ABSTRACTS
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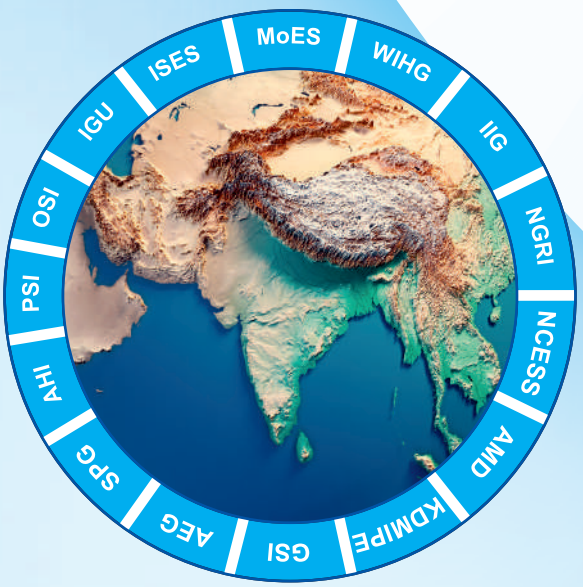
SOUVENIR

3rd Triennial Congress
of
Federation of Indian Geosciences Associations
on
Geosciences of Himalaya for Sustainable Development
16-18 November, 2022



Organised by

Wadia Institute of Himalayan Geology
Dehradun 248001

3rd Triennial Congress of Federation of Indian Geosciences Associations on Geosciences of Himalaya for Sustainable Development 16-18 November, 2022

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Dr. P.C. Kumar

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of
Federation of Indian Geosciences Associations
on
Geosciences of Himalaya for Sustainable Development
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Organised by

WADIA INSTITUTE OF HIMALAYAN GEOLOGY
(An Autonomous Institute of Department of Science & Technology, Government of India)
33, General Mahadeo Singh Road, Dehradun, Uttarakhand-248001
EPABX: 0135-2525100; Fax: 0135-2625212
Email: dir.off@wihg.res.in; Web: http://www.wihg.res.in

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डॉ. जितेन्द्र सिंह
राज्य मंत्री (स्वतंत्र प्रभार),
विज्ञान एवं प्रौद्योगिकी मंत्रालय,
राज्य मंत्री (स्वतंत्र प्रभार) पृथ्वी विज्ञान मंत्रालय,
राज्य मंत्री प्रधान मंत्री कार्यालय,
राज्य मंत्री कार्मिक, लोक शिकायत एवं पेंशन मंत्रालय,
राज्य मंत्री परमाणु उर्जा विभाग तथा अंतरिक्ष विभाग
भारत सरकार

सत्यमेव जयते

DR. JITENDRA SINGH
Minister of State (Independent Charge),
of the Ministry of Science and Technology,
Minister of State (Independent Charge)
of the Ministry of Earth Sciences,
Minister of State in the Prime Minister's Office,
Minister of State in the Ministry of Personnel,
Public Grievances and Pensions,
Minister of State in the Department of Atomic Energy and
Department of Space,
Government of India

I am extremely delighted to know that the 3rd Triennial Congress of Federation of Indian Geosciences Associations(FIGA) is being held at the Wadia Institute of Himalayan Geology (WIHG), Dehradun - An Autonomous Institute of Department of Science & Technology, Government of India from 16th to 18th November, 2022. FIGA provides a common platform to eight Geosciences Associations and seven Geosciences Ministries/Institutions with an overall objective of synergizing the efforts of Earth-sciences communities towards comprehending scientific programs. This can provide effective solutions to the societal challenges for sustainable socio-economic development, suggest scientific activities, and recommend policies for implementation at national and international levels.

Geosciences is one the most important subjects having potential to address major scientific challenges related to energy security, water security, expansion of mineral industries, assessment of geo-hazards & plausible mitigation, understanding climate change and its impact on ecosystem and biodiversity, glacial dynamics, Geo- resources etc. for sustainable development of our country. The theme of the congress "Geosciences of Himalaya for Sustainable Development" is very apt and contemporary, encompassing wide range of geo-scientific issues of the Himalaya.

I congratulate and extend my good wishes to the organizing team who have put in relentless efforts under the able leadership of the Wadia Institute of Himalayan Geology, Dehradun and wish the FIGA a grand success.

(Dr. Jitendra Singh)
MBBS (Stanley, Chennai)
MD Medicine, Fellowship (AIIMS, NDL)
MNAMS Diabetes & Endocrinology

Anusandhan Bhawan, 2, Rafi Marg
New Delhi - 110001
Tel.: 011-23316766, 23714230
Fax: 011-23316745

South Block, New Delhi - 110011
Tel.: 011-23010191, Fax: 23017931
North Block, New Delhi - 110001
Tel.: 011-23092475, Fax: 011-23092716

Pushkar Singh Dhami

CHIEF MINISTER
SECRETARIAT

Chief Minister Office,
Vidhan Sabha, Dehradun
Uttarakhand - 248001
Vidhan Sabha Phone :0135-2665497
0135-2665100
Fax:0135-2666166
Secretariat Phone:0135-2716262
0135-2650433
Fax : 0135-2712827
E-Mail
chiefministeruttarakhand@gmail.com

Message

It is indeed a matter of pleasure to know that the Wadia Institute of Himalayan Geology, Dehradun is organizing the 3rd Triennial Congress of the Federation of Indian Geosciences Association (FIGA) during November 16-18, 2022.

Geoscience is an emerging area of science for the safety and benefit of society particularly for the people leaving in the Himalayan region. As has been observed during recent years, there is an increase in frequency and magnitude of geo-hazard in the Himalaya in general and Uttarakhand in particular, therefore it is high time to carry out inter-disciplinary research bringing the major institutions, and associations working in earth sciences and allied disciplines under one roof. The theme of the conference is highly significant to provide effective solutions to societal challenges for sustainable socio-economic development as well as to find plausible solutions or mitigation of geo-hazards.

I am sure that this Triennial Congress of FIGA will provide a good platform for deliberations and discussions that will be useful to disseminate the knowledge of Himalayan Geosciences. The scientific outcome and recommendations for sustainable development will be useful for policy implementation at national and international levels. I firmly believe that this initiative shall create interest among young students/researchers in pursuing geoscientific research and synergy to yield excellent research outcomes.

I congratulate and convey my best wishes to the organizers and all delegates of the 3rd Triennial Congress of FIGA 2022 for the grand success of the conference.

(Pushkar Singh Dhami)

सत्यमेव जयते
स्वच्छ भारत
एक कदम स्वच्छता की ओर
आज़ादी का अमृत महोत्सव

डॉ. एस. चंद्रशेखर
Dr. S. Chandrasekhar

सचिव
भारत सरकार
विज्ञान एवं प्रौद्योगिकी मंत्रालय
विज्ञान एवं प्रौद्योगिकी विभाग
Secretary
Government Of India
Ministry of Science and Technology
Department of Science and Technology

11th November, 2022

Message

I am happy to note that the 3rd Triennial Congress of the Federation of Indian Geosciences Association (FIGA) is being organized bythe Wadia Institute of Himalayan Geology, Dehradun during 16-18 November2022 as an endeavour to bring scientists and stakeholders to address major scientific questions focusing on the main theme "Geosciences of Himalaya for Sustainable Development".

The Himalayan region occupies a special place in the mountain ecosystems of the world and it is not only important from the standpoint of climate and as a provider of life, giving water to a large part of the Indian subcontinent, but also shelter a rich variety of flora, fauna, human communities, and cultural diversity. In recent days, the people of the Himalayan regions face major global challenges such as different geo-hazards related to earthquakes, landslides, floods, cloud bursts, climate change, environmental degradation, and energy sustainability. I am sure that the deliberations by the geoscientists and stakeholders in this conference will provide a significant platform for taking up challenges related to various geosciences aspects like climate change, energy resources, engineering geology, geohazards, geoheritage, water resources, hydrogeology and mineral & rock resources, etc. for sustainable development and secured living in the Himalayan regions and adjoining areas.

I believe that deliberations by eminent experts, researchers, and academicians in the 3rd Triennial Congress of FIGA will bring out meaningful recommendations for planners, scientists and common people for sustainable development in the Himalayan regions.

I congratulate the organizers and convey my best wishes for the grand success of the conference.

(S. Chandrasekhar)

Technology Bhavan, New Mehrauli Road, New Delhi - 110016
Tel: 0091 11 26511439 / 26510068 | Fax: 00 91 11 26863847 | e-mail: dstsec@nic.in | website: www.dst.gov.in

डॉ. (श्रीमती) एन. कलैसेल्वी
सचिव
वैज्ञानिक और औद्योगिक अनुसंधान विभाग तथा
महानिदेशक
Dr. (Mrs.) N. Kalaiselvi
Secretary
Department of Scientific & Industrial Research and
Director General

भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद
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Government of India
Ministry of Science and Technology
Council of Scientific & Industrial Research
Department of Scientific & Industrial Research

Message

It is heartening to note that the Wadia Institute of Himalayan Geology, Dehradun is organizing the 3rd Triennial Congress of the Federation of Indian Geosciences Association (FIGA) during November 16-18, 2022. The theme of the conference is focussed on the Geosciences of Himalaya for Sustainable Development, which is very pertinent and timely for the development of the Himalayan region.

Geoscience deals with various important aspects like climate change, energy resources, agro-geology, geohazards, disaster risk reduction, geo-heritage, water resources, hydrogeology, and mineral resources, etc, and plays a significant role in the realization of most of the sustainable development goals of our country. To address such issues, it is essential to apply a multidisciplinary approach with increased involvement of all other basic science disciplines creating the need to have a common platform to exchange and interlace the views and activities within the earth science communities. In this direction, FIGA is playing a significant role by bringing in all the Geosciences Associations/Societies/Unions and Institutions onto a single platform to address a common goal of fostering the developments in Geosciences for the benefit of society.

I wish a great success for the congress.

(N.Kalaiselvi)

New Delhi
November 15th, 2022

Anusandhan Bhawan, 2, Rafi Ahmed Kidwai Marg, New Delhi-110001
Tel: 23710472, 23717053, Fax: (91-11) 23710618. E-mail: secy-dsir@gov.in; dgcsir@csir.res.in; and dg@csir.res.in; **Website:** www.csir.res.in

सत्यमेव जयते
डॉ. एम. रविचंद्रन
Dr. M. Ravichandran

सचिव
भारत सरकार
पृथ्वी विज्ञान मंत्रालय
पृथ्वी भवन, लोदी रोड, नई दिल्ली–110003
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
PRITHVI BHAWAN, LODHI ROAD, NEW DELHI-110003

9th November 2022

Message

It gives me immense pleasure to note that the 3rd Triennial Congress of the Federation of Indian Geosciences Association (FIGA) is being organized at the Wadia Institute of Himalayan Geology, Dehradun during November 16-18, 2022. At the very outset, I would like to congratulate the organizers and best wishes for the grand success of the conference.

