated lunar gravity mission, Gravity Recovery and Interior Laboratory (GRAIL) provided high resolution gravity field of the Moon. In this study, gravity anomalies of selected basins of lunar far-side are analyzed using gravity anomalies extracted from recent gravity model GRAIL900C up to degree and order 660^0, since higher harmonics of gravity field is dominated by stripping. The Bouguer crustal density of the part of Lunar far-side region is determined by using the fractal dimension method, which considers the fact that gravity data are a combination of scale - independent and scale – dependent components while topography data are primarily scale-independent.The Fractal dimensions have been estimated from the power spectra of Bouguer anomalies, which were computed on the spherical surface for different densities ranging between 2.5 g/cm^{3}and 3.0 g/cm^3. The minimum points of the fractal dimensions correspond to the density, which minimize the topography effect. From this study, we found that the density of2.8g/cm^3 is the appropriate Bouguer density for the study region.This density is further used to determine the isostatic anomalies over these basins, which are interpreted as density heterogeneities and structural variations.

A GEOINFORMATICS BASED COMPARATIVE ANALYSIS OF AEROSOL□NGSTR□M EXPONENTCONCENTRATIONOVER RANCHI URBAN AREA AND SOUTH KARANPURA COALFIELD REGION, JHARKHAND, INDIA

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Atmospheric aerosolsare one of the major pollutants that affect air quality in urban, ruraland mining regions of the world.The present study investigates the concentration of aerosol optical thickness (AOT),measured at 40 locations in Ranchi urban area(RUA) within urban boundary layer and 42 locations in South Karanpura coalfield region to identifythe status of atmospheric conditions over the area.Aerosol concentrationwas measured by using a five-channel (340, 500, 870, 936, and 1020 nm) handheld microprocessor-based MICROTOPS II Sun photometer instrument in the month of January 2014 (peak winter season).It was observed that AOT concentration was higher (1.92-3.33 at 340nm) in the vicinity of thermal power plant, sponge iron factory, mining area, coal-based small industries and construction sites, whereas lower (<1.50) in the forest and low population density areas within agricultural lands.In comparison withthe urban area of Ranchi city, AOTconcentration shows variation with high values (0.68-0.34 at 340nm)at main centers of railway and road traffic junctions (Lalpur, Khelgoan, Jumar, Main Road, Kanke), whereas lower (<0.34) in planned residential area (Gandhinagar and HEC Sector III).The spatial distribution of AOT in the wavelength region 340-1020 nm exhibits that the AOT values are higher for smaller wavelengths (340nm) and lower for larger wavelengths (1020nm) indicating dominance of fine particles in the atmosphere compared to

larger size particles. Ångström parameters (α, β) are calculated for wavelength pair 340-870nm using MICROTOPS-II Sun photometer data for both the areas. The results showed that the value of 'α_{340}'lied between 0.47 to 2.59 and 0.60 to 1.04 in mining region and RUA, whereas variation of 'β'values lied between 0.03 to 1.92and 0.07 to 0.20, respectively. The study exhibited that aerosol concentration is higher over mining region as compared to urban areas because of expansion in industries and coal mining activities over the years.

A BROAD CLIMATOLOGY OF VERY HIGH LATITUDE SUBSTORMS: AN UPDATE

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In our previous study (Singh et al., 2012, Adv. Space Res.), we reported the broad climatology of isolated substorms occurringpoleward of the standard auroral region using magnetic field data from Indian Antarctic station, Bharati (CGM coordinates 75^0S, 97^0E) and its near-conjugate station Hornsund (CGM coordinates 74^0N, 108^0E) of the IMAGE chain in the European region. Previously, only ~100 days data, collected during the austral summer season of years 2007-2010, were available from Bharati.Based on a small statistics, we had observed that the very high latitude substorms tend to occur in the winter hemisphere near the magnetic mid-night meridian, during northward as well as southward interplanetary magnetic field conditions. Following the year-round operation of Bharati research base since March 2012, about 3-years continuous high resolution digital magnetic records are currently available. In this study, we updatethe climatology of very high latitude substorms for different seasons of a year and hemispherical asymmetry.For 2013-2015, the solar activity cycle varied from the maximum phase to the early declining phase.Polar substorm characteristics in relation to the solar cycle variation, interplanetary magnetic field and solar wind conditions have been also examined.

HIGH RESOLUTION CONVECTION-PERMITTING AND RESOLVING NWP MODEL SIMULATIONS FOR A CONVECTIVE EVENT OVER THE INDIAN REGION

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As severe weather threats and hazards are common these days, the Numerical Weather Prediction (NWP) has become very critical, considering the public safety and welfare. Though current NWP models can predict such events in advance, the intensity of the weather phenomena and their exact location of attack may not be accurate for most of the times. To provide suitable guidance for severe weather warnings, since recent times many national meteorological services are operating very high-resolution convection-permitting NWP systems for their region of interest where the initiation of convection and its structure are handled explicitly. Despite the increased resolvability offered by finer resolution models, these models are still constrained by multiple factors such as inherent errors and uncertainties in specifying the initial state of the atmosphere, and simplifications in physics and parametrization of sub grid scale processes. This work provides a contribution to understand how the uncertainty in the NWP forecast of severe weather events is influenced by increasing the model grid resolution in the scenario of a deep convective event. Also the present study aims to explore the micro-physical

challenges at high resolution, especially the atmospheric boundary layer parametrization in predicting the convective event, associated rainfall episodes and the evolution of near surface parameters over the Indian region. Here, three different horizontal resolution experiments having the first one with coarse resolution where convection is parametrised, second with convection-permitting resolution where convection is partly explicit and third with large eddy resolution where convection is fully explicit, (7 Km, 2 km and 500 m respectively) are performed in the COSMO (COnsortium for Small-scale MOdelling), a non-hydrostatic atmospheric model over the Indian region to explore the applicability of the NWP model to a realistic convective event. It is found that the intensity and onset of precipitation episode associated with the convective event shows drastic change with respect to horizontal resolution. The study also explains the role of boundary layer parametrization for the initiation of convection and onset of precipitation.

EVALUATION OF PROMPT PENETRATION EFFECTS ON COUNTER ELECTROJET EVENTS AT TWO EQUATORIAL SITES IN THE NORTHERN INDIAN OCEAN

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Prompt penetration Electric Field Model (PPEFM) is used to identify the influence of penetration effects on counter electrojet (CEJ) events at the two equatorial electrojet (EEJ) stations Vencode (VEN, KanyakumariDt) and Campbell Bay (CBY, Great Nicobar), separated longitudinally by 15° . One year of concurrent data (2011-2012) from the ground observations and corresponding penetration data from PPEFM are used in the present study. The equatorial electric field (EEF) derivedfrom one year of concurrent EEJ strength (2011-2012) for daytime hours (07-18 LT) at VEN and CBYand the corresponding penetration field is downloaded for VEN and CBY from PPEFM. A total of 93 CEJ events with amplitudes greater than -5nTwere identified, of which 21 events are observed at both sites and of the others: 57 are observed at VEN and 15 at CBY, highlighting the longitudinal variability of CEJ. Penetration fields were obtained from PPEFM for all these events. Cross correlation between the values of EEF and penetration field over the few hours' duration of CEJ, for each event were computed and summarised here. The results of our analysis show that (i) good correlation (r) > 0.6 is observed for 8 events at VEN and 9 events at CBY between the observed and modelled penetration data and (ii) correlation is weak (r < 0.6) for 77 events. From this analysis we demonstrate the effects of penetrationon selected CEJ events and for the other events we infer that the occurrence of CEJ events is independent of penetration field. This analysis is a demonstration of the efficacy of using PPEFM to identify the influence of prompt penetration on CEJ events. This helps in differentiating the magnetospheric and interplanetary influences on the EEJ from the stronger, more pervasive effects of ionospheric and atmospheric influences.

SENSITIVITY EXPERIMENT FOR SIMULATION OF ONSET PHASE USING DIFFERENT CONVECTIVE SCHEME OF REGCM4.3

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The most awaited weather over the Indian subcontinentis the onset of Indian summer monsoon (ISM). A considerable change in the large-scale atmospheric and oceanic circulation in the Indo-Pacific region influences the onset of the Indian summer monsoon. The climate processes like cloud radiation forcing, physical process and cumulus convection processare widely used by researchers to develop onset models. Several studies have also been carried out to understand Intraseasonal variability associated with the ISM using Regional Climate Model (RegCM) and simulation.

It is found that the technique behind RegCMis good for the simulation of large-scale atmospheric circulation with a suitable high-resolution resolving complex topography, which deals with Land Sea contrast.In the current study, Upper version of RegCM, developed by ICTP, is considered. An attempt has been made to investigate the performance of six parameterization convective scheme (Kuo, Grell, Tiedteke, Emanuel and two mixed scheme (Emanuel over land Grell over ocean;Grell over land and Emanuel over Ocean) to simulate the onset phase of ISM over Kerala. Each scheme has run at 50 Km horizontal resolutions for the period of 2001-2010.For onset simulation, onset date has been recognized by the simulated precipitation over the 14 stations over Kerala. For identification of onset phase over Kerala, a criterion provided by IMD is used.Parameter like rainfall, depth of lower tropospheric westerly (0-10 ^{0}N, 55-80 ^{0}E), strength of zonal wind (5-10 ^{0}N, 70-80 ^{0}E) and Outgoing long wave radiation (OLR) over the region of 5-10 ^{0}N and 70-75 ^{0}E are also considered.