Geoscience is truly an interdisciplinary field of research with an increasing realization to have a common platform for interlacing and exchanging views and activities by several scientific societies. The FIGA is making continuous efforts to synergize the Earth Science communities and comprehend jointly the scientific programs taken up by individual associations or societies. The Himalayan regions are frequently suffering several geo-hazards related to earthquake, landslide, rock fall, flood, etc. which creates a huge loss of life and property. Now it is the need of the hour to focus on these issues. Earth scientists and engineers are at the forefront to address these complex problems. I hope this conference will provide a platform for all participating geoscientists to disseminate knowledge related to sustainable development in the Himalayan regions.

I feel privileged to congratulate the organizers of the 3rd Triennial Congress of FIGA and wish a grand success of the conference.

M. Ravichandran

(M. Ravichandran)

Tel. : +91-11-24629771, 24629772 ❑ Fax : +81-11-24629777 ❑ E-mail : secretary@moes.gov.in

PRESIDENT'S MESSAGE

It's a great pleasure and privilege to extend warm wishes to the Federation of Indian Geosciences Associations (FIGA) on the eve of organizing its 3rd Triennial Congress at Wadia Institute of Himalayan Geology, Dehradun during November 16-18, 2022. I am glad that the Wadia Institute of Himalayan Geology, Dehradun will be hosting the Congress. The FIGA continuously strives to generate scientific knowledge on geological processes that could provide clues to understand scientific issues and impetus to natural resources and disaster risk reduction for the sustainable development of a nation.

Professional organizations viz., IGU, GSI, SPG, OSI, AEG, AHI, PSI and ISES along with major geosciences institutions like MOES, NCESS, AMD, CSIR-NGRI, IIG, KDMIPE-ONGC, WIHG, would be engaged in the 3rd Triennial Congress to discuss various facets of Geosciences particularly focusing on the theme 'Geosciences of Himalaya for Sustainable Development' encompassing a wide range of topics extending from the Geodynamics of the Himalaya, natural hazards such as floods, landslides, earthquakes, active deformation studies, fluvial and glacial landscapes, climate-tectonic interaction, continental scale deformation, and lithospheric growth, and other relevant themes involving surface and subsurface processes. I believe the deliberations and exchange of ideas at the conference would increase our understanding on Himalayan Geosciences and their role in realizing the sustainable developmental goals.

It is quite fascinating that more than 200 researchers will participate in the Congress. It is a matter of satisfaction that the Wadia Institute of Himalayan Geology, Dehradun has put in relentless efforts towards making this event a grand success. I congratulate the organizers and wish all a grand success in the 3rd Triennial Congress.

Date: 16th November 2022

Prof. V.P. Dimri
President, FIGA

PREFACE

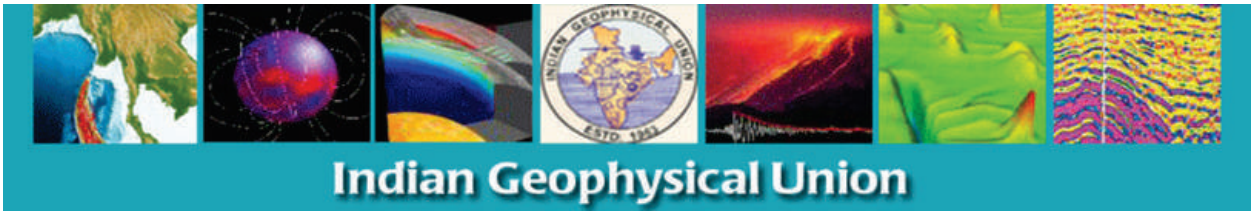
It is heartening to note that the 3rd Triennial Congress of the Federation of Indian Geosciences Associations (FIGA) is going to be held at the Wadia Institute of Himalayan Geology, Dehradun during 16-18 of November, 2022. It is a matter of pleasure and pride for our Institute to host such a grandeur and timely event in the field of Geosciences.

The Congress theme on "Geosciences of Himalaya for Sustainable Development" would address several issues related to the Himalayan Geodynamics, Geo-hazards, and Geo-resources from the surface and subsurface observations and analysis of Geoscientific data. The Congress will surely provide a platform for the exchange of views/ideas among budding researchers, mid-career scientists, and stalwarts working in Geosciences and allied subjects in the Himalaya and adjoining areas.

The Wadia institute is making all necessary arrangements for successfully organizing this event.

Dr. Kalachand Sain
Congress Director (FIGA)
Director, WIHG

INDIAN GEOPHYSICAL UNION (IGU)



भारतीय भूभौतिक संघ
(REGISTRATION No. 26 of 1964)

Indian Geophysical Union (IGU) was formed in 1963 by sixty geophysicists and were styled as Foundation Fellows. The IGU was formally inaugurated by Prof. Humayun Kabir, the then Minister for Cultural Affairs and Scientific Research at a pleasant function organized in the Geology Department, Osmania University.

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

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

The IGU has organized 58 annual conventions on various themes at research organizations, universities, and academic institutes. The IGU has provided a platform for the dissemination of knowledge of earth system science through plenary lectures, invited talks, and oral/poster presentations, on Current topics of interest in the earth sciences having societal relevance.

IGU has extended its presence Globally by joining the Global Geoscience Societies leadership committee along with AGU, EGU, JPG, GSA, IUGG, African Geophysical Society, Deutsche Geophysikaische Gesellschaft, and Korea Geoscience Union.

The aims and objectives of the Union are:

- To bring together all geophysicists active in various disciplines such as seismology, magnetism, meteorology, geodesy, volcanology, oceanography, hydrology and tectonophysics and to provide them with opportunities for meeting and discussing current problems of geophysics of solid earth and the oceans.
- To encourage the study of and research in geophysical problems and to provide media for publication of the results.
- To organize and arrange for the meetings and conferences of the Union and encourage the publication and dissemination of knowledge of geophysics and of important research in various branches of geophysics.
- Conducts IGU-students chapters at different universities, institutes, organizations under the outreach program
- To cooperate with similar learned societies in organizing and taking part in meetings, symposia, research projects, etc., and to represent geophysics in the national and international sphere.

- To secure and administer funds, grants and endowments for the furtherance of and research in geophysics.
- To undertake and execute all other acts which shall assist and promote the usefulness, aims and purposes of the Union.

Recognition

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

Journal of Indian Geophysical Union (JIGU)

The Journal of IGU (JIGU) started its publications in 1997. It started publication bimonthly (January, March, May, July, September and November) from 2016 onwards as open access. It is an ESCI journal by Clarivate Analytics, approved by the Council of Scientific and Industrial Research-NISCAIR, UGC and citied in Indian Citation Index (ICI), New Delhi

The Journal's Aims and Scope are :

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

GEOLOGICAL SOCIETY OF INDIA (GSI)

Founded in 1958, the Geological Society of India is one of the oldest scientific societies in the country. Starting in a modest way with the issue of only one annual number in 1959, the Journal has grown into monthly issues since 1977 and reaches a large section of geoscientists in academia, governmental organizations and mining industry in India and abroad. The tradition left by our predecessors has made the Journal appear with unfailing regularity each month without missing a single issue over these many years, which in itself is a major achievement in our context. The Society has continued its co-publishing the electronic version of the Journal with Springer Nature India during the Triennium under review.

The Society also prints and sells text-books for professional geologists and for students at a very reasonable price without any profit motives. The Society also organises topical scientific conferences, educational activities and outreach programmes to the general public and school-children. It also provides impartial scientific information and analysis to support policy-making and informed public debate about the challenges facing humanity such as climate change, pollution of the land, water bodies, preserving and augmenting water resources and others from the geological perspective.

1. Diamond Jubilee Year (2018-19) and Publications thereof

As part of the Diamond Jubilee year (2018-19) activities, the Society has organized Seminars/Symposia in different parts of the country primarily to take stock of the present mineral resources position of the country from the perspective of future requirements and environmental concerns. In addition to mineral resources, such as gold, REE, Rare metals and Critical Minerals, water resources were also covered under this programme. A special volume on Gold Mining in India was published, an outcome of the seminar on the topic held at KGF in 2019. The Society has also brought out 4 Special Publications on water resources of different parts of the country as an outcome of the brain storming sessions organized during the Diamond Jubilee and text book of Geology of Himachal Pradesh.

2. Significant Growth in Impact Factor

During the period under review, the impact factor of the JGSI, that was 0.7 in 2019, has more than doubled during the past three years and stands at 1.5 currently. The efforts initiated during the Golden Jubilee year mentioned previously also contributed to the growth of the impact factor. A total of 519 research publications (186 + 154 + 179) in the triennium under review have been published. The Journal has also initiated to include major review papers in diverse fields such as the Deccan Volcanic Province, Carbonatites of India, Rare Metal and Rare Earth resources of India and others and these were published in the JGSI during 2019-2022.

3. Acquisition of a new Office Complex for the Geological Society of India

The Society purchased a two-story house at No. 30 & 31, 1st Main, 3rd Cross, Byrappa Garden, Kathriguppe, BSK 3rd Stage, Bengaluru - 560 085 in order to have a more spacious Office and Meeting area with liberal space for the Library and a Guest room for visiting Fellows. Existing funds combined with a substantial donation from BPR's family members, industry and Fellows enabled the purchase. The building was named as B P Radhakrishna Bhavan in December 2021, in a function that was held in hybrid mode and attended by BPR's relatives, Fellows besides the President Harsh K. Gupta, Office bearers, Council Members and other major donors.

4. Monthly lectures, Endowment lectures and Special Lectures

A total of thirty-two (32) monthly lectures and thirteen Endowment lectures (13) were conducted during the period under review, mostly under virtual mode due to Covid pandemic.

Thirteen special lectures were arranged in the virtual mode by leading experts from USA, UK, Australia and Netherlands on a variety of topics in Earth Science and climate-related fields.

5. Regional Centres of the Society and their activities

Late Shri R.H. Sawkar, Secretary General, as part of extending the Society's activities to different parts of the country, contacted active Fellows of the Society to initiate action on opening of new Regional Centers. The Northern Regional Centre had been formed during the 1990s by the late Dr. K. R. Gupta. The opening of new Centres were revived in the 2019 with the starting of the Western Regional Centre at Pune. This was followed by the Chapters at Belgavi, Karnataka in 2021, Kharagpur, West Bengal in 2021, Bhuvaneswar, Odhisa in 2022, Madurai, Tamil Nadu in 2022 and at Dharwar, Karnataka in 2022. A total of 13 lectures, including 5 webinar lectures by Earth Scientists from USA, UK, France and India were conducted at Pune during 2020 - 21. Virtual lectures were also organized by Delhi and Khargpur Regional Centres.

6. Seminars and Workshops

During the triennium, due to the Covid lock down the physical events were restricted to the following workshops and Conferences:

i) National Field Workshop on Iron ore Deposits of Hosapet-Sandur Sector during 11-14 December 2019 at Hosapete, Karnataka
ii) Conference on "Water Resources of Peninsular India" from 17-19 January 2020 jointly with Indian Institute of Science, Bengaluru
iii) A workshop on "Universal Stage: Principles and Practice" was organized by Regional Centre, Pune at Department of Geology, Savitribai Phule Pune University from 17-18 January 2020
iv) The Madurai Regional Centre organized a Conference on "Preservation of Western Ghats and optimum use of its water Resources" during 7-9 May 2022 at Aluva, Kerala.

The Annual conventions of the Society and associated Webinars were organized during 2020 and 2021 were organized virtually:

- AGM-2020 was organized by the Department of Environmental Studies, NEHU, Shillong along with a webinar on "Sedimentation, Tectonics and Metallogeny of North East India" during 21-23 September, 2020
- AGM-2021 was organized by Guru Jambheshwar University of Science and Technology, Hisar jointly with National Institute of Disaster Management, New Delhi along with a seminar on "Disaster Management with focus on Geohazards" on 23-24 September 2021.

7. Earth Science Olympiad

The Geological Society of India is organizing the Earth Science Olympiad (IESO) since its beginning in 2007 with the financial support of the Ministry of Earth Sciences (MoES). The entrance test for the 14th IESO was conducted on 1st December 2019 and further activities were cancelled due to Covid pandemic during 2020 and 2021. Eight students participated in IESO 2022, which was organized virtually by Italy and brought laurels to the country with a total of 20 medals (10 gold, 4 silver & 6 bronze) from various events.

SOCIETY OF PETROLEUM GEOPHYSICISTS (SPG)

In 1992, a group of Indian geophysicists in Dehradun spawned on the bright idea of forming an association of petroleum geophysicists. From that nucleus, grew the Society of Petroleum Geophysicists (SPG), India to its full glory today. They had a dream of forming a society that can eventually reach the level of other International Societies. The Society got registered in the year 1993 with its registered office at Dehradun. As the society grew, it expanded its activities and has developed excellent working relations with other international societies. Today SPG is affiliated to the International Societies viz; Society of Exploration Geophysicists (SEG)-USA, European Association of Geoscientists & Engineers (EAGE)- Netherlands & Australian Society of Exploration Geophysicists (ASEG), Australia.

The membership of the society grew progressively from a couple of hundreds in 1993 to more than 3000 (which includes Life, Annual & Student membership) today. To enable coordination of activities across the country, 10 (Ten) regional chapters are constituted including North American chapter of the society at Houston, USA which was formed in the year 2002 amidst the large congregation of Indian American Geoscientists.

With the objective of supporting students pursuing geosciences, 18 student chapters are established across the various regions in India. These student chapters have emerged as an effective means of promoting geosciences as a subject, exposing students to nuances of HC exploration & exploitation and imparting training to students.

The society has been playing a pivotal rule in large scale integration of geoscientists cutting across disciplines and providing a platform to launch programs for training, organizing International Conferences & Expositions on emerging cutting-edge technologies and most importantly, providing continuing education to all its members so that its members get continuous exposure to the emerging technologies and remain updated with the developments taking place in the industry. SPG promotes excellence and technological advancement in geosciences and provides a forum for technical exchange among exploration disciplines. SPG-India publishes half yearly technical journal “Geohorizons” which contains technical papers, case studies and activities of the various regional and student chapters.

Over the years, the society has organized biennial 13 international conferences with the participation of large number of Indian and overseas geoscientists, companies, academic institutions, and professional societies enabling SPG to serve the cause even more effectively in time to come. All the Conferences arranged by SPG were successful and were well acclaimed by the industry. These conferences acted as gateways for new cutting-edge technologies, viz. Virtual Reality Centre, Q-Technology, CSEM, Virtual Drilling, Multi-component Seismic, Cluster PC systems, AI/ML, Big Data Analytics, non-conventional sources of energy like solar, wind and Geothermal energy, etc., to flow into this part of the sub-continent.

OCEAN SOCIETY OF INDIA (OSI)

The Ocean Society of India (OSI) has a mission to provide a forum for sharing the knowledge and experience of individuals, research institutions, and industrial organizations in ocean science, technology, engineering and allied fields. OSI with its registered office at CMLRE, Kochi has life members from all over the country. Presently OSI has its local chapters at Chennai, Kochi, Pune, Delhi and Goa.

OSI has signed MoU with various national and international organisations related to ocean research viz. Indian Meteorological Society (IMS), Federation of Indian Geosciences Associations (FIGA), UN Decade 2021-2030. It has an Observer Status at International Seabed Authority (ISA).

Objectives

The objective of the Ocean Society of India is advancement and dissemination of knowledge in science, technology, engineering, and allied fields related to oceans. To achieve these objectives the Society strives to:

- provide a forum for sharing the knowledge and experience of individuals, scientific institutions and industrial organizations for promoting science, technology, engineering, and allied fields related to oceans.
- act as a link among academic and R&D institutions, national policy making bodies, operational organisations and ocean industries by organizing programs such as short-term courses, lectures, symposia and topical reviews.
- act as the exchange bureau for dissemination of scientific and technical information by way of periodic and special publications.
- achieve the above objectives and to have better reach to the ocean community through Local Chapters at selected locations.

Membership

OSI has the following types of memberships:

(i) **Member/Life Member:** A person who is associated with teaching or research or any other activity that promotes the knowledge of science, technology, engineering and allied fields related to oceans, is eligible to apply for membership. A member should have a minimum qualification of either Bachelor's Degree in science/ technology / engineering or at least 3 years of professional experience in any ocean related field. For the life members, a certificate will be given as Life Member of the society.

(ii) **Institutional Member**: A registered /recognised institution which is interested in promoting the objectives of the society shall be eligible to apply to become an Institutional Member on payment of the required fee.

(iii) **Corporate Member**: An organization engaged in promoting research/ manufacture/ maintenance/ trade/ business related to oceans, marine instrumentation and marine technology shall be eligible to apply to become a corporate member after paying the required fee.

Activities of OSI

(i) **Organisation of Workshops / Conferences / Webinars**

OSI has been organizing the biennial OSI Conference (OSICON) since 2009. Seven OSICON conferences have been organised so far. All these conferences were hosted by leading academic/research institutes of the country such as Andhra University, Visakhapatnam; NIOT Chennai; IITM Pune; NIO Goa; NCESS Thiruvananthapuram, CMLRE Kochi and NCPOR Goa. The next conference in the series (OSICON-2023) will be held at INCOIS, Hyderabad in 2023.

OSI through its local chapters has also been conducting workshops, seminars and training programmes periodically. Monthly webinars initiated during the pandemic has been a big success. OSI also collaborates with other organisations in organising conferences such as TROPMET, World Meteorological Day, INTROMET, Oceans 2022, etc.

(ii) Conferment of Awards/Fellowships

Dr. D. Srinivasan Endowment Award: OSI has instituted an award in memory of Dr. D. Srinivasan, former Director of NPOL and one of the pioneers of naval ocean research in India to honour eminent scientists/ engineers and other professionals who have contributed to the growth of ocean related science and technology. The award is to be given once in two years and commenced from the year 2019, with a citation, memento, and cash prize presented during OSICON.

Honorary Fellowship: Honorary Fellowship of OSI is awarded to a distinguished scientist/engineer every year for his/her contribution in Ocean Science and Technology. Commenced in 2021, this Fellowship carries a citation and memento.

OSI Fellowship: OSI has also introduced a Fellowship program for its Life Members who have made outstanding contribution in the field of Ocean Science and Technology. Two Fellowships for Life Members of OSI is being conferred every year on the most outstanding Indian researchers/ professionals.

PG Dissertation Awards: OSI has instituted PG Dissertation Awards to motivate PG students in the field of Ocean Science and Technology from the year 2019-2020. Selection of awardees is done every year through an Awards Committee consisting of eminent scientists and academicians nominated by GC OSI. Altogether 7 awards, each carrying a citation, memento and cash prize are being presented every year under different themes.

Best Paper Awards: Awards are presented for the best Oral and Poster presentations in 7 different themes of the OSICON conferences with a citation, memento and cash prize during OSICON.

(iii) Publications

Ocean Digest, the quarterly E-Journal of OSI, is being published regularly. An editorial team consisting of senior scientists and engineers form various organisations is entrusted with the responsibility of bringing out the Ocean Digest.

(iv) Observation of World Oceans Day

OSI joins the international community every year to observe the World Oceans Day which falls on June 8 in a befitting way. The activities taken up by OSI and its Local Chapters on the day involves organisation of meetings and awareness programmes to highlight the importance of conserving the oceans to protect mankind and other biotic organisms. Beach cleaning programmes undertaken on the day cover different coastal locations of the maritime states.

ASSOCIATION OF EXPLORATION GEOPHYSICISTS (AEG)

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

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

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

Main Objectives of the AEG

- To promote the cause of advanced study and research besides effective co-ordination of Research and Development in all disciplines of Exploration Geophysics and allied fields.
- To promote and exchange ideas amongst the Geoscientific community and also to promote discussions on subjects of interest in the field of Exploration Geophysics and related disciplines. This is achieved by organizing conventions, meetings, seminars, symposia and annual lecture programs etc
- To strengthen the level of geophysical education by providing published teaching and training aids related to the field of Exploration Geophysics
- To encourage research activities and disseminate information of Exploration Geophysics by publishing research bulletins, journals, memoirs, monographs etc
- To institute prizes, medals, etc and honor scientists for their outstanding contribution in any branch of Exploration Geophysics or related discipline and encourage young and talented scientists in their pursuits in such disciplines
- AEG membership is open to all geo-scientists engaged in Exploration Geophysical activities.

ASSOCIATION OF HYDROLOGISTS OF INDIA (AHI)

Hydrology is the science of water – needed for all living beings. Keeping this as the motive, the Association of Hydrologists of India was instituted in 1981 with the objective of providing a common platform to scientists working on various aspects of hydrology like civil engineering, meteorology, geophysics, geology and remote sensing, environmental engineering and sciences etc., for exchange of ideas and concepts. To realize its objectives a number of National / International seminars are organized annually in different locations in the country. During the last 40 years of its existence AHI has organized 39 seminars including three international seminars in different parts of India and abroad. The AHI is an accredited member of the United Nations Committee on Environment and Development (UNCED).