EMPIRICAL MODE DECOMPOSITION ANALYSIS OF SEISMO-IONOSPHERIC COUPLING PHENOMENA FOR FINDING THE SHORT TERM EARTHQUAKES PRECURSOR

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Researche have reported anomalous variation of foF2 signal in the vicinity of an earthquake's epicenter, few days before the incoming earthquake. We have analyzed foF2 signal observed by ionosonde located at Kokubunji, during 2010-2015, using Cross Correlation analysis method in conjunction with the Empirical Mode Decomposition. The EMD method is used to remove the geophysical noise from the foF2 signals. In cross correlation analysis method stations located inside the earthquake preparation area, as evaluated using Dobrovolsky equation captures the ionospheric disturbances generated by the seismic event. On the other hand the stations outside of this area are expected to remain unaffected. The results of our study are in agreement with the previous work, evidencing anomalous variation in foF2 signal prior to earthquake in a certain area around the epicenter. Our experimental results also show that precursors may appear as early as 22 days prior to the event. These precursors occurred on different days at an interval of 2-10 days prior to the earthquakes. The main cause of the possible earthquake precursors is E×B drift with the electric field generated over earthquake preparation area and its penetration in to the ionosphere.

SEASONAL AND SPATIAL VARIATION OF VERTICAL STRUCTURE OF AEROSOLS AND MINERAL DUST TRANSPORT OVER THE BAY OF BENGAL USING MULTI-SATELLITE OBSERVATIONS

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Aerosol system over the Bay of Bengal is highly heterogeneous due to its proximity to heavily populated land masses with distinct aerosols sources and seasonally varying synoptic circulations associated with the Indian summer monsoon. Continental aerosols transported through elevated heights over to Bay of Bengal lead to significant impacts on the vertical thermal structure and affect the thermal structure and stability of the atmosphere over this region. The present study examines the spatial and seasonal heterogeneity of altitude distribution of aerosols over the Bay of Bengal and estimates the vertical profiles of dust extinction over this region using observations from Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP). Being capable of scattering shortwave and absorbing longwave radiation, mineral dust aerosols can affect the energetics of the atmosphere over any region.

Owing to its influence on the Indian Monsoon and regional climate the study aims to comprehensively present the spatial and seasonal variation of mineral dust transport over the Bay ofBengal. Vertical profiles of dust extinction coefficients were estimated using a dust separation scheme that used the depolarization ratio measurements (from CALIOP), a priori knowledge on lidar ratio of dust and, that on typical values of dust and nondust depolarization ratios. Seasonal variation of dust fraction over the Bay of Bengal is estimated separately using dust extinction coefficient profiles from CALIOP observations, using MODIS AOD and fine mode fraction measurements, and also from GOCART simulations.

ALTITUDE STRUCTURE OF TROPICAL TROPOSPHERIC TURBULENCE AND STABILITY PARAMETERS FROM RADIOSONDE OBSERVATIONS

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Altitude structure of turbulence in the troposphere and lower stratosphere at Trivandrum (8.5°N,76.9°E) and Gadanki (13.5°N, 79.2°E) are studied using GPS-radiosonde observations (~1000 profiles) during the period December 2010 to March 2014 as part of the Tropical Tropopause Dynamics (TTD) Experiment under CAWSES-India program. In the this study, the turbulence in the troposphere and stratosphere were delineated by applying the raw data of temperature, pressure and humidity obtained from radiosondes to Thorpe analysis by taking into account the effect of saturation in the temperature profiles and also the instrument noise. In general, the tropospheric turbulence is largely intermittent in space and time. The study shows the altitude region of 10–15 km (region below COT altitude) is highly turbulent with its occurrence comparable to that in the ABL. But the in-between altitude region (3–8 km) is relatively less turbulent. In the TTL region, occurrence of turbulence is

very weak. In the troposphere, the turbulent overturns show large variability with Thorpe scale (LT) varying from 20 to ~1200m, with majority of them (~90%) ranging between 20 and 800m. Thorpe scales are smaller than 200m in ~55% of the cases at Trivandrum and ~45% of the cases at Gadanki. Turbulence in the troposphere at both sites shows significant difference in its strength and in the seasonal dependence. In the 5–15 km altitude region, the mean turbulence strength at Gadanki is higher than at Trivandrum during all seasons. Stability parameters such as gradient Richardson number (Ri), square of Brunt- Väisälä frequency (N^2) and square of the wind shear ($|\partial U/\partial z|^2$) were used to delineate the possible generation mechanism of turbulence in the troposphere. Below 15 km, while the turbulence is mainly governed by the convective instabilities at Gadanki, both convective and dynamic instabilities contribute for the generation of turbulence at Trivandrum. Above 15 km including the TTL region, dynamic in- stability dominates the convective instability in the generation of turbulence.

TROPICAL INDO – PACIFIC SST VARIABILITY AND ITS HIGH LATITUDE RESPONSE – SIMILARITIES AND DIFFERENCES.

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Various modes of tropical Sea Surface Temperature (SST) variability have distinct imprints in the southern high latitudes. Most of the variability influences the high latitudes by means of the Rossby wave trains generated by the SST variability in the tropics. These changes in the atmospheric circulation pattern have distinct influence on sea – ice, precipitation, air temperature, etc. The most remarkable factor is the influence of ENSO. During ENSO the standing wave pattern in the atmosphere, called the Pacific South American (PSA) wave train generates a high pressure anomaly west of the Antarctic peninsula. These high pressure anomalies drive southward heat flux anomalies and warm/cool the regions west of the Antarctic peninsula. Another tropical pacific SST mode, called the ENSO modoki, also has a similar influence but the location of the high pressure anomaly centre is slightly to the west of what was generated during and ENSO event. The Indian Ocean SST variability is primarily driven by the Indian Ocean Dipole mode (IOD). During an IOD the low pressure system near the Ross sea intensifies, driving warm air to the west of the Antarctic peninsula by southward(warm) atmospheric transport, but the northward (cold) heat transport was located west of the Ross sea, rather than near the peninsula as in the case of the Pacific events, viz, ENSO and ENSO modoki. The behaviour of IODs influence on southern high latitude is different in the case when ENSO and IOD co – occurs together. In that the Rossby wave train follows a more northward path before it converges in to the Ross sea region. In the absence of ENSO, the IOD influences the Indian Ocean sector of the Antarctica as well. However the influence of IOD is mostly limited to the western hemisphere. But in the most recent decade influence of IOD can be seen in the eastern hemisphere also. We examine this aspect also in the present study.

SOLAR AND OCEAN DYNAMICAL FORCING ON INDIAN TEMPERATURE

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Indian temperature variability and climate response to internal and external forcing has been studied and discussed by several researchers. The researchers have diverse views on the role of external

solar and internal forcing. We analyse here various time series: Indian maximum and minimum temperature data, TSI (Total Solar Irradiance), ENSO (El-Niño Southern Oscillation), PDO (Pacific Decadal Oscillation), NAO (North Atlantic Decadal Oscillation) for the period 1901- 2007 using the advanced spectral (Singular Spectrum Analysis, MTM etc) and statistical correlation techniques to quantify the role of external solar and internal ocean atmospheric circulation on Indian temperature variability. We compute the correlation and weighted correlation functions between Eigen modes of Indian temperature with the Eigen modes of TSI, ENSO, PDO, and NAO to precisely understand the source of the independently interpretable Eigen / principal modes in the Indian temperature. Our results suggest that the correlation between first Eigen Mode representing maximum variance of Indian maximum temperature (94.7%) and minimum (92%) temperatures with TSI data is considerably high compared to the correlation with ENSO, PDO, and NAO. Similarly, high correlation values are also observed between the respective individual Eigen modes of temperature and TSI. Maximum weighted correlation observed between the first PC's of T_{max} and T_{min} with first PC of TSI (with correlation coefficient > 0.99) attesting the significant role of solar forcing on Indian temperature variability. Power spectra of ENSO reveal the periodicities of ~11yrs and 22yrs corresponding to Schwabe cycle and Hale cycle respectively suggesting that the ENSO phenomena is also directly/indirectly influenced by the external solar forcing.

AN INTEGRATED STUDY OF ANOMALOUS SPIKY VARIATIONS IN VLF ELECTROMAGNETIC SIGNALSASSOCIATED WITHWESTERN MEDITERRANEAN SEA EARTHQUAKE

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In the present work electromagnetic signals have been critically examined to delineate their correlation with earthquakesbecause these electromagnetic signals can be contaminated by various types of noises during the seismic activities.The anomalous variations in electromagnetic waves that range from Extremely Low Frequency (ELF) to Very Low Frequency (VLF) are very promising tools for finding the earthquake precursors. The signal amplitude and number of spikes like structure in VLF signal are known to increase just before the major and largeearthquakes with high probability indicating a close relationship to the earthquake preparation process. We report the anomalous changes in VLF electromagnetic signals observed during the Western Mediterranean SeaEarthquake occurred on July 7, 2011 with the magnitude of M=5.3.We analyzed the VLF signals transmitted fromIsola di Tavolaratransmitter (ICV) located inItaly and received at Sudden Ionospheric Disturbances Receiver Station located in France. It is found that the amplitude and number of spikes of VLF signals have increased anomalously few days before the preceding earthquake. They continued for several days even after onset of the earthquake, then decreased gradually and finally ceased.Our study suggests thatspiky variations in VLF signals are not a direct consequence of seismic activity. They seem to be produced by an electromagnetic instability process in the Earth`s atmosphere up to the ionosphere, triggered by charged aerosols or electromagnetic waves induced in the preparatory stage of shallow (Depth≤55 km) earthquakes.