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

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

Realizing the need to bring out a quality journal in Hydrology 'Journal of Applied Hydrology' has been published quarterly since 1988. Since then the journal, with the patronage of the readers and the authors, has been brought out uninterruptedly. The AHI has been establishing a strong relationship with IAHS and been regularly associated with the activities of IAHS for more than a decade. The AHI has been playing a key role in bringing together National Hydrological Associations and became a member of 'National Hydrological Associations' forum created under the aegis of International Association of Hydrological Sciences (IAHS). AHI has represented the NHA meetings held in Iguassu, Melbourne, Gothenburg and Prague and Montreal. The AHI has been the founder member of FIGA and has been actively participating in its endeavors to propagate geosciences at national and international levels including the present 3rd Triennial Congress.

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

A few recent national wide activities of AHI are enlightened here:

Under the aegis of Federation of Indian Geosciences Association (FIGA), AHI has organized a 34th Symposium on" Water resources & Water Policies" jointly with AEG & IGU and "Geosciences Education - Experiences and Future Perspectives" (Jointly with GSI, AEG, IGU & PSI) at the 1st Triennial congress of FIGA during 8- 10 November, 2016 at ISM, Dhanbad.

The 35th & 36th AHI national convention and seminar on "Hydrology" with a colloquium on 'Nature Based Solutions to Water Challenges' were organized during 22nd and 24th March, 2018 at AU.

37th AHI Annual convention and Symposia on "Water Resources Management under Changing Environment and Climate" (Jointly with GSI & IAHS) in conjunction with 2nd Triennial Congress of (FIGA during 13 - 16 October, 2019 was held at NGRI Hyderabad. A workshop on Synergic Management of Water Resources in Changing Climate was also held during 12-13 October, 2019.

38th & 39th AHI Annual Convention and National Seminar on "Hydrology" with a *Focal theme on* 'Changing Climate and Extreme Hydrological Events' was held during 25th – 26th Feb, 2022 along with a one-day *Pre-Workshop* on "Emerging Contaminants in Water Resources Management" *on* 24th Feb, 2022 at Andhra University.

AHI will be conducting its 40th Annual convention and National seminar on Hydrology during 3rd Triennial Congress of FIGA being held at Wadia Institute of Himalayan Geology during 16-18th November, 2022 and chosen its focal themes as Floods: past and present besides Natural Water and thermal springs.

AHI initiated Sholapur and Gujarat Chapters to enlarge its activities in the national perspective long back. The AHI would be taking a leading part in the growth and development of hydrological sciences in India as also its dissemination not only among the scientists but also the larger public.

Adbhyassambhutah Prthvyairasacca

THE PALAEONTOLOGICAL SOCIETY OF INDIA (PSI)

(Registered under Society's Registration Act XXI of 1860 at Lucknow on 12/08/1950)
Centre of Advanced Study in Geology, University of Lucknow, Lucknow 226007.
Website: www.palaeontologicalsociety.in

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

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

The society publishes a SCI journal of international repute biannually, the **Journal of the Palaeontological Society of India** which is of international repute. 66 volumes have been published till date. This journal has citation index of 0.76. In addition, Special publication (6), Monographs (3), Field Guide books on different geoscientific areas (5), Atlas (1) and Proceedings of seminar and symposia have also been published. The Society encourages free dissemination of palaeontological knowledge. It makes available all its publications as an open access on its website

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

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

Being a Corporate Member of the International Palaeontological Association (IPA), the Society initiated organising the **International Fossil Day (IFD)** on 16th October since **2016** to popularise the branch of fossils study, i.e. palaeontology in India. Since 2018, several **Student / University / Regional Chapters** of the Society in India are celebrating IFD by organising lectures, Poster presentations, Quiz programmes, museum & field visits, etc.

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

INDIAN SOCIETY OF EARTHQUAKE SCIENCE (ISES)

Indian Society of Earthquake Science (ISES) was registered on 29.07.2009. Currently over 270 are its Life Members.

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

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

Organizational set up of Indian Society of Earthquake Science

Patrons: Secretary, MoES, GOI, New Delhi; and Secretary, DST, Govt. of Gujarat

Executive Committee Members:

President : Dr. B. K. Rastogi,
Vice Presidents: Prof. V.P. Dimiri, NGRI and Prof. T.G. Sitharam, IIT, Guwahati Secretary: Dr. Abhey Ram Bansal, NGRI,
Jt. Secretary: Mr. Md. Rafique Attar, NGRI,
Treasurer: Dr. K. M. Rao, ISR

Council Members:

(1) Dr. Sandeep Gupta, NGRI
(2) Dr. Vineet K. Gahalaut, NGRI
(3) Dr. Prantik Mandal, NGRI
(4) Dr. Sushil Gupta, RMSI, New Delhi and
(5) Prof. Sagarika Mukhopadhyay, IIT Roorkee

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

MINISTRY OF EARTH SCIENCES (MoES)

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

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

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

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

The Earth System Science Data Portal (ESSDP) of MoES hosts metadata of the data generated by its institutions and available across multiple data portals and provide links to respective geo-spatial datasets covering different themes of earth system sciences such as Atmosphere, Ocean, Polar and Geo Sciences.

MoES launched several mobile applications such as Meghdoot (Weather+Agriculture), Mausam (weather), Damini (Lightning), SAFAR AIR (air quality), SARAT (oil sleek pollution), RISEQ (now Bhookamp), Thoondil (for fishermen), which have helped disseminate real-time information on weather, Ocean, and seismological services.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY (WIHG)

The Wadia Institute of Himalayan Geology (WIHG) at Dehradun is an autonomous research Institute of the Department of Science & Technology, Govt. of India, which was established in 1968. It has been pursuing basic research to unravel the orogeny of majestic Himalaya and to provide an improved understanding of seismogenesis, geodynamics, climate-tectonic interaction, biotic evolution, ores/minerals forming processes, glacial dynamics, fluvial system, geo-hazards (landslides, flash floods, avalanches, earthquakes), geo-resources (minerals, ore bodies, hydrocarbons, cold/hot springs), anthropogenic impact, etc. towards the well-being of the population and safeguarding the properties and structures in the Himalaya and adjoining areas.

The research activities to understand the mountain building processes and shed light on the above themes are based on observations and modeling of different sets of data on structural geology, petrology, geochemistry, paleontology, biostratigraphy, sedimentology, glaciology, hydrology, geomorphology, engineering geology, seismology, gravity & magnetic, seismic, well logs, environment & engineering geology, quaternary geology, remote sensing, etc.

The institute is equipped with sophisticated analytical facilities like LA-MC-ICP-MS, Stable Isotope Mass Spectrometer, EPMA, ICP-MS, XRF, SEM, XRD, Raman Spectrometer, TL/OSL, Magnetic Susceptibility meter, etc., run by competent scientists and technicians. It has state-of-the-art geophysical data acquisition, processing, modeling, and interpretation laboratories coupled with the AI/ML Centre of Excellence for Geosciences data. The analytical and laboratory facilities are being utilized by the scientists of WIHG as well as researchers from state and central universities, other institutes, and organizations. It has as many as 75 Broad Band Seismographs and 25 Acceleragraphs spread over Himachal Pradesh, Uttarakhand, Punjab, Haryana, and Arunachal Pradesh states, and Jammu & Kashmir and Ladakh Union Territories. Around 20 GPS instruments are installed in Himachal Pradesh and Uttarakhand states, and Jammu & Kashmir and Ladakh Union Territories.

The Institute has been nurturing a unique set up to perceive changes in subsurface properties that may lead to earthquake precursory study in the Himalayan region by hoisting and monitoring an integrated 'Multi-

Parametric Geophysical Observatory (MPGO)' at Ghuttu in Tehri district of Uttarakhand. The institute also provides consultancy services for engineering projects, drinking & ground water surveys, natural hazards, road and rail alignments in the Himalaya and adjoining regions.

The institute serves as a National Centre of excellence in Himalayan Geoscience Education and Research; provides training and produces Ph.Ds in the field of Geosciences; collaborates with Universities, Industries and other Institutes on Himalayan Geosciences; maintains a modern Geological Museum decorated with varieties of rocks, minerals, and fossils of the Himalaya for Education; conducts outreach programs for Science Education and Geo-hazards awareness; organizes illustrious Award Lectures and National/International Seminars, etc.

During the glorious journey, a few scientists have brought accolades with the Padma Awards, many researchers with the National Geosciences Awards, Academy Fellowships, and Young Scientists Awards. The vision of WIHG is "Questing for Himalayan Seismogenesis, Geodynamics, Geo-Hazards, Climate Variability, and Geo-Resources through Geoscientific study to fulfill the Societal Needs and pursue Basic Sciences".

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

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

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

Uranium Exploration

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

Rare Metal and Rare Earth elements Exploration

AMD also carries out survey, prospecting and exploitation of rare metals (Nb, Ta, Be and Li) and rare earth

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

Beach Sand Minerals Exploration

The beach sands of Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra and parts of Gujarat contain rich concentration of heavy mineral resources of titanium (ilmenite, leucoxene and rutile), zirconium (zircon), thorium and REEs (monazite), garnet and sillimanite. All these minerals occur as placers in the sand. AMD identifies such heavy mineral rich placer sand regions along the coast, and estimates the resources of individual minerals. Further, the inland placer sands of Odisha and Andhra Pradesh and Teri (red coloured) sand occurring in the southern part of Tamil Nadu also contain heavy minerals.

INDIAN INSTITUTE OF GEOMAGNETISM (IIG)

The legacy of **Indian Institute of Geomagnetism** (IIG) dates back to 1841, when geomagnetic field observations commended at Colaba observatory, Mumbai (then Bombay). With an enviable antiquity of over 181 years, IIG has evolved as esteemed organisation including modern state-of-the-art research tools for Geomagnetism and allied studies. IIG was given a full-scale mandate to pursue geomagnetic and allied field research in 1971. IIG has been an autonomous institution since its inception and is now functioning directly under the Department of Science and Technology, Government of India.

The evolution of geomagnetism in the country has been interminably linked with the growth of this institution. IIG currently operates twelve geomagnetic observatories across the length and breadth of the country and three regional research laboratories at strategic locations of Tirunelveli, near equatorial region, Prayagraj, near the northern crest of equatorial ionization anomaly and Shillong, situated in one of the most active earthquake prone regions of the country. The Institute regularly participates to the Indian Expeditions to the Antarctica right from their inception in 1981 and has permanent base in Antarctica for geomagnetic field measurements and aeronomy studies. IIG has also been participating in Indian Expeditions to Arctic.

Geomagnetism has enormous societal applications and this science impacts all of humanity in one form or other. A significant contribution to research in the field of geomagnetism started in India as back as in 19th century. Geomagnetic observations commenced in India and rest of the world almost concurrently. **The first magnetic observations in India were started at Madras in 1822, followed by the recordings at Simla (1841), Trivandrum (1841) and Colaba (1841).** Among these, only IIG's Colaba observatory continued uninterrupted since 1841. The combined observations at Colaba and Alibag observatories provide the longest series (nearly 181 years) of magnetic field data.

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

IIG aspires of making India a global knowledge centre in Geomagnetism and allied fields. IIG has been doing cutting edge contemporary science in deciphering the cause and effects related to Earth-Atmosphere coupled observations on various time scales using a variety of geophysical tools. In the areas of space geomagnetism and plasma physics, radio and optical remote sensing along with geomagnetic field variations are employed as diagnostic tools to probe the Earth's near space environment. Several theoretical studies are being carried out on charged particles, electric fields and currents in the space environment comprising the solar wind, magnetosphere and ionosphere. IIG is one of the leading national institute in interdisciplinary studies promoting three multidisciplinary research programs viz., (i) Coupling of Lithosphere-Atmosphere-Ionosphere during geohazards (ii) Space Weather – Observations and Modelling and (iii) Climate change and genesis. It is needless to mention that each of these programs contains immense societal value and relevance. The institute is determined to build reliable early warning systems for earthquake, tsunami and landslide and make steady and substantial progress in this direction.

The Institute's mandate is also to maintain and modernize the magnetic observatories under its magnetometer network, establish new observatories and publish high quality data as Indian Magnetic Data volumes. The magnetic records from these observatories serve as useful tools for the study of electrical current systems

flowing in the near space environment, which provide crucial information for understanding solar-terrestrial relations that along with atmospheric-ionospheric monitoring instruments have a bearing on monitoring and assessing the health of satellite navigation systems. The World Data Center (WDC)-Geomagnetism, Mumbai, is now a member of the International Council for Science-World Data System and is the only international center for geomagnetic data based in South Asia, serving to the Earth and Space science communities.

IIG is actively involved in the calibration of magnetic compasses of Indian Navy, Indian Coast Guard, Naval Air Stations, and providing services to ISRO, DRDO, DoS, NHPC etc besides providing high resolution digital magnetic data to several research and other government organizations. The institute has a modern laboratory for design and fabrication of instruments used in Geomagnetism and allied fields. The instrumentation division of IIG is presently actively engaged in developing an in-house cost-effective Overhauser Magnetometer for geomagnetic field measurements.

Inspiring young minds for research and development is another major activity of the IIG. To attract, motivate and train young talented minds to pursue research in geomagnetism and allied areas, IIG conducts Inspiring Minds of Post-graduates for Research in Earth and Space Sciences' (IMPRESS) program annually and also offers Dr. Nanabhoy Moos Post-Doctoral Fellowship to young research scientists.

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

Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE) is the oldest and most premier research Institute of Oil and Natural Gas Corporation Limited (ONGC) located at Dehradun. KDMIPE was established as Research and Training Institute in 1962 to provide geoscientific insights to ONGC in its quest for hydrocarbon resources. In 1970, it was renamed as Institute of Petroleum Exploration (IPE) and on 19th December, 1981, it was rechristened as Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE) in the memory of the father of Indian Petroleum industry and first chairman of ONGC, as well as first Petroleum Minister of Independent India, Shri Keshava Deva Malaviya.

KDMIPE is credited to have prepared the first ever Tectonic Map of India in 1968, which was later revised in 2003. The institute has prepared the sedimentary basin map of India with exploration categorization and steered preparation of first detailed document on Lithostratigraphy of Indian proliferous basins. It spearheaded R&D on unconventional resources, such as CBM, Gas Hydrates, Shale Gas, and Basin Centered Gas and played key role in planning, monitoring and execution of expeditions for India's National Gas Hydrate Program.

KDMIPE is the nodal agency for multidisciplinary synergistic basin analysis and domain specific research in hydrocarbon exploration. Equipped with state-of-the-art facilities, softwares and cutting-edge technologies; the Institute caters to the exploration needs of all the petroliferous basins. KDMIPE also provides consultancy services in areas of geosciences and exploration to national and international oil companies. Various innovative and investigative projects are undertaken to cater to the requirements of different Assets/ Basins of ONGC as well as other upstream companies in India and abroad.

The core strengths of this Institute are in the fields of :

- Basin Analysis and Petroleum System Modeling
- Fundamental Geoscience Research
- Exploration in Frontier & Foreign Basins
- Non-seismic Prospecting, Well logging and Reservoir Studies
- Unconventional Hydrocarbon Research

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

From outcrops to exploratory tests, KDMIPE covers all aspects of Geoscientific and Basin Research.

GEOLOGICAL SURVEY OF INDIA (GSI)

Introduction

Geological Survey of India (GSI) is the premier geoscience organization involved in mineral exploration in the country since its inception in 1851. The growth of mineral industry is directly linked to the mineral endowment of a country. The mineral endowment is established through successive efforts in mineral exploration by discoveries and resource augmentation. The baseline geoscience data collected by GSI is the core for generating more mineral exploration work which leads to mineral discoveries. During the inception of GSI, the prime mandate was to carry out (i) geological survey of the country, and (ii) exploration in specific parts of the country with special objectives to locate mineral resources.

Major Activities

Mission-I: Baseline Geoscience Data generation: The National Mineral Exploration Policy (NMEP), 2016 emphasises that acquisition and dissemination of pre-competitive baseline geoscience data of the highest standards, creation of a geoscience data repository, and special initiative to probe deep-seated/concealed mineral deposits are primary requisites to promote mineral exploration in the country.

Accordingly, GSI is on a mission to generate nation-wide baseline geoscience data e.g. geological, geochemical, geophysical and aero-geophysical data which are of paramount importance for planning mineral exploration activities. GSI has geologically mapped 99.15% of the mappable part of the country at 1:50,000 scale. Presently GSI is carrying out Pan-India mapping projects like National Geochemical Mapping (NGCM), National Geophysical Mapping (NGPM), National Aero-Geophysical Mapping (NAGMP) and Specialized Thematic Mapping (STM) programmes with a primary aim to identify new target areas for prognostication of natural resources, and also to address fundamental geological problems as well as geo-societal issues.

GSI has also been engaged in spectral mapping of potential zones using multi-spectral and hyperspectral imageries.

In the field of Marine Geology, GSI has been contributing immensely with its state-of-the-art research vessel R.V. Samudra Ratnakar (RVSR) and other coastal vessels in sea bed mapping and reconnaissance mineral resource estimation.

Mission-II: Natural Resource Assessment: GSI is augmenting natural mineral and coal resources for enhancing Mining Sector's contribution in GDP of India. GSI carries out 'reconnaissance survey' [G4], 'preliminary exploration' [G3] and 'general exploration' [G2] following the UNFC guidelines with an aim to augment resource for various mineral commodities.

In response to the national requirement, thrust has been given on exploration for strategic and critical minerals like tungsten, molybdenum, nickel, lithium, cobalt, REE/RM, rock phosphate, potash etc. and to probe deep-seated and concealed deposits under Project “Uncover India”, in collaboration with Geoscience Australia. Regional Mineral Targeting (RMT) projects have been introduced for scanning of larger areas with multi-thematic data integration approach for identification of promising areas for further exploration.

In the field of Offshore Marine Mineral Exploration GSI has so far delineated 5.9 lakh sq km offshore prospective area for focused explorations for various mineral commodities like Lime Mud, Fe-Mn encrustation, hydrothermal minerals and Phosphorite/ phosphatic sediments, etc.

Mission-III: Geoinformatics: GSI has implemented Online Core Business Integrated System (OCBIS) portal to fulfil the responsibility to disseminate multi-thematic geoscientific information freely for the use of all concerned stakeholders through "*Bhukosh*", the flagship Geospatial portal of GSI, following extant policies and guidelines.

GSI is also taking up lead role in setting up of National Geoscience Data Repository (NGDR) for hosting exploration related geoscientific data collected by all stakeholders to facilitate, expedite and enhance the exploration coverage of the country.

Mission-IV: Fundamental & Multidisciplinary Geosciences and Special Studies

GSI has been systematically involved in public good geoscientific programs since decades with an aim to contribute to the societal causes which includes landslide studies, geodynamic/seismic studies, engineering geology/ geotechnical studies, environmental geology, climate study, glaciology & Polar studies and fundamental geoscience research.

Mission-V: Training and capacity building: Training and capacity building is considered as the basic tenet for the growth and development of an organization as well as for the Nation in a larger perspective. Geological Survey of India Training Institute (GSITI), the training and capacity building arm of GSI, was established in 1976 with the intent of providing induction-level orientation training to the new entrants of GSI. GSITI functions through its centres located at Hyderabad, Nagpur, Lucknow, Kolkata, Shillong, Raipur, Zawar, Chitradurga and Kuju.

GSI promotes a platform like Central Geological Programing Board (CGPB) which facilitates synergy and avoids duplication and waste of resources, where all State Governments, central ministries, PSUs and academic institutes participate and GSIs programs are discussed. GSI formulates its national programmes through this consultative process and ensures that the programmes are in consonance with the current global and national thrust areas and aligns to the national and international policy directives and sustainable development goals.

BIRBAL SAHNI INSTITUTE OF PALAEOSCIENCES (BSIP)

Professor Birbal Sahni, FRS, established the Institute in the year 1946 to explore and develop palaeobotany as a science in itself, visualizing its potential in solving issues of origin and evolution of plant life, other geological issues including exploration of fossil fuels. Originally plant fossils and a few related studies were the focus of research at the BSIP. However, the mandate of the BSIP was recently expanded for interdisciplinary research in palaeosciences, and creating modern facilities to achieve this end. The newly widened mandate aims to look at

- Understanding the origin and evolution of life through time
- Understanding climate change in recent and deep geological times
- Understanding past civilization and human history
- Application of palaeosciences to exploration programmes for the oil and coal industry

BSIP is striving to attain excellence in R&D through a dedicated scientific team together with integrated innovative ideas in basic and applied research. In its broadest sense, the BSIP seeks to interpret evolution of plant life and geological processes involved, environmental evolution and climate change through time.