MICROWAVE RADIOMETER OBSERVATIONS OF VERTICAL STRUCTURE OF WATER VAPOR AND CHARACTERIZATION OF CONVECTIONS OVER A TROPICAL STATION

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The study of water vapor variability over a tropical station is important to understand the influence of water vapor on small scale weather phenomenon like convection to complex and organized phenomenon like monsoon. This paper presents results of multi-year (2010-2014), multi-frequency microwave (Ka & V bands) radiometer profiler (MRP) measurements from the tropical coastal station, Thiruvananthapuram (TVM).The measurements have been used for the characterization of intra-seasonal and inter-annual variability of atmospheric water vapor and water vapour vertical distribution and its link with the strength of monsoon over the station. The potential, accuracy and consistency of MRP of water vapor over equatorial coastal condition including the monsoon period have been established by comparing the concurrent and collocated measurements of PWV by MRP and GPS using a station-based regression model between PWV and GPS wet delay component for TVM. Significant diurnal and intra-seasonal variations of PWV are observed during winter and pre-monsoon seasons. There is large inter- annual PWV variability during pre-monsoon, owing to frequent local convection and summer thunderstorms. Whereas, during monsoon we have observed presence of low inter-annual variability, due to water vapor advection by southwest oceanic monsoon winds. However, significant inter annual variability is noticed for the humidity in the 2 to 6 km height altitude layer ,which is also linked to the monsoon strength over the station. Prior to the onset of monsoon over the station, the specific humidity increased up to 5-10 g/kg in the altitude layer above 5 km and remained consistently so throughout the active spells. Apart from the studies of organized systems like monsoon, radiometric observations have also been used to characterize the occurrence of local convective events, their genesis and strength. Radiometric observations are also useful to derive a methodology in depicting temperature variations in terms of brightness. This study assumes significant importance for study of monsoon and tropical convection.

STUDY OF CONVECTIVE ACTIVITY OVER A CENTRAL INDIAN REGION FROM 2009 TO 2013 BY USING RADIOSONDE DATA

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The study of both radiosonde data and INSAT 3A satellite images is useful for better understanding of atmospheric thermodynamics. In this study, using radiosonde data of pre -monsoon seasons (April, May and June) for five years (2009 – 2013) , thermodynamic structure of convective atmosphere during pre-monsoon over a central Indian region - Bhopal (23.28^{o}N and 77.35^{o}E) and Gwalior (28.23^{o}Nand 78.25^{o}E) has been obtained. The stability indices studied for the regions are showalter index (SI), Lifted Index (LI), Total totals index (TTI) and Thermodynamic parameter such as convective available potential energy (CAPE). INSAT-3A satellite images over a central Indian region are also used for study. There is convective activity over a central Indian region. In this study we have made a comparison of radiosonde data and INSAT-3A satellite thunderstorm convective activity on 29th April 2010 of Bhopal and Gwalior stations. Showalter index values range between - 4 and – 5,

over this unstable region. LI has very low negative values in the range - 5 and - 6 over this unstable region. The value of K index ranges between 26 and 39, over a small convective potential. The TTI values rangebetween44 and 50. CAPE values range between 264 and 141 J/Kg .After evaluating various results we have come to the conclusion that over this marginally unstable region,thunderstorm can be generated at temperature 850 hPa.

MULTI-YEAR MODEL SIMULATIONS OF MINERAL DUST DISTRIBUTION AND TRANSPORT OVER THE INDIAN SUBCONTINENT DURING SUMMER MONSOON SEASONS

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Aerosol distribution over the Arabian Sea and the Indian subcontinent during the northern hemispheric summer is dominated by mineral dust transport from the West Asian desert regions. This study examines the transport of mineral dust over the West Asian desert, the Indian subcontinent and the surrounding oceanic regions during summer monsoon season with help of a regional scale model, WRF-Chem. Geographical locations of prominent dust sources, altitude ranges of mineral dust transport and their inter-annual variations are examined in detail. Multi-year model simulations were carried out during 2007 to 2012 with a model integration from 15th May to 31st August of each year. Six-year seasonal mean (June to August) vertically integrated dust amount from 1000 hPa to 300 hPa level. This shows prominent dust loading over the eastern parts of Arabian desert and northwestern part of India, which are identified as two major sources of dust production. The model simulations clearly show that most of the dust distributed over the Indo-Gangetic plains originate from the Rajasthan desert, whereas dust observed over the Central and Southern Peninsular India and over the Arabian Sea are mainly transported from the Arabian Desert.

DYNAMICAL PROCESS OF ACTIVE AND BREAK PHASES WITH THE SIMULATION OF REGIONAL CLIMATE MODEL VERSION 4.3 (REGCM4.3)

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Asian summer monsoon is a significant process of global climate. On the sub-seasonal timescale, the Indian summer monsoon (ISM) undergoes through the periods of enhanced and reduced rainfall activity over the core region India. These intra-seasonal variations are termed as active and break phases of the monsoon. In the active phase, the monsoon trough usually lies south of its normal position. The low-level jet (LLJ) becomes strong and passes through peninsular India. In lower atmosphere levels, the cyclonic vorticity is increased along with the enhancement of rainfall over the core region of India; the prominent features associated with the active phase. Monsoon depressions are quite frequent in this phase. During the activity of break phase, the LLJ becomes weak and the monsoon trough is shifted close to the Himalayan foothills. In the lower levels of the atmosphere, the anticyclonicvorticity develops over the core region of India. In this phase, the rainfall activity is reduced much below the normal rainfall. Monsoon disturbances generally form during the peak monsoon months of July and August. They generally form at the eastern end of the trough over the

head Bay of Bengal and move west-northwestward across it. Sea surface dynamics plays an important role in the genesis and intensification of this type of variability. The feedback process between the sea surface and the atmospheric disturbances is important. In view of these facts, present study makes an attempt to simulate the dynamics of Active and Break phases with the simulation of Regional Climate Model version 4.3 (RegCM4.3) developed by International Center for Theoretical Physics (ICTP). Four convective schemes viz. Kuo, Mix98 (Emanuel over land and Grell over the ocean), Mix99 (Grell over land and Emanuel over the ocean), Tiedtke, Emanuel and Grell are evaluated at 50 km horizontal resolution over South-Asia CORDEX (Coordinated Regional Climate Downscaling Experiment) domain. An endeavor is made to evaluate the performance of different parameterization schemes on the simulation of active and break dynamics for this current study.

IONOSPHERIC ABSORPTION OF DIFFERENT SOLAR SPECTRA

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In this paper we explain the response of the ionosphere to high energy perturbations, mainly solar flares of different types and strengths. This study is very useful in modeling the ionosphere, especially to understand the ionospheric chemistry. The X-ray and UV components of the solar flares penetrate down to the lower ionosphere causing enhancements of the electron and the ion densities. The ionization due to ultraviolet rays is calculated numerically following the D-region ion-chemistry model, Sodankyla Ion Chemistry (SIC) model. To obtain the UV altitude profile during a flare we have used UV light curves from the Solar EUV Monitor (SEM) onboard the Solar and Heliospheric Observatory (SOHO). The x-ray part of the flare spectra was taken from RHESSI satellite observation. We have used Monte-Carlo simulation, with well known detector simulation software GEANT4, to calculate the energy deposition at different altitudes due to different solar spectra. GEANT4 includes all physical processes and interaction phenomena required to produce an electron-ion pair in the atmosphere by energetic photon interactions. The simulation gives an altitude distribution of electron production rate for the photons obtained from the RHESSI spetrum. For a given spectrum (say, C, M or X) we just normalize this altitude profile to get the actual altitude distribution for that spectrum. For long duration flares solar zenithal angle changes significantly; the variation in solar flux due to this has been taken into account in the simulation.

Comparing the different spectra and altitude profile of electron density we have seen that, UV rays produced maximum number of electrons per cm^{-3}/sec (> 6000) at the height of maximum energy deposition followed by the X-ray flares [X(1350), M(55) and then C(35)]. The ion-chemistry model for UV rays verifies that the production by UV is limited in the E-region, and below 90 km the ionization effect is small. The simulation confirms that the ionization effect due to solar X-ray is dominant in the D-region (~ 60 – 100 km) only.

A SEARCH FORIONOSPHERIC PERTURBATIONS IN VLF ELECTROMAGNETIC SIGNALS ASSOCIATED WITH LARGE EARTHQUAKE IN GREECE REGION

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The phenomenon of ionospheric perturbations in electromagnetic signals associated with large($M \geq 6$) earthquakes is considered to be one of the most promising tools for earthquake studies. The

observations of pre-seismic electromagnetic signals during the large earthquake in Greece region have been investigated as earthquake precursors. Since the electromagnetic signals can be contaminated by various types of noises during the seismic activities,we have analyzed the Very Low Frequency (VLF) electromagnetic signals recorded at Sudden Ionospheric Disturbances Monitoring receiver during the large (M≥6) earthquake in Greece region. The signal amplitude and number of spikes like structure in VLF signal are known to increase just before the major and large earthquakes with high probability indicating a close relationship to the earthquake preparation process. These signals have been critically examined to delineate their correlation with earthquake occurence. It is found that the amplitude and number of spikes of VLF signals have increased anomalously few days before the preceding earthquake. Our study suggests that spiky variations in VLF signals are not a direct consequence of seismic activity. They seem to have been produced by an electromagnetic instability process in the Earth`s atmosphere up to the ionosphere, triggered by charged aerosols or electromagnetic waves induced in the preparatory stage of shallow (Depth≤55 km) earthquakes.