Initially, the BSIP laid emphasis on more fundamental aspects of Indian fossil floras, but diversified in due course to include sequence biostratigraphy, magnetostratigraphy, and geochronology to help in the correlation of surface and subsurface sediments, geochemistry, vertebrate palaeontology, palaeogenomics and exploring areas favourable for fossil fuel deposits. The main research work involves the understanding of biotic evolution through geological time. Emphasis has been made to derive knowledge about the diversification of Precambrian life; diversity, distribution, origin, evolution of Gondwana and Cenozoic flora in a phylogenetic framework, intra- and inter-basinal correlation during Gondwanan and Cenozoic time-slices and work on organic petrology to evaluate the quality of Gondwana coals and Cenozoic lignites for their economic utilization, besides depositional conditions is well under way. In addition, research is being carried out on the origin, evolution, diversity, distribution of Mesozoic-Cenozoic vertebrate fauna in a palaeogeographic context. Understanding the link(s) between climate change and vegetation during the Quaternary Period is also an important part of research at the BSIP. Research on tree-rings to deduce palaeomonsoon/climatic fluctuations are significant aspects studied at the institute. Further, dating and study of samples for archaeobotanical research including ancient DNA analysis that are critical to understand the co-evolution of culture and civilization are also been carried out at the BSIP. Geological samples including fossils of both flora and fauna are constantly been explored at various locations across the country to study towards fulfilling the BSIPs mandate. In addition, geological samples have also been collected from the polar (Arctic/Antarctic) regions. The museum of the institute offers a rich repository of fossils collected from India and the ones received from abroad. A special attraction is the Foundation stone itself, put up in 1949, with 77 fossils inlaid. The Institute has a rich collection of literature on palaeosciences. With the newly widened research mandate, the Institute has acquired the TL/OSL system useful for precise dating of archaeological artefacts and Quaternary sediments. The IRMS, ICP-MS, GC-MS, XRF, TFIR systems have been recently added for geochemical analyses, besides the establishment of the Palaeomagnetic Laboratory, Vertebrate Palaeontology and Preparation Laboratory, Ancient DNA laboratories, FE-SEM Laboratory, Confocal Laser and Raman Spectroscopy Laboratory and Industrial Micropalaeontology Laboratory. The institute publishes a journal 'Journal of Palaeosciences' of international repute. The Institute, now renamed as the Birbal Sahni Institute of Palaeosciences, is presently functioning as an autonomous research organization under the aegis of the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India.

CSIR-CENTRAL BUILDING RESEARCH INSTITUTE (CBRI)

The CSIR – Central Building Research Institute (CBRI), Roorkee in Uttarakhand is one of the premier Institutes of India, providing innovative solutions to all aspects of building science and technology. Commencing as a Building Research Unit in 1947, the unit transformed into an institute of the Council of Scientific and Industrial Research (CSIR) in 1950 and in Feb. 2022, CSIR-CBRI completed its 75th anniversary. CSIR-CBRI works as a world-class knowledge - base for providing solutions to all areas from habitat planning to building construction, including building materials, technology, disaster mitigation, fire engineering, repair and rehabilitation of deteriorated buildings, etc. Fire research is the only laboratory in the country where state-of –art facilities for fire testing of full scale building components are available; for example: testing of roof slab, false ceiling, floors, glass and other building elements etc. The main thrust areas of the Institute are: housing for all and shelter planning, energy efficient buildings, advanced materials, waste to value added building products, automation in construction, disaster mitigation, heritage structures, structural health monitoring of buildings, building acoustics, repair and rehabilitation of deteriorated buildings, etc.

In order to address housing shortage in a time-bound manner, the conventional system of housing construction is not adequate to achieve the target by 2024. Hence, there is a need to look for new emerging, disaster-resilient, environment friendly, cost- effective and speedy construction technologies which would form the basis of housing construction in India. To meet the challenges being faced in Mass housing, a considerable leap in knowledge in many disciplines of architecture, urban, rural & regional planning, social sciences, engineering, and information technology is required. With the explicit purpose to bridge the gap in practice through innovation that meet six basic principles of safety, functionality, sustainability, aesthetics, speed and economy, well-conceived holistic R&D programs have been taken-up recently at CSIR-CBRI to reinforce the National Mission of Housing for All and others in line with Government of India Missions and Programs.

To introduce standardization in housing using the concept of modular coordination complying performance parameters e.g. space efficiency, climate responsiveness, energy efficiency, disaster resilience and cost effectiveness; a study on 'Standardization of designs and layouts of prefab housing units' has been conducted at the Institute in which typology house designs for EWS, LIG and MIG categories with improved thermal and energy performance were considered. Based on this, a Book on 'Structural Designs and Detailing for Confined Masonry EWS Houses has been published by CSIR-CBRI. This book can be used by any user as Ready-Reckoner for design of one to four storey buildings in different seismic zones of the country.

As the construction industry is one of the major waste producers in all countries; to reduce the demand - supply gap in construction sector, recycling and reuse of waste arising from construction and demolition is addressed through studies on recycling of agricultural / industrial / solid wastes for building infrastructures.

The innovative materials and technologies developed for building construction during the past 3-5 years are demonstrated in "Construction Technology Demonstration Park" at CSIR-CBRI Roorkee. Numerous technologies are being evaluated for different functional tests viz. water tightness, acoustics, thermal comfort, axial/lateral loads etc. The emerging technologies being evaluated are: Precast Hybrid buildings, Confined Masonry, Cold Form Steel, Dry Construction, Bamboo Housing System; 3-S Precast Building System; Insulated Concrete Formwork system, prefab steel housing building; and stay-in-place formwork system.

The other research outcomes in the form of materials / products/technologies are:

(i) Bricks made from recycled masonry aggregates /recycled concrete dust using C&D wastes, Agro-waste based gypsum hollow core blocks and RC Planks & Joists Roofing

The bricks and blocks made from Construction and Demolition (C&D) waste, gypsum hollow core

blocks, expanded clay aggregates blocks, RC Planks and Joists system for flooring / roofing etc. have been used in the low-energy demo building at CSIR- CBRI Roorkee.

(ii) Expansive mortar for silent cracking of stones

Expansive mortar is a soundproof, safe and non-explosive demolition agent; the major chemical constituent is calcium oxide and a low percentage of other additives.

1/2-M^3 M60 Concrete sample cracked in 12h

Cracking pattern of CBRI formulation cracked after 15h

Cracking pattern of CBRI silent cracking mortar.

(iii) Expansive mortar for silent cracking of stones

Expansive mortar is a sound proof, safe and non-explosive demolition agent; the major chemical constituent is calcium oxide and a low percentage of other additives.

Expansive mortar does not contain any harmful compounds; it can be safely used while providing controlled expansion or cracking. The expansion capacity of mortar is tunable and can break from soft stone (Sandstone) to hard stone (Granite). The technology has been transferred to M/s Asia Pacific Export, Jodhpur. The Salient Features are: (a) Eco-Friendly, (b) Controlled Expansion (in terms of time), (c) Non- Explosive, Safe & Sound proof, (d) Cost- effective, (e) Non-hazardous, and (f) Sustainable solution.

(iv) Process Know-how on the Manufacturing of Silica Nanoparticles (SNPs), are being used for achieving high performance in the cementitious system thereby enhancing the service life of concrete structure.

Nanomaterials are gaining widespread attention in construction sector so as to exhibit enhanced performance of materials in terms of smart functions and sustainable features. Silica nanoparticles (SNPs) are being used for achieving high performance in the cementitious system thereby enhancing the service life of concrete structure.

The salient features are: (a) Speedy Construction, (b) Enhanced durability, (c) Improved ITZ, (d) Reduced GHG emission, and (e) Natural resource conservation.

(v) Wall-climbing Robots

AIMS/FCP-MA group of CSIR-CBRI, Roorkee developed two prototypes of wall- climbing robots for inspection of ferrous structures and cleaning of glass façades. The first prototype product presents a wall-climbing robot based on coupled magnetic wheel and arm-type locomotion mechanisms with 5-10 kg payload and peak speed of 10 m/min. The robot can have potential applications for routine/periodic inspection of the inaccessible location of ferrous structures. The developed glass façade cleaning robot (GFCR) includes its unique design concept, dynamic modelling, and control strategies for efficient coverage path planning. The robot has 10 kg payload and peak locomotion speed of 5 m/min. The GFCR can have potential applications for cleaning high-rise glass façade buildings and photovoltaic (PV) solar panels.

(vi) Affordable Modular Mobile Crane

The developed affordable modular crane has a lifting capacity of 2000 kg-m to a height of 12 meters when the crane is standing at the ground level. The mobile crane is designed based on the modular concept; therefore, this concept may be scaled up for more height and boom length for high-rise construction without shifting to the floor level. Similarly, the crane design can be scaled down to work in confined places or at different floor levels of the building.

(vii) Underground Horizontal Boring Machine

The purpose of the machine is for laying underground services (sewer pipelines, conduits, water pipelines etc.) without disturbing the surface structures. The developed machine is of portable type and can bore maximum of 160 mm diameter holes up to a length of 20 m at a depth of 1 m below the surface. The machine requires low maintenance. The machine is capable of making underground horizontal bores in dry state using open flight auger and in wet state using combination of cutter and water jet. The required power for operating the machine is 3.0 HP (single phase). The technology has been transferred for commercialization.

(viii) Semi-automatic Wall Plastering Machine

The plastering machine for plastering of vertical walls economically and effectively has been developed at CSIR-CBRI. The machine consists of an VFD controlled motors, gear box, chain drives etc. and has been validated through testing in real-time environment. It can plaster wall height of 3m and 1.4m width in one go with openings for windows and doors. Uniform quality of plater and excellent finishing can be achieved using the machine. It is portable, easy to transport & install, economic and less labour intensive. It can plaster any length of wall and enhances speed of plastering.

(ix) Trenchless Mechanized Retrofitting System for Sewerage Pipe Lines

The integrated trenchless solution for damage identification and mechanized retrofitting of domestic buried sewerage pipelines of diameter ranging 75 mm to 300 mm has been developed by CSIR-CBRI. A front-mounted camera of the retrofitting system assesses the damage inside the sewer pipes. The retrofitting of the damaged part of buried pipe is achieved by a developed mechanism which applies fibre reinforced polymer (FRP) composite sheet with epoxy and hardener inside damaged portion of the buried pipe line. The retrofitted sewer pipe can be resumed after 3-4 hours of applying the impregnated GFRP composite.

The other environment friendly materials/products/technologies are as follows:

- Internal Fuels Based Eco-friendly and Energy Efficient Burnt Clay Bricks
- Hemp Concrete from Agro – forestry waste

- Geopolymer concrete brick and blocks using fly ash, slag, red mud, wastes
- Building blocks and tiles using Kota stone waste
- Light weight blocks using expanded clay aggregate
- Standalone air disinfection system for indoor spaces,
- High Strength Plaster using FGD Gypsum
- High volume fly ash gypsum composite plaster using fly ash
- Alternate aggregates (M-sand) for construction using steel and iron slag
- Fire retarding coatings, structural fire behaviour of materials, reaction to fire characterisation of materials and numerical simulation
- Collapsible and foldable type lightweight shelters as temporary / Make-shift hospitals for the Covid-19
- Multifunctional coatings, Cathodic protection & prevention, corrosion inhibitors, chemical admixtures, hybrid rebar couplers,
- Imaging of concrete and masonry structures using ultrasonic, and many more.

Apart from these, CSIR-CBRI has completed construction of about 6 lakh houses using S&T intervention and CBRI technologies in Orissa state and conducted training of 4500 engineers of different states of the country on multi-hazard resistant housing construction during the past three years.
The other notable contributions of the Institute are:

(i) CSIR Guidelines on Ventilation and Air Disinfection Solutions for Residential and Office Buildings for Mitigation of SARS-CoV-2 Transmission - Version 2.0.