FROST-POINT HYGROMETER OBSERVATIONS OF WATER VAPOUR IN THE TROPICAL UPPER TROPOSPHERE AND LOWER STRATOSPHERE OVER INDIA

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Water vapour is one of the most important greenhouse gases in the atmosphere and plays a key role in the atmospheric part of the climate system. The water vapour distribution in the upper troposphere and lower stratosphere (UTLS) region is of central importance in several ways: (i) plays a pivotal role in ice cloud formation and dehydrates the upper troposphere, (ii) regulates the atmospheric motion by absorbing radiation, and (iii) plays a key role in the UTLS chemistry. Water vapour in the UTLS region originates mostly from deep convection that penetrates, the so called Tropical Tropopause Layer (TTL), but dehydrated as it passes through cold region, forming ice clouds by freeze-drying and cold trap mechanisms. Deepest atmospheric convection over the entire globe occurs over the Bay of Bengal during the Asian summer monsoon season. This can pump significant amount of water vapour into the lower stratosphere. However, the amount of moist air entering the stratosphere and how it is freeze-dried, are not well understood. In spite of its importance, not many *in situ* measurements of water vapor in the UTLS region have been made. This is mostly because of the difficulty in making accurate measurements of extremely low water concentration by using conventional detectors. Frost Point Hygrometer (FPH) accurately measures water vapour in the altitude region from surface to 25 km. First direct measurements of the trace amount of water vapour in the UTLS over the Indian region was carried out using balloon-borne Frost Point Hygrometer (FPH) launched from Thumba at 17:00 IST on 17 April 2014. Regular observations of water vapour in the UTLS region are being carried out using FPH from Trivandrum and Hyderabad since May 2014 as part of Tropical Tropopause Dynamics (TTD) Experiment under GARNETS (GPS Aided Radiosonde Network Experiment for Troposphere-stratosphere Studies) program. In general, water vapour mixing ratio (WVMR) decreases with increase in altitude in the troposphere and varies by four orders of magnitude from ~20,000 parts per million by volume (ppmv) near the surface to less than 10 ppmv above 15 km. The minimum value of ~1 to 3 ppmv is observed near the cold point temperature (CPT), which acts as a trap for freeze drying and dehydration of the air that enters into the stratosphere through stratosphere-troposphere exchange (STE) process. In the lower stratosphere, the WVMR slowly increases with altitude to attain a value of ~4-5 ppmv around 25 km altitude during winter season ,which is almost double of that at CPT. The increase above CPT is caused by the long residence time of water vapour in the lower stratosphere and plays a significant role in the chemistry and thermodynamics of this region. The water vapour distribution in the UTLS region over Indian region during different seasons will be discussed.

CHARACTERIZATION OF MICROPHYSICAL AND RADIATIVE PROPERTIES OF AEROSOLS OVER ARCTIC (NYALESUND)

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Investigations of atmospheric aerosols over Arctic have special significance on the backdrop of the recent increase in anthropogenic emissions and their contributions on observed climate change over the Polar Regions. Even though, Arctic is located far away from the source regions, significant aerosol loading (called Arctic Haze) is observed during the spring time in association with long range transport of aerosols from mid and high latitudes of northern hemisphere. In collaboration with National Centre for Antarctic and Ocean Research (NCAOR, Goa), extensive measurements of aerosol properties are being carried out from the international research station, NyAlesund (79°N, 12°E), Norway under the ISRO Geosphere Biosphere Programme (I-GBP) to understand the background aerosol characteristics, anthropogenic aerosol pathways and aerosol induced snow albedo changes over Arctic. In addition to the long term measurements of black carbon(BC) measurements, thematic campaigns were also carried out to understand the seasonal changes in microphysical properties of aerosols. The first phase of campaign was carried out during October to November 2014 and March-April, 2015.

Long term data along with the specific campaign observations are used to characterize the microphysical and radiative properties of aerosols over the Arctic region. Simultaneous measurements of scattering coefficients, absorption coefficients, size segregated aerosol mass concentration, black carbon mass concentrations were carried out during the campaign period. In general, atmospheric BC mass concentration values are very low during June to November and then increase to high values during winter and spring. During October-November 2014, BC mass concentration was 13 ± 14 ng m^{-3}. This contributed almost 1.9 % of the total aerosols mass concentration (PM10). The estimated mass scattering efficiencies were 4.3 ± 1.7 m^2g^{-1},which further confirm the dominance of fine mode scattering aerosols over the region. The single scattering albedos estimated from the simultaneous scattering and absorption measurements showed very high values (0.965±0.05) during the campaign period. The black carbon deposition on to the snow surface is estimated and its implications on the radiation budget will be discussed in the poster presentation.

TEXTURAL FEATURES STUDY FOR GEOPHYSICAL EXPLORATION OVER THE KRISHNA-GODAVARI OFFSHORE USING SATELLITE GEOID/GRAVITY DATA

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Texture is an important spatial feature, useful for identifying objects of regions of interest in an image. The concept of texture is closely associated to tone, as texture represents the spatial pattern of tone in an image. There are a number of methods for identification of textural parameters e.g. edgeness, frequency domain analysis, gray tone co-occurrence approach etc. Textural analysis of satellite geoid/ gravity field using different methods including gray-level co-occurrence matrices (GLCM) can be used for enhancement of subtle features .

Krishna-Godavari (KG) Basin is a peri-cratonic passive margin basin in India.This proven petroliferous basin has potential reservoirs ranging in age from the Permian to the Pliocene. Majority

of the oil and gas deposits are found in the areas of Kaza Horst, Tanuku Horst, Narsapur, Razole, Amlapuram and Ravva field falling within this linear basin .Our study area comprises the KG Offshore (latitude 13°N–17° N, longitude 79°E–84°E, approx).

The radar altimeter is a nadir-viewing instrument, which transmits short-duration microwave pulses with known power in a pencil beam towards the earth's surface and then measures the reflected energy. The time delay (i.e. the two way travel time of the pulse) when coupled with a knowledge of the velocity of propagation through the atmosphere can be converted into a highly accurate measurement of the altitude of the satellite and, therefore, a measurement of the sea surface height (SSH).High resolution satellite geoid/gravity maps and their spectral components have been generated over the Krishna-Godavari offshore.

Texture statistical features computed from the co-occurrence matrix can be used to represent, compare, and classify textures. Accordingly, few statistical textural features were generated using gravity image over the Krishna-Godavari Offshore like, Contrast, Entropy, Energy and Second Moment after generating the statistical vectors.

KG offshore residual geoid map exhibits a big geoidal low ranging between -4 m and -5.5 m in the middle of the basin. The Entropy map over the area of interestshows a no. of features matching with the existing anomalies along with the existing faults. The Bouguer gravity anomaly over the KG offshore along with various faults patterns as well as the locations of oil seepages have also been generated. Most of the seepages are lying in the Bouguer anomaly low. Thus, textural features extraction is very useful for geophysical exploration over the Krishna-Godavari Offshore.

Solid Earth Geosciences - Oral

CAN MAGNETIC DATA IMAGE SUB-BASALT STRUCTURES? A CASE STUDY FROM CHIKOTRA RIVER BASIN IN THE DECCAN VOLCANIC PROVINCE OF MAHARASHTRA

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A large portion of the West-Central India is covered by the Deccan trap flows due to which little is known about the sub-trappean geology as looking below basalt has always been a challenging problem. On the south and south-east peripheral region of the Deccan trap lays the Proterozoic Kaladgi&Bhima basins which host mineralized zones. However, the northward extension of these basins below the traps has not been mapped. Hence, it is of paramount importance to probe below the traps using geophysical methods. In the present study, ground magnetic data collected over Chikotrariver basin (located approximately 100km from the exposed Kaladgi basin) in the peripheral region of Deccan Volcanic Province (DVP) in Kolhapur district of Maharashtra was analyzed to throw light on the structural pattern and distribution of magnetic sources within the basin. In order to isolate the magnetic anomalies showing varying trend and amplitude, several transformation operations including wavelength filtering, and upward continuation have been carried out. Qualitative interpretation of these products helpsto identify the distribution of magnetic sources in the subsurface. Present study suggests that the Chikotra basin is composed of three structural units; a NE-SW unit superposed on deeper NW-SE unit with randomly distributed trap flows on the surface. One of the major outcomes of the present study is the delineation of almost 900m thick ProtrozoicKaladgi sediments below the Deccan trap flows in the Chikotra River Basin. The deeper NW-SE trends are interpreted as the northward extension of the Dharwars underneath the Deccan lava flows that form the basement for the deposition of Kaladgi sediments.

CHARACTERIZATION OF CARBONACEOUS COMPONENTS IN URBAN DUST AND SOIL OF DELHI MEGACITY

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Increasing global concern about carbonaceous components (Organic Carbon, Elemental Carbon and Carbonate Carbon) in the atmosphere has evidently confirmed that carbon content is very important constituent of the atmosphere which affects various atmospheric processes such as biogeochemical cycle, hydrological cycle, local climate and air quality. Abundance of mineral dust in south Asian region also highly affects these processes. Soil derived dust is a potent source of OC and CC but not EC because it is mostly emitted by the burning at high temperature. Interaction of soil dust with urban anthropogenic emissions remarkably modifies its composition. The present study reports the concentration of carbonaceous components (mg/g) in urban dust and soil of 3 sites in Delhi, NCR. Results showed that urban dust wasvery highly enriched withOC, EC and CC (3 to 9 times) which suggested that the local emissions have considerable impact on the dustfall. Source identification of carbonaceous components along with water soluble inorganic ions (Na^+, NH_4^+, K^+, Ca^{++}, Mg^{++}, F^-, Cl^-, NO_3^- and SO_4^{--}) have shown the diesel vehicles, biomass burning and internally mixed soot-sulphate particles as the major sources of OC and EC while soil dust as the major source of CC suggesting the alkaline nature of Indian soil. The results of this study will be helpful in making more accurate budget of atmospheric carbon, especially in South Asia.