(ii) Quality Assurance works of New Parliament Building and Central Vista Avenue Development, New Delhi, Atal Akshay Oorja Bhavan, New Delhi.

(iii) 3D structural analysis and foundation design of Shri Ram Mandir, Ayodhya, and Reconstruction of schools, hospitals and other types of buildings in Nepal after earthquake.

Furthermore, being located at the gateway of the Himalayas, CSIR-CBRI has been engaged in providing solutions to natural disasters like earthquakes and landslides. The institute is contributing immensely towards landslide hazard and risk assessment of landslide prone zones of Himalayas; slope stability and design of control measures for construction of vital infrastructures, development of sensors and web based landslide monitoring for early warning etc.

Since 2010, CSIR-CBRI is also offering M.Tech. and Ph.D. programmes on "Building Engineering and Construction Technology" under the aegis of Academy of Scientific and Innovative Research (AcSIR) for the bright engineering and science students. In addition, the institute is also imparting technical training to UG/PG students in the field of building science & technology and its allied areas for better "technical know-how" and also providing skill development programme to the engineers of different organisation for best construction practices to build disaster resilient and environment friendly buildings and infrastructures.

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES (INCOIS)

Indian National Centre for Ocean Information Services (ESSO-INCOIS), Hyderabad is an autonomous body under the Ministry of Earth Sciences, Government of India *mandated to provide the best possible ocean information and advisory services to society, industry, government agencies and the scientific community through sustained ocean observations and constant improvements through systematic and focused research*.

ESSO-INCOIS provides ocean information, warnings, advisories, and forecasts to various stake holders namely fisher folk, the coastal population, government agencies involved in coastal zone management and disaster management, the shipping industry, the oil and natural gas industry, the Indian Navy, the Coast Guard, researchers, academia and students. Advisories, forecasts and are disseminated in local languages through the ESSO-INCOIS website, email, SMS, Village Information Centers, local radios, local TV channels, Electronic Display Boards installed at major fish landing centres, websites of NGOs, social etc. 'Sagar Vaani' downloadable from the Google Play store is a single platform app that conveniently provides all INCOIS services at user' fingertips.

ESSO-INCOIS provides three main services viz.

- **Tsunami Early Warning Service** provides round the clock services to the coastal population and national and state disaster management agencies through the state-of-the-art Tsunami Early Warning Centre established in 2007, following the devastating Indian Ocean Tsunami in 2004. The tsunami warning system utilizes data from national and international networks of seismic stations, sea-level gauges and tsunami buoys, detecting earthquakes and providing warnings on tsunamis, if any occur, within 10 minutes of the earthquake. The centre is considered the best in the world and specializes in alerting only affected locations rather than putting whole coastlines on alert.
- **Potential Fishing Zone Advisory Service** providing special maps and related information about all 14 sector's of India's coastline, in local languages to fisher folk on a daily basis to guide them to locations where they can find abundant fish. Currently, ***almost 7 lakh*** fisher folk are using this service, as these advisories help to locate fishing grounds without wasting fuel and time in searching.
- **Ocean State Forecast (OSF) Service** provides forecasts of ocean waves, ocean currents, sea surface temperature etc. These forecasts cover the next 5-7 days and are provided on a daily basis to fisher folk, the shipping industry, the oil and natural gas industry, the Navy, the Coast Guard, etc. to ensure safety at sea. High Wave Alerts and Warnings during onset of cyclones are provided jointly with IMD. Additionally, value added products ex. the Search and Rescue Tool and Online Oil Spill Advisory are also provided
- INCOIS services are supported by a world-class **high performance computing system and dedicated data communication networks**.
- The **International Training Centre for Operational Oceanography (ITCOocean) at** INCOIS provides training to ocean scientists from all over the world. This training centre was set up with a Memorandum of Agreement (MoA) with UNESCO.

NATIONAL CENTRE FOR POLAR AND OCEAN RESEARCH (NCPOR)

National Centre for Polar and Ocean Research (NCPOR), an autonomous organization under the Ministry of Earth Sciences (MoES), Government of India, is India's premier R&D institution responsible for the country's research activities in the Polar and Southern Ocean realms.

Mission mandate of NCPOR is to plan, promote, co-ordinate and execute the entire gamut of polar science and operational activities of the country in order to ensure a perceptible and influential presence of India in the polar regions and to uphold our strategic interest in the global framework of nations engaged in the studies of the polar regions and surrounding oceans

The NCPOR activities are truly global in nature and it mandate includes the following:

- Leadership role in niche areas of scientific research in the domain of polar and ocean sciences.
- Facilitatory role in the scientific research activities being undertaken by several national institutions and organizations in Antarctica, Arctic and Southern Ocean as well as in Himalayas.
- Management role in all operational and logistics activities related to the annual Indian Expeditions to the Antarctic, Arctic and Southern Ocean.
- Management and upkeep of the Indian Antarctic Research Bases “Maitri” and “Bharati”, and the Indian Arctic base “Himadri” as well as the “Himansh” base in Himalaya.
- Lead role in the study of benchmark glaciers and its hydrological impact in the Western Himalaya
- Lead role in the deep ocean survey and exploration for hydrothermal minerals under the Deep Ocean Mission, geoscientific surveys of the country's exclusive economic zone, extended shelf, Arabian Sea drilling and the Indian Ocean Geoid Low.
- Management of the Ministry's research vessel ORV Sagar Kanya as well as the other research vessels chartered by the Ministry

The NCPOR activities are spread across from frozen poles to warm tropics, from deep ocean to interior of Earth, from troposphere to upper atmosphere.

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130. Tectonothermal evolution of the Lohit Valley, Eastern Himalaya: New Low-Temperature Thermochronological Constraints
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185. Synthetic studies using an in-house Acoustic Full Waveform Inversion (AFWI) code
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188. Tomographic Imaging to identify the Sub-basalt Sediments and Active Tectonics in the Narmada-Tapti Rift Zone, Central India - a Review.
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189. Conservation of Geoheritage sites in Himalaya: Siwalik Fossil Park, a case history
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190. Signatures of a 17th century great earthquake at Hime village, Subansiri river valley, Eastern Himalayan Front, India
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193. Thermal conductivity at elevated temperature and physical properties of the granitoids from the Singhbhum and Bundelkhand Cratons, India: Implications on crustal thermal modeling
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195. Gender Equity in Geosciences
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196. Geomagnetic signatures associated with the Hunga-Tonga Volcanic eruption event on January 15, 2022
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197. Dynamic Rockfall Analysis of NE Region: Prediction and Prevention
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198. Machine learning passive Seismic imaging
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Keynote

Evolution of the Ladakh-Karakorum Magmatic Arc: evidence of subduction, accretion and obduction processes

Talat Ahmad
Wadia Institute of Himalayan Geology, Dehradun
Email: tahmad001@gmail.com

The Ladakh-Karakorum terrain is marked by the presence of Indus Suture Zone in the south and the Shyok suture zone in the north. The Indus suture zone encompasses the Nidar ophiolite and the Zildat ophiolitic mélange zone in the eastern Ladakh and Dras volcanic arc sequences and the Shergol ophiolitic mélange. These are followed by Indus formation sediments followed by the Ladakh batholith. The Shyok suture zone comprises of Shyok and Nubra volcanics followed by the Karakorum Batholith. The two suture zones are the remnants of the Neo-Tethyan ocean, preserved as the Zildat and Shergol ophiolitic mélange zones in the Indus suture zone. These mélange zones preserve N-type MORB and Ocean Island Basalt (OIB) indicating their derivation from N-MORB sources at shallower mantle regions at the Tethyan ocean ridges and the OIB were derived from deeper mantle sources represented by asthenosphere upwelling. The Nidar and Dras island arcs represent intra oceanic arc systems derived because of within ocean subduction of one part of the Neo-Tehthyan ocean under the other. This caused arc magmatism with little enrichment of the incompatible trace elements. It is observed that there is maturity of the arc from south (Nidar-Dras) towards north represented by the Ladakh batholith. This is indicated by compositional variation from more mafic to more felsic components, the Ladakh batholith is represented by granodioritic to granitic components but like the mafic rocks these granitoids have very little enrichment expected in intra-oceanic Mariana type subduction scenario. As opposed to the magmatic rocks of the Indus suture zone, the magmatic rock of the Shyok suture zone represents Andean type arc magmatism, with severe enrichment of the incompatible trace elements including the rare earth elements (REE). This enrichment is caused because the northern portion of the Neo-Tethyan ocean got subducted under the southern margin of the Tibetan / Eurasian plate, which was more of continental crust which supplied fluids and incompatible trace elements to the Shyok and Nubra magmatic arc. The Karakoram batholith also show enrichment of incompatible trace elements unlike the Ladakh batholith. Thus, the Ladakh-Karakoram region represent sequences of Intra oceanic Mariana tyke arc and Andean type continental arc.

Genesis of the interplate earthquakes occurring in the Uttarakhand Himalayan seismic zone of India

Prantik Mandal
CSIR-National Geophysical Research Institute, Hyderabad - 500007
Email: prantikmandal62@gmail.com

The Uttarakhand Himalaya, located in the central Himalayan GAP area, is the only part of the Himalayan frontal arc to have experienced two major earthquakes, the 1505 M_w8.5 and the 1803 M_w7.8. In addition, two moderate-sized earthquakes, the 1991 M_w6.8 Uttarkashi and 1999 M_w6.5 Chamoli, occurred in the Uttarakhand Himalaya. Since October 2017, the CSIR-NGRI in Hyderabad has been monitoring the Uttarakhand seismicity with a dense seismic network of 60 three-component broadband seismographs. Using earthquake data from the aforementioned seismic network, we performed seismic velocity tomography and the joint inversion of radial P-receiver functions (PRFs) and fundamental mode group velocity dispersion data of Rayleigh waves to delineate the detailed crustal and lithospheric structures beneath the region, in order to comprehend the earthquake generation processes involved in India's Uttarakhand interplate seismic zone.

Our seismic velocity tomography in the Uttarakhand Himalaya revealed a north dipping (~ 2°) low-velocity zone at 10-20 km depths that coincided with the main Himalayan thrust (MHT). The majority of the current micro-seismicity has been mapped to be confined along the MHT. Our modelling also revealed that the 1999

Chamoli earthquake zone is characterised by a low-velocity zone (low V_p, low V_s, and high V_p/V_s). As a result, we believe that the presence of metamorphic or aqueous fluids within the MHT triggered the 1999 main event and recent micro-earthquakes. We also mapped a double Moho structure beneath the epicentral zone of the 1999 Chamoli earthquake using the Common Conversion Point (CCP) stacking of radial PRFs, which is thought to accumulate large crustal stresses to facilitate the occurrence of moderate to large earthquakes in the region.

Our H-K stacking of radial PRFs and joint inversion of radial PRFs and the group velocity dispersion of Rayleigh waves have modelled three NNE-SSW trending transverse crustal blocks with marked thinning of mafic crust, which are modelled to extend down to the lithosphere-asthenosphere boundary. These three transverse lithospheric structures correspond to the northward extension of the Delhi-Haridwar ridge, the Moradabad fault, and the Great Boundary fault, respectively. As a result, we propose that these transverse structures may have segmented the lithosphere (below the MHT) in the Uttarakhand Himalaya, reducing the available rupture lengths and thus the probability of future great earthquakes (M8) in the region.

Climate Change and Extreme Weather Events

M. Mohapatra
India Meteorological Department, New Delhi
Email :m.mohapatra@imd.gov.in

The economy of India and it's growth are adversely affected by the extreme weather events like *(i)* drought & flood, active and break cycle of monsoon, heavy rainfall leading to flash floods and landslides, *(ii)* cyclones during pre and post-monsoon seasons, (*iii*) heat & cold waves, *(iv)* thunderstorm and lightning etc. India being largely an agrarian economy, the monsoon rainfall distribution and intensity in the country have a significant impact on the socio-economic sectors, especially agriculture, hydrology and power besides other ecosystems. However, the frequency and intensity of the extreme weather events are also changing under the influence of the climate change. The average annual mean temperature over Indian landmass during 1901-2021 showed an increasing trend of 0.63^0C/100 years with a significant increasing trend in maximum temperature (0.99^0C/100 years) and a relatively lower increasing trend (0.26^0C/100 years) in minimum temperature. Although there is inter-annual variability, the total precipitation during the Indian summer monsoon has remained largely stable with interannual variations, there have been significantly increasing trends of heavy rainfall events in India leading to increasing flood conditions. The increasing trend in interannual variability has led to increased frequency of both floods and droughts in the country. The longer and more intense heat waves are becoming increasingly frequent in India due to climate change. Increasing trends in the Heat Wave are observed over most of the stations except a few stations in the plains along the foothills of the Himalayas, southern parts of central India, and east India, which showed decreasing trends. The duration of heat waves over central and northwest India has increased by about five days over the past 50 years. The number of cold wave days shows decreasing trend at most of the stations. The frequency of cyclonic disturbances (Depression and cyclonic storms) over the north Indian Ocean shows decreasing trend both during the monsoon season and post-monsoon season. However, there is an increased trend in frequency of extremely severe cyclonic storms over the Arabian Sea since 1990s. There is increasing trend in frequency of thunderstorms along with cloud-to-ground lightning activity. Based on various projections, climate change may lead to further increase in the frequency and intensity of these hazards. Thus, the socio-economic impacts of extreme weather events such as floods, droughts, heavy rainfall, cyclones, heat waves, thunderstorms, and lightning are likely to increase under the impact of climate change.

Recently, IMD has taken major steps in improving the weather, climate, and hazard warning services capabilities in the country. With the improvement in observational and forecasting tools including augmentation of numerical weather prediction models, Radar network and satellite products, forecasting/warning services in respect of severe weather including tropical cyclones, heavy rainfall, thunderstorms, flash/urban floods etc have shown significant improvement in the skill and lead time.

However, in the backdrop of climate change there are major challenges to the prediction of severe weather and its risk reduction at local/regional scales. Considering this, IMD has introduced impact-based forecasts and risk-based warnings in recent years and plans to augment in further. The IMD continuously enhances and upgrades all components of early warning system including meteorological observations, numerical modelling, forecasting, early warning and communication and computational infrastructures so as to enable the disaster managers, stakeholders and general public to minimise the loss of life and property based on early warning.

Geology of Floods in the Himalaya: an overview

Pradeep Srivastava[1*], Pankaj Sharma[2], Sandeep Panda[2], Anil Kumar[2], Poonam Chahal[2,3], Saurabh Singhal[2]

[1]Department of Earth Sciences, Indian Institute of Technology-Roorkee, 247667
[2]Wadia Institute of Himalayan Geology, Dehradun, 248001
[3]The Institute of earth Science, Hebrew University of Jerusalem, Israel
[*]Email: pradeep@es.iitr.ac.in

The increasing frequency of large floods and population in Himalaya compounds the fragility of this active mountain belt into successively bigger hydrological disasters. The historical and geological records of floods archived in the sediments and the flood landscape inform greatly on how the continental scale geology of Himalaya controls the flood magnitude and pattern of landscape and societal damage. The large scale geology of Himalaya as is composed of several southward propagating thrust sheets that are separated by major thrust zones like the Main Central Thrust (MCT), the Main Boundary Thrust and the Himalayan Frontal Thrust builds a unique orography. It is the geometry of the Décollement of Himalayan wedge that induces duplexing below the MCT zone and steep rise in the topography that acts as an orographic barrier to northerly trajectory of the Indian summer monsoon (ISM). The geomorphic investigations after the 2013 Kedarnath floods exhibited damage zone clustering over this zone that implied predictable linkages between midcrustal ramp and intensity of flood hazard. This also indicated that in ISM dominated southern Himalayan front, the flooded rivers largely erode and exhume the Higher Himalayan Crystalline core. Similarly, the continental scale geomorphology of the Southern edge of Tibet seems forcing the flood intensities in the rivers Indus and the Brahmaputra that are orders of magnitude higher in the later catchment. The large part of these rivers drain through drier northern front of Himalaya and the knowledge on their water-sediment routing, erosional hotspots and ISM-flood dynamics is much warranted.

Geochronology, sediment and provenance studies on the Slack Water Deposits (SWDs) preserved along the rivers like the Indus, the Brahmaputra provided a detailed geological perspective on (i) what are flood magnitudes in these rivers and what controls the difference? (ii) In case of large floods where these rivers erode the most? (iii) How ISM variability controls the flood frequencies in these rivers? (iv) do the floods control Human migration? The talk will dwell on the field and laboratory datasets and will attempt answer these questions.

Earthquake Generating Processes beneath the Himalayan Region and Risk Mitigation Strategy

O.P. Mishra
Director, National Centre for Seismology, Ministry of Earth Sciences
Email: opmishra2010.saarc@gmail.com

Earthquake-generating processes associated with the Himalayan region's seismotectonic settings are significantly controlled by drastic changes in the structural heterogeneities estimated in terms of seismic velocity and seismic attenuative characteristics of the source zones that were witnessed by several strong to

mega earthquakes cause gigantic losses to both flora and faunas. It is intriguing to note that locations of past pre-instrumental earthquakes posed a serious constraint in demarcating the affected earthquake zones to assess the degree of earthquake shaking. Recent studies demonstrated that the nature and extent of intricate Seismogenesis beneath the Himalayan region are dictated by the known seismogenically active regional faults beneath the Himalayas, besides the ambient structural heterogeneities, which have a pivotal role in earthquake rupture initiation, propagation, and termination differently in its different segments of the Himalaya from north-west to north-east, which in turn suggests adopting a comprehensive earthquake risk mitigation strategy for sustainable development of the region by reducing recurrences losses of lives and properties during earthquakes.

During the presentation, various aspects of earthquake-generating processes derived from the recent independent seismological and geophysical studies will be discussed to arrive at a conclusion for making the Himalayan earthquake risk resilient through a better understanding of the Seismo-tectonic vulnerability of the region.

Impending threat of great Himalayan earthquakes and how to deal with it

Vineet Gahalaut
CSIR-National Geophysical Research Institute, Hyderabad - 500007
Email: vkgahalaut@yahoo.com

The Himalayan arc, the highest and longest subaerial accretionary prism on the Earth, although may appear generally uniform all along its ~2500 km length in terms of geography, climate and topography, it exhibits variations along it in terms of earthquake occurrence processes both in time and space. The subaerial nature of this accretionary prism, making it accessible all along its arc length, also provides ample opportunity to launch experiments to understand the details of subsurface structure and geodynamic processes which govern the seismogenesis. Although, in past few decades significant attempts have been made towards this, our understanding of seismogenesis and the impact of earthquakes on the built up environment is very limited. In part this could also be due to the complexity of this accretionary prism, arising because of continent-continent collision/subduction. In the known history of Himalayan earthquakes, we have witnessed a large variation in their occurrence processes. Thus, just assuming a repeat of past event and developing earthquake damage scenario on that basis, is not going to help. We need to develop earthquake damage scenarios considering all the possible variations in the earthquake processes. Other than requiring good understanding of past earthquake rupture processes, we will also require precise delineation of the subsurface geometry of the seismogenic faults, variation in the lithology and rheology, structures governing the rupture limits, quantification of dynamic forces and their response on the subsurface structure (in terms of coupling), variation in strain accumulation, etc. So my take on dealing with the earthquake threat is to work towards earthquake damage scenarios as this will force us to improve our understanding on the process and collect more data needed for this, with the sole aim of mitigating seismic hazard.

Landslide and related hazards in the present climate change scenario in the Himalaya: a way forward for sustainable development

Vikram Gupta
Wadia Institute of Himalayan Geology, Dehradun - 248001, Uttarakhand
Email: vgupta_wihg@yahoo.com

Landslides and related hazards are ubiquitous phenomena in the Himalaya and have been occurring since the geological past. These phenomena cause irreparable loss to the environment along with the loss of numerous

lives and damage to property worth Crores of Rupees. It has been observed that over the years, there has been an increase in the frequency and magnitude of these phenomena resulting in increased losses to lives as well as damage to the environment. These are primarily because of the change in the climatic pattern and the increased vulnerability in the region.Though there are many causes for the occurrence of these 'hazards,however, these are generally triggered by excessive rainfall, earthquake, or anthropogenic intervention.

In the present-day climatic change scenario, there is a shift in the rainfall pattern in the form of advancement of rainfall towards the north, increasing the area under the influence of rain, and an increase in the frequency of the concentrated rainfall, including cloudbursts. The developmental activities in the form of construction of dams, tunnels, bridges, new road cuts and widening of the existing roads, and increasing tourism activities are continuously growing the vulnerability in the region. It is, therefore, necessary to evaluate therisk that is the cumulative effect of the hazard and vulnerability of the area, and the risk must be minimized either by reducing the hazard and/or the vulnerability of the region. In this context, landslide hazard and susceptibility maps at regional and local scales play an essential role.

Over the years, many developed countries have developed their own hazard maps atdifferent scales,and their landuse policy in terms of kind of development and the price of the land is linked to these hazard maps. For the fastest-growing economy like ours, where rapid developmental activities are continuing in the Himalaya, it is essential to have these kinds of hazard maps. Therefore regional scale hazard maps for the state of Himachal Pradesh, Uttarakhand, and Sikkim Himalaya and local scale hazard maps for the different transacts of the various river valleys have been prepared using state-of-the-art machine learning algorithms. Besides, large-scale maps at the municipal ward level scale for the Mussoorie and Nainitaltownships in Uttarakhand have been prepared