A REAPPRAISAL OF THE CRUSTAL ARCHITECTURE AND EVOLUTION OF COMORIN RIDGE AND ADJOINING REGIONS USING GEOPOTENTIAL DATA

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Comorin Ridge, a NNW-SSE trending bathymetric feature located south of Cape of Comorin, is one of the least studied aseismic ridge in the Indian Ocean despite its close vicinity to Continental Margin, Indian Ocean Geoidal low and Magnetic Cretaceous quite zone. Delineation of Ocean-Continent boundary as well as mapping variation in crustal thickness over a passive continental margin is of paramount importance to understanding the continental rifting processes and break up and also the evolution of hydrocarbon systems within the margins. Demarcation of Ocean-Continent Boundary (OCB) over the Comorin Ridge and adjoining regions achieved from geopotential data employing various edge enhancement techniques, along with newly identified fracture zones suggests that the northern block of the Comorin Ridge is either continental or transitional in nature while the south is Oceanic. Gravity inversion technique incorporating lithosphere thermal gravity correction was undertaken to map the crustal thickness variation over the study region. The results shows a progressive decrease in thickness from 20km in the north to 12km in the south for a length of 500km over the Comorin ridge whereas eastern flank of the ridge is marked by sudden decrease in crustal thickness. 3D admittance analysis using gravity and bathymetry was carried out to understand spatial variation of effective elastic thickness over the Comorin ridge. From admittance analysis we found that the elastic thickness of the northern block is approximately 10km while that of the central and southern block is around 6km. This suggests that the ridge is emplaced in a relatively weaker crust in the central and south while it was comparatively rigid in the north. Results of these will be presented and discussed.

ROLE OF CRUSTAL AEROSOLS IN THE SUMMER TIME FLUXES OFREACTIVE NITROGEN SPECIESIN DELHI

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Abundance of mineral dust rich in carbonate and bicarbonate of Ca^{2+} and Mg^{2+}over the Indian atmosphere has been well established for its role in the efficient scavenging of atmospheric SO_2. However, with the global declining levels of sulphate aerosol formation and the rising emissions of nitrate precursor gases,there is need for a comprehensive study linking the role of mineral dust in the transport and removal of reactive nitrogen species (Nr) from the atmosphere. For the purpose of substantiating the available estimates of Nr deposition fluxes and deciphering the interaction mechanism of Nr with the ionic composition of the mineral dustfall fluxes, the present study has, therefore, been carried out at six monitoring stations of the Delhi – NCR region characterized by the changing dynamics of its different land use pattern. The results showed the variability in the dustfall fluxes of oxidized Nr (NO_3^-) and reduced Nr (NH_4^+) species. Neutralization ratios, ion balance regression plots and enrichment factors revealed the significance of relative abundance of Ca^{2+} and SO_4^{2-} in Nr scavenging. Dominance of Ca^{2+} in the stoichiometric neutralization reactions resulted in a low median equivalence ratio of NO_3^-/ SO_4^{2-} (< 1) in the dustfall fluxes at all the sites owing to its affinityfor SO_4^{2-} as compared to NO_3^-. NH_4^+ being a weak base cation, on the other hand, showed an overall weak scavenging which could be attributed to the predominance of Ca^{2+} as a major base cation in the dustfall. Though the summer time meteorology of strong winds and unstable atmospheric conditions provided constant Nr fluxes, sharp peaks of high $NO_3^-$and low NH_4^+ were observed corresponding to the timings of the dust storm events.

RECONNAISSANCE GROUND MAGNETIC SURVEY OVER BAYYARAM IRON ORE REGION, TELENGANA STATE, INDIA.

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Geophysical methods play an important role in the discovery of mineral deposits, especially in the case of ferrous minerals, which are occurring in metasedimentary geological situations. Gravity and magnetic methods are most suitable with occasional support from Electrical resistivity technique. This so as the deposits are usually large, shallowstructurally conspicuous and bear characteristic contact of physical property with the surrounding. The iron ore deposits of Bayyaram, Khammam district Telangana state are gaining interest in the recent times, particularly after the formation of Telangana state. These deposits are occurring along the NS boundary zone of the peninsular gneissic complex in the west and the Proterozoic metasedimentary Pakhal on the east.

Reconnaissance ground magnetic survey was conducted by the authors by laying five traverses in near E-W direction by covering the available tracks and roads with a total field magneto meter with observations at every 50m spacing along the traverse. The length of each traverse is about 5km. These reconnaissancetraverses are spaced approximately at 1 to 1.5 km.

After appropriate corrections for the diurnal and normal variations, magnetic anomaly map is prepared and analysed through processes like upward continuation, construction of vertical derivative and analytical signal. In the light of available geological information, the magnetic maps helped, distinguishing different lithological boundaries and possible zones of valuable iron ore concentrations. By supplementing physical property data measured on the samples from the field, a few selected magnetic profiles were analysed for estimating the shape and size of the iron ore occurrences.

HOW CLOSE IS CALCULATED THERMAL CONDUCTIVITY TO THAT OF MEASURED THERMAL CONDUCTIVITY?:A CASE STUDY FROM THE GRANITOIDS OF THE BUNDELKHNADCRATON

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Granite is an important part of the upper crust and its thermal conductivity plays an important role in understanding the lithospheric thermal structure in a region. In the Bundelkhandcraton (BC),central India,over 70% of the cratonic part is covered by Neoarchean-Paleoproterozoic granites, also known as Bundelkhand granite whichis sub-divided into three categories based on the mineralogical, geochemical and textural composition. These are pink granitoid (K-feldspar enriched granitoid), grey granitoid (Mafic minerals and Na-Feldspar enriched granitoid) and biotitegranitoid.Another important rock formation of the craton is Meso-Neoarchean TTG gneiss. An attempt is made here to study the difference between the measured and calculated thermal conductivity of these granitoidsand gneisses.

The bulk thermal conductivity is measured in the laboratory on 18 rock samples, at dry and saturated conditions, using the steady-state divided-bar method that covers pink, biotite, grey granitoids and TTG gneisses from BundelkhandCraton.Results show that mean thermal conductivity varies between 2.5 to 2.8 W $m^{-1} K^{-1}$. Density and porosity are also calculated by measuring weight of the rock samples in dry and saturated conditions to characterize these rocks. Mean density varies between 2.6 and 2.7 g $cm^{-3}$and porosity is very low (<1%) for all samples.

Mineralogical compositions for these set of samples wereacquired by petrographic analysis on thin sections and geochemical analysis using high resolution ICPMS and XRF datasets. Thermal conductivity of these samples are calculatedusing various mathematical mixing models, namely, arithmetic mean, geometric mean, harmonic mean, effective mean andHashin-Shtrikman mean,on the basis of theirmineralogical composition and thermal conductivity of individual minerals.Results show that among all models, the harmonic mean provides lowest deviation from the measured values. Thus, it is inferred thatthe bulk thermal conductivity of granitoid rock with very low porosity could be satisfactorily determined by assessing its modal mineralogyand harmonic mean is the closest to the measure value.

EVALUATION OF CRUDE OIL FOR PRODUCTION DIFFERENT REFINERY PRODUCTS

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This study is based on the characterization of Crude Oils obtained from the Upper Assam Basin based on the conversion of ASTM data that are obtained from ASTM distillation apparatus to TBP by Edminster's method. It was found that the behaviour of the crude oils ranged from class A to E. The characterization factor and Correlation Index showed that the crude oil behaviour is mixed based and inclined both towards Naphthenic and Aromatic side. This study is aimed to tentative determination of crude oil products (petroleum fractions) from the TBP data. The TBP analyses also indicate that the likely products from this crude oil are mainly Naphtha fractions and lesser amount of Kero and gasoil fractions and least amount of lube oil base stock fraction.

RADIOELEMENTAL (TH, U, K) ABUNDANCES AND RADIOGENIC HEAT PRODUCTION OF THE GNEISSES AND THE GRANITES IN THE NORTHERN PART OF THE SINGHBHUM CRATON, EASTERN INDIA: PRELIMINARY RESULTS

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The Singhbhum craton in the eastern India is one of the oldest craton in the Indian shield covering ~40,000 km^2. Core of the craton consists of ~3.45 Ga Older Metamorphic Group (OMG), Older Metamorphic Tonalitic Gneisses (OMTG) and 3.4–3.3 Ga Singhbhum Granites (SBG). The OMG and OMTG occur as enclaves within younger SBG. The time difference between the emplacements of the OMTG and the early phases of younger granitic intrusion was of the order of 100 to 200 Ma. On the basis of geochronological and geochemical variations, three phases of the granites have been identified namely SBG I, SBG II and SBG III; SBG III being the youngest.

Heat flow and heat production studies are extensively conducted in various provinces of Indian shield except the Singhbhum craton. Core of the Singhbhum craton is uncovered. Available radioelemental data on the Singhbhum craton is confined in the Thrust Belt along the northern fringe of the craton. In the present study, we have systematically measured radioelemental (^{232}Th, ^{235}U and ^{40}K) abundances on 104 rock samples that consist of OMTG, SBG I, SBG II and SBG III from northen part of the Singbhum craton using laboratoy low-level counting gamma-ray spectrometer to characterize their radiogenic heat production. Study shows that the radioelemental abundances vary in a narrow range for the above rock formations. Mean values of Th for OMTG, SBG I and SBG II are similar but lower than SBG III whereas mean values for U and K for all formations are similar. Consequently, radiogenic heat production of SBG III is higher than other formations. Study brings out very striking result that the gneisses and the granites of the Singbhum craton have very low radioelememtal abundances compared to the most of the granites in the different geological provinces of the Indian shield, such as the granites of the Bundelkhnad craton, the Bastar craton, the Aravalli province, the Eastern Dharwar craton, etc. Plausible causes for the lower radioelemental abundances need to study to arrive final conclusion.

FORWARD MODELING OF GRAVITY EFFECT DUE TO A FAULT

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Gravity method is one of the geophysical methods that explore the variation in the density of the sub-surface by measuring the gravitational field at the surface. The density is least varied physical property of the sub-surface as compare to the other physical properties of sub-surface. Gravity surveys are conducted in previously unexplored area. The applications of gravity method includes detection of subsurface voids, mapping of thickness of sedimentary basin, mapping of boundaries of landfills, estimation of excess mass, mapping of dipping contacts like faults.

The solution to forward problem is required to solve an inverse problem. The forward modeling of gravity effects due to simple shapes is useful for the interpretation of gravity profiles. The forward modeling of gravity shape due to a semi-infinite slab has been discussed in this study. The semi-infinite slab has been used compute the gravity effect due to a fault. The faults are important geological features for mineral as well as oil exploration. They act as a barrier to the fluid flow and may also migration of oil. The minerals accumulations are likely to found in faults. The detection of faults is also important from the hydrological point of view as fracturing along faults may produce hard-rock aquifers. The simple types of faults are categorized as normal fault, reverse fault and strike slip fault. The actual fault may be combination of these simple faults.

The gravity effect due to a fault is represented by a mass anomaly that is function of the thickness of slab and density. The gravity effect of semi-infinite slab changes according to position relative to slab's edge. The amplitude and gradient are the two important properties of gravity anomalies due to semi-infinite slab. The effect of various parameters like dip of the fault, depth and thickness of block on the amplitude as well as gradient of gravity anomaly has been illustrated. The effects of edges of the fault have also been discussed.

SUB-BASALT CHARACTERISTICS USING SEISMIC TOMOGRAPHY

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Oil industries show interest to delineate sediments below basalt cover, as 50% oil has been discovered in sub-basalt sediments worldwide. The normal reflection profiling has not been very successful to image such sediments due to contamination by noise caused by brecciation, vesicles and interbed-multiples. However, the effect of these noises get reduced at large-offset, and hence seismic refraction/wide-angle reflection experiment show promising results in such a geological set up, of course with low resolution. Here we construct four scenarios with younger basalts (4.8 km/s), older basalts (5.2 km/s), sediments (4.0 km/s) and basement (5.8 km/s). In the first model, sediments are sandwiched between younger basalts and basement. The second model consists of younger basalts, older basalts and basement. In the third model, the sediments replace the middle part of older basalts of the second model, whereas in the fourth model, the older basalts replace the middle part of sediments of the first model. We have calculated the synthetic dataset by simulating the wave field propagation using elastic finite difference scheme, with 4^{th}order accuracy in space and 2^{nd}order accuracy in time

that was implemented on a staggered grid. The first arrival seismic refraction data have been used to invert for the model parameters using the regularized least squares inversion approach. The results demonstrate that the velocity anomaly in the first model could not be retrieved, whereas the second model is well resolved. The third and fourth models are indicated from the traveltime inversion. This suggests that a combination of refraction and reflection traveltime data could be used or fullwaveform inversion should be performed for fair delineation of the subsurface Earth.

INVITED TALKS

MY FIFTY YEARS OF ADVENTURES WITH MEASURING GRAVITY OVER THE OCEANS

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The author has made gravity measurements at sea, utilising various instruments including an underwater gravimeter, the Vening Meinez pendulum apparatus on a submarine and the Graf Askania surface ship gravimeter. He has made airborne gravity gradiometer measurements using the Lockheed Martin gravity gradiometer. He has also sent a modified Bosch Arma dual string gravimeter for the Apollo 17 astronauts to make measurements on the Moon. Human interactions in making gravity measurements and errors caused by horizontal accelerations as well as their remedies will be discussed.

SCALING APPROACH FOR API IN GEOPHYSICS

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It has been observed that the sources of geophysical anomaly are neither uniform nor random. Rather these sources like density, susceptibility, conductivity, reflectivity etc follow scaling/fractal distribution. The API stands for acquisition, processing and interpretation which are three main steps in geophysics. All 3 are important and need careful understanding. The proper design of acquisition of data can enhance signal to noise ratio of geophysical response. Fractal theory has been applied to decide a survey network. Similarly the second step, data processing for interpolation of missing data is key to reduce spurious anomaly due to aliased-interpolated data. And finally interpretation is main step which depends on the nature of source. So, new interpretation methods such as scaling spectral method have been developed to accommodate scaling/fractal distribution of source for scaling geology.

DECIPHERING CLIMATE-TECTONIC INTERACTIONS IN THE WESTERN HIMALAYA THROUGH SCIENTIFIC DRILLING IN THE ARABIAN SEA: IODP EXPEDITION 355

Dhananjai K. Pandey[1*], Peter D.Clift[2], Denise Kulhanek[3] and Expedition 355 Scientists
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Understanding nature and scale of interactions between the solid Earth and climate systems through long marine sedimentary records has been one of the key issues being pursued by the International Ocean Discovery Program (IODP). The IODP expedition 355 – (Arabian Sea Monsoon) was carried out in the Eastern Arabian Sea during March –May 2015 with similar scientific objectives. IODP expedition-355 attempts to address the questionof how mountain building, weathering, erosion and the climate in South Asia have interacted over long and short timescales.

Two sites (U1456 and U1457) were drilled in Laxmi Basin in the eastern Arabian Sea using the drilling platform JOIDES Resolution.More than 1700m long sediment cores were retrieved from these two sites. Drilling and coring operations at Sites U1456 and U1457 were completed with total

depths (TD) of 1109.4 and 1108.6 m below seafloor (mbsf), respectively. At Site U1456 we recovered sediments dated to 13.5–17.7 Ma (late early to early middle Miocene), with a large hiatus between TD and overlying deposits older than10.9 Ma. However, at Site U1457, a rather long hiatus was observed near TD, spanning from 10.9 to ~62 Ma.

Multidisciplinary studies are planned onthese cores to document coevolution of tectonics and climate.Further, geochemical and geo-chronological data from the igneous basement retrieved from U1457 is being carried outto constrain paleogeographic reconstruction models in the Arabian Sea. This would also shed light on the early rift history of the western continental margin of India with special emphasis on continental breakup and its relationship to Deccan volcanism.

CHALLENGES AND OPPORTUNITIES IN WATER RESOURCES SECTOR: AN INDIAN PERCEPTION

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Exploiting population, changing climate, ever increasing industrialization, urbanization and irrigation needs coupled with imminent pollution have been mounting heavy stress on water resources availability and use in time and space. Though India could till now, has been successful in meeting such requirements through a phenomenal development of water resources, the increasing need for safe quality water resources to meet the national demand in domestic, agricultural and industrial sectors has become a challenge both from resource and environmental points of view. The growing pollution affecting the quality of available fresh water resources, the environment and the human health has induced a great deal of complexity in water resources system as a whole.

India as a whole has been experiencing quite a reasonable amount of rainfall of around 1210 mm annually, which in any dimension should be able to address all the needs of the human kind and the environment. But in recent times, affected by a variety factors triggered by anthropogenic and geogenic sources, the per capita water availability and the possible water storage capacity has reduced multi fold while the use of ground water for irrigation has been on the rise. Added to this the widening temporal and spatial distributions in availability of water supplemented by changing climate and lack of awareness on the scarcity and economic value of water leading to uneven usage has badly influenced the Indian water sector. In spite of the fact a number of geogenic contaminant sources could be understood and addressed to a large extent, there has been a spurt in the identification of new sources, and the associated process response phenomena.

Further the increasing urbanisation, intensive agricultural practices, industrialisation, demanding living standards have been contributing to an exponential growth in waste water generation, and emerging pollutants, affecting the quality of available water resources and the very environment as a whole. The fact that a number of STP units were established, in urban regions, many of them do not perform to the expected level due to a variety of reasons beyond the comprehension of a common man.

In a national perception, the water conflicts within and across the States is ever increasing. These conflicts, influenced by extreme events, tend to become more complex.

Thus, growing pollution of water sources, especially through industrial effluents, thereby affecting the availability of safe water besides causing environmental and health hazards, wide temporal and spatial variation in availability of water coupled with floods and droughts, extraction and use groundwater beyond replenishable levels, lack of awareness and consciences approach to the scarcity and economic value of water resulting in its wastage and inefficient use, lack of a holistic and inter-institutional approach are some of the challenges and the possible approaches will be discussed.

Thus, though India, once upon a time was able to address the increasing water needs through development, adopting effective scientific and management solutions towards sustainability can provide a comprehensive solutions and opportunities in water sector.

CLIMATE CHANGE: PROBLEM AND PERSPECTIVE CHANGE FOR FUTURE PREDICTABILITY

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Climate is complex system and has changed over the time on multiple time scale. The impact of climate change has been realized globally. Here, we address some of the pertinent and acute problems of paleo and recent climate changes/variability through the analyses of new available data series using the appropriate time series analysis approaches. We also venture on the factors affecting the climate change and deliberate over the possibilities of how can we speculate know the future climate change and variability.

INDIAN OCEANIC LITHOSPHERE: DEPARTURES FROM COOLING PLATE MODEL

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Oceanic lithospheric plate model assumes conductive cooling of a half space or a plate to determine its thermal structure. This thermal structure is then used to fit model predictions with geophysical observations to derive unknown parameters. This model is also used to predict the geophysical fields in uncharted areas. This model has been applied extensively to the studies of the Indian oceanic lithosphere. However there are significant departures in observations of topography, geoid (such as highly negative geoidal low) and heat flow from model predictions. This requires supplementing the cooling plate model with additional features in terms of initial and boundary conditions and also internal heat sources. For instance the boundary condition at the ridge can include both better ocean crust formation processes and deeper hydrothermal circulations. The basal boundary condition can have more complex condition by specifying a combination of temperature and heat flow to represent underlying small scale thermal convection. The basal boundary can be taken moving boundary. The internal heat sources can use both advection of heat and also strain heating associated with lithospheric folding, faulting and instability. Thermal properties can have more general spatial and temperature dependent distributions. There have been several studies to incorporate such departures from cooling plate model of the Indian oceanic lithosphere. These developments will be reviewed and their implications for the exploration of resources, such as hydrocarbons and hydrothermal deposits, and quanitification of tectonic risks in terms of subsidence and fractures,will be discussed.

SCIENTIFIC DEEP DRILLING TO STUDY RESERVOIR TRIGGERED EARTHQUAKES AT KOYNA, WESTERN INDIA

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Koyna dam, located in western India, is a classical site of artificial reservoir triggered earthquakes. Detailed investigations carried out by the National Geophysical Research Institute and others since the occurrence of the 1967 M6.3 Koyna earthquake have brought out the (i) persistent seismicity in the Koyna area during the past five decades, with 22 M≥5 earthquakes, more than 200 M∼4 earthquakes and several thousand smaller earthquakes, (ii) strong association of the activity with the annual loading and unloading cycles of the Koyna and the nearby Warna reservoirs, and (iii) isolated nature of the seismic zone, restricted to ∼30x20 km^2 area and up to 10 km in depth, with no other source of activity within ∼50 km of Koyna dam (Gupta et al., 2014). The region has been probed extensively using geological and geophysical methods during the past few decades.However, more comprehensive studies are required to develop a model to explain the triggered earthquakes.

A major programme comprising scientific investigations through drilling in the area to comprehend the genesis of the earthquakes has been launched by the Ministry of Earth Sciences, Government of India. The primary objectives of scientific deep drilling are: (i) to drill a borehole up to the hypocentral depth (∼5km) and establish a deep observatory to record ongoing seismic activity, (ii) to monitor changes in physical, chemical and mechanical properties of rocks before, during and after occurrences of earthquakes, (iii) to study in-situ stress regime at the fault and its adjacent zones, (iv) to study mechanics of faulting and rupture propagation and (v) to sample fluids from the fault and nearby zones to study co-seismic changes in chemical properties of fluids.

Scientific drilling in the area was planned to be carried out in three phases: (i) exploratory drilling at about 8-10 sites surrounding the Koyna seismic zone, with each borehole penetrating the Deccan Traps and going into the basement rock to constrain subsurface geology and rock properties prior to deep drilling, (ii) pilot borehole drilling up to a depth of 3000m in the seismic zone to constrain the disposition of subsurface fault zones and other critical parameters such as in-situ stress, temperature and rock properties, and (iii) deep drilling up to 5000m to establish a fault zone observatory at depth for measurements and long term monitoring of seismicity, pore pressure, temperature and other parameters. The exploratory phase has been completedand the pilot borehole phase is ongoing.

INFORMATION OF IGU AWARD, MEDAL, PRIZE, LECTURE AND GRANTS

IGU invites nominations to recognise young and senior geoscientists for following four national Medal/Awards/ Prize in the prescribed proforma from past recipients, fellows and EC members of IGU. It also recognises earth scientists for their outstanding contribution with five IGU memorial and endowment lectures. Four Young women researchers and first and second rank holders of Geophysics & Applied Geophysics of recognised Universities/ Institutes are encouraged to participate in the annual convention of IGU with travel support, registration fee waiver and free accommodation. Besides, two researchers and two students receive ONGC- IGU Best Poster Awards. Two Young researchers are also recognise with Best Presenter Awards. IGU also honours with the Best Paper Award from all papers published in its journal (JIGU) during a calendar year.

Krishnan Medal:

1. Preamble - instituted in 1964 by IGU. Dr. Manik Talwani received the first medal.
2. Nature of Prize - a gold medal (since 1993) and a citation.
3. Purpose - to recognize the achievement of a Geophysicist/Geologist and to provide a platform to disseminate his/her knowledge to the Earth Scientific community.
4. Eligibility - an outstanding Geophysicist/Geologist whose age does not exceed 40 years (on 1st January of the year).
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a CV (in a given proforma) must be sent by the EC members, past recipients or Fellows of IGU to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - a three-member committee, duly constituted by the President and EC of IGU.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Decennial Award:

1. Preamble - instituted in 1975 by IGU. Dr. Hari Narain received the first Award.
2. Nature of Prize - a gold medal (since 1993) and a citation.
3. Purpose - to recognize the achievement of a Senior Geophysicist and to gain knowledge from his/her deliberation.
4. Eligibility - an outstanding Senior Geophysicist who has established a school of geophysics in India with indigenous resources and talent.
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a CV (in a given proforma) must be sent by the EC members, past recipients or Fellows of IGU to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - a three-member committee, duly constituted by the President and EC of IGU.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Dr. Hari Narain Lifetime Achievement Award:

1. Preamble - instituted in 2011 by IGU. Dr. S.Z. Qasim and Prof. Harsh Gupta jointly received the first Award.
2. Nature of Prize - a gold medal and a citation.
3. Purpose - to recognize the achievement of an eminent Senior Scientist and to gain knowledge from his/her deliberation on recent topic of interest.
4. Eligibility - an eminent Senior Geophysicist for exceptional contribution to the causes of India Earth Sciences and establishing a school of Earth Sciences.
5. Award of the Prize (approving body) - President of IGU.

6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a CV (in a given proforma) must be sent by the EC members, past recipients or Fellows of IGU and distinguished Professor/Earth Scientist (must be a member of IGU) to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - a committee, duly constituted by the President and the EC of IGU.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Anni Talwani Memorial Prize:

1. Preamble - instituted in 2013 from a grant offered by Prof. Manik Talwani. Dr. K. S. Krishna received the first Prize.
2. Nature of Prize - a gold medal and a citation
3. Purpose - to recognize the achievement of a Senior Earth Scientist and to gain knowledge from his/her deliberation on recent topic of interest.
4. Eligibility - a meritorious Earth Scientist (below 60 years as on 1st January of the year) for his/her outstanding contribution covering both land and/or offshore in India
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a CV (restricted to 2 pages) and 3 supporting letters (with no more than 2 pages each) must be sent by the EC members, past recipients or Fellows of IGU and distinguished Professor/Earth Scientist (must be a member of IGU) to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU. Nominator may kindly note that exceeding the limits is not permitted.
7. Selection Committee - a committee, duly constituted by the President and the EC of IGU.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Prof. D. Lal Best Paper Award (instituted in 2013 by IGU) Rs. 10,000/- Cash Prize is given to the best paper appeared in four issues of the IGU journal in the calendar year to motivate author(s) to publish his/their scientific work.

ONGC-IGU Best Poster Awards (instituted in 2009 from IGU-ONGC Fund): ONGC-IGU cash prizes will be awarded to two students and two research scholars below 30 years (as on 1st January of 2015) for pursing quality research in the field of Geosciences.

Prof. Jagdeo Singh & Dr. S. Balakrishna Memorial Grant (reinstituted in 2012 from ISM Grant and IGU Money): Meritorious students of Geophysics/App. Geophysics will be provided the second sleeper class fare, local hospitability, accommodation and registration fee waiver to participate in the Annual Convention of IGU. Names of the first and second rank holders of pre-final examination (PG) are to be forwarded to IGU by the Head of the Department of Geophysics/App Geophysics of recognized University.

Anni Talwani Memorial Grant for Women Researcher (Instituted in 2015): Indian women researchers/ students below 28 years (as on 1st January of 2015) are encouraged to participate in the Annual Convention through this grant. The selection of grantees will be based on the merit of a full paper submitted to the Annual Convention by an applicant, certified by the Head of the Department/Organization. The 3rd AC class fare, accommodation and registration fee waiver will be provided to four grantees.

Prof. K.R. Ramanathan Memorial Lecture:

1. Preamble - instituted in 1993 by IGU. Prof. P.R. Pisharoty delivered the inaugural lecture.
2. Nature of Prize - a gold medal and a citation.
3. Purpose - to disseminate the Earth System Science knowledge in the frontier area of research and to understand the recent results/discoveries in the field of Earth/Atmosphere Sciences, and to recognize the achievements of a Earth Scientist.

4. Eligibility - an eminent Earth/Atmospheric Scientist who has established his research in the relevant field during the last 20-25 years
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a brief CV must be sent by the EC members or past recipients to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - current EC.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Dr. H. N. Siddique Memorial Lecture:

1. Preamble - instituted in 2001 from a grant by NIO and IGU Money. Prof. Harsh Gupta, delivered the inaugural lecture.
2. Nature of Prize - a gold medal and a citation.
3. Purpose - to disseminate the Earth System Science knowledge in the frontier area of research and to understand the recent results/discoveries in the field of Earth/Ocean Sciences, and to recognize the achievements of a Geoscientist.
4. Eligibility - an eminent Earth/Ocean Scientist who has established his research in the relevant field during the last 20-25 years
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a brief CV must be sent by the EC members or past recipients to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - current EC.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Prince Mukarram Jah Endowment Lecture:

1. Preamble - instituted in 1964 from a grant offered by his family and IGU Money. Dr. S. Bhagavantham delivered the inaugural lecture.
2. Nature of Prize - a gold medal (since 1993) and a citation.
3. Purpose - to disseminate the Earth System Science knowledge in the frontier area of research and to understand the recent results/discoveries in the field of Earth Sciences, and to recognize the achievements of a Geoscientist.
4. Eligibility - a distinguished Earth Scientist who has established his research in the relevant field during the last 20-25 years
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a brief CV must be sent by the EC members or past recipients to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - current EC.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Sri L.N. Kailasam Memorial Lecture:

1. Preamble - instituted in 2005 from a grant offered by his family and IGU Money. Shri V. K. Sibal delivered the inaugural lecture.
2. Nature of Prize - a gold medal and a citation.
3. Purpose - to disseminate the Earth System Science knowledge in the frontier area of research and to understand the recent results/discoveries in the field of Environmental Geosciences/ Exploration of Natural Resources, and to recognize the achievements of a Geoscientist.

4. Eligibility - a distinguished Environmental Geoscientist/Earth Explorationist who has established his research in the relevant field during the last 20-25 years
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard copy with signature) stating the scientific calibre along with a brief CV must be sent by the EC members or past recipients to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - current EC.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Electrotek & Geometrics Endowment Lecture:

1. Preamble - instituted in 2007 from a grant offered by M/s Electrotek & M/s Geometrics and IGU Money. Dr. Sukumar Devotta delivered the inaugural lecture.
2. Nature of Prize - a gold medal and a citation.
3. Purpose - to disseminate the Earth System Science knowledge in the frontier area of research and to understand the recent results/discoveries in the field of Earth Sciences, and to recognize the achievements of an Earth Scientist.
4. Eligibility - a distinguished Geo-scientist/explorationist who has established his research in the relevant field during the last 20-25 years
5. Award of the Prize (approving body) - President of IGU.
6. Nominations (who can nominate, format for nominations, address of secretary) - Nominations (both soft and hard with signature) stating the scientific calibre along with a brief CV must be sent by the EC members or past recipients to the Hon. Secretary of IGU at least two months before the Annual Convention or the date set by IGU.
7. Selection Committee - current EC.
8. Presentation (when it will be presented) - a special lecture on a topic of current scientific interest at the Annual Convention of IGU.

Nomination Proforma for Krishnan Medal and Decennial Award

1. Name of the Award
2. Full name, age and address of the nominee
3. Academic qualifications (bachelor's degree onwards)
4. Position held (in chronological order)
5. Brief statement (within 250 words) on significant contribution for justification
6. Professional achievements
   (i) List of publications with IF (> 1.0) and citations. Attach reprints of 4 important publications
   (ii) Awards/Honours
   (iii) Memberships in Academics/Societies/Professional bodies
   (iv) Impact of scientific contribution
7. Remarks of nominator
8. Name and Address of Nominator

Nomination Proforma for IGU-Hari Narain Lifetime Achievement Award

1. Name of the Award
2. Full name, age and address of the nominee
3. Academic qualifications (bachelor's degree onwards)
4. Position held (in chronological order)
5. Brief statement (within 250 words) on significant contribution for justification
6. Professional achievements
   (a) Awards/Honours/Fellowships
   (b) Memberships in Academics/Societies/Professional bodies
7. Name and Address of Nominator

IGU AWARDS-2015

Dr. Hari Narain Lifetime Achievement Award: Prof. VLS Bhimasankaram, Hyderabad

Decennial Award:	Prof. SK Nath, IIT Kharagpur, Kharagpur
Krishnan Medal:	Dr. Parthasarathi Chakraborty, CSIR-NIO, Goa
Krishnan Medal:	Dr. M.S. Girishkumar, Scientist-C, INCOIS, Hyderabad
Anni Talwani Memorial Prize:	Dr. O.P. Mishra Scientist - "F" / DDG, Ministry of Earth Sciences, New Delhi
Sri. LN Kailasam Memorial Lecture:	Shri A. K. Dwivedi Director (Exploration) Oil & Natural Gas Corporation Limited, New Delhi
Dr. HN Siddiqui Memorial Lecture:	Dr. M. Sudhakar Director Centre for Marine Living Resources and Ecology, Cochin
Electrotek & Geometrics Endowment Lecture:	Prof. A.K. Sinha Director Suresh Gyan Vihar University, Jaipur
Prince Mukarram Jah Endowment Lecture:	Prof. Talat Ahmad, Vice Chancellor, Jamia Millia Islamia University New Delhi
Prof. D. Lal Best Paper Award:	Dr. Uday Bhaskar Deputy General Manager (Geophysics) Singareni Collieries Company Limited, Kothagudem
	Mr. A. Srinivasa Rao Superintending Geophysicist Singareni Collieries, Godavarikhani
	Mr. G. V .S. Prasad Superintending Geophysicist Singareni Collieries, Godavarikhani
	Mr. B. Sravan Kumar Senior Geophysicist Singareni Collieries, Godavarikhani

Announcement

The 53rd Annual Convention

of Indian Geophysical Union (IGU)

along with the 1st Triennial Congress of Federation of Indian Geosciences Association (FIGA)

will be held

at Indian School of Mines (ISM),
Dhanbad

during November/ December 2016.

The Hon. Secretary,
Indian Geophysical Union
NGRI Campus, Uppal Road
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Side Scan Sonar Image of Platforms


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HP IBM Lenovo Dell Oracle SAP Microsoft SAS Teradata Siemens VM ware EMC Cisco Sanovi Schneider(APC) Tableau TIBCO Red Hat Honeywell Hexagon Trimble	• Channel Fast Track 100 : 2008 • SAP e-Gov Partner for Public Sector • Oracle Strategic Deal Partner • ISO 9001:2008 • ISO 20000-1: 2011 • ISO 27001:2005 • PCMM Level 3 • Member NASSCOM • HP Enterprise Storage Award 2015	e-Governance Projects Big Data Projects ERP Projects Business Intelligence Projects Enterprise Document Management Projects Data Centre Projects Sustenance Support & FMS services

For any Sales Enquiry, Please contact:

CORPORATE office	Registered office
#A –2/10, Shopping Centre, SECTOR-110, NOIDA 201 301 TeleFax No: +91-120-2460648/49 E-mail ID: sales@omniinfoword.com	#B1/144, NEW KONDLI MARKET NEAR MAYUR VIHAR PHASE-III, DELHI-110 096 Telefax No: +91-11-22615345,6,7 E-mail ID: sales@omniinfoword.com

Indian National Centre for Ocean Information Services

INCreasing the utility of the Ocean Information Spectrum

An Autonomous Society under the Earth System Sciences Organisation, the Ministry of Earth Sciences, Govt. of India, ESSO-INCOIS strives to fulfill its mission to provide ocean information and advisory services to society, industry, government and the scientific community through sustained ocean observations and constant improvements through systematic and focused research.

Key Activities

Early Warnings for Tsunamis and Storm Surges

Potential Fishing Zone Advisories for Fishermen

Ocean State Forecasts for Fishermen,
the Navy, the Coast Guard and Offshore Industries.

National and Regional Oceanographic Data Centre

Satellite Coastal and Oceanographic Research

Coastal Geospatial Applications

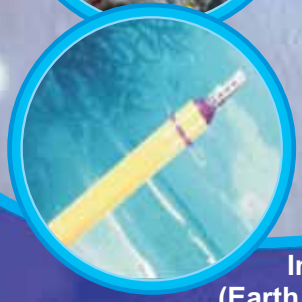
Ocean Modelling Studies

Ocean Observing System
(Member of the Indian Ocean Global Ocean Observing System)

Web-based Ocean Data, Information and Advisory Services

International Training Centre for Operational Oceanography

Public Outreach, User Interaction Workshops



Riding the Wave of Change ....

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-(0)40-23895000/23886000, Fax: 91-(0)40-23895001 | email: director@incois.gov.in,
URL: http://www.incois.gov.in

राष्ट्रीय अंटार्कटिक एवं समुद्री अनुसंधान केंद्र

पृथ्वी विज्ञान मंत्रालय, भारत सरकार

NATIONAL CENTRE FOR ANTARCTIC AND OCEAN RESEARCH

Ministry of Earth Sciences, Government of India

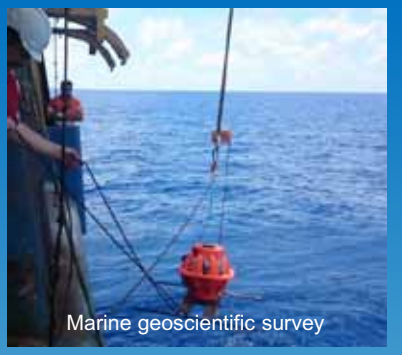
NCAOR, an autonomous R&D institution under Ministry of Earth Sciences is the nodal agency for coordinating and implementing research activities in the marine geoscientific realms. It plays a pivotal role in niche areas of Indian scientific research by facilitating Annual Indian expeditions to Antarctic, Arctic and several other projects relating to the country's Exclusive Economic Zone (EEZ), Extended Continental Shelf (ECS) and Integrated Ocean Discovery Program (IODP).

Scope of research work

- Polar Science & Cryoshpere
- Geoscientific studies
- Logistics for polar expeditions
- Surveys for EEZ and ECS
- Scientific involvement in IODP

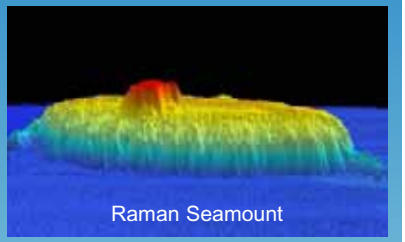

Himadri Station - Arctic


NCAOR campus, Goa


Marine geoscientific survey


Bharti Station - Antarctic

IODP - Expedition 355


Raman Seamount


Maitri Station - Antarctic


ORV Sagar Kanya

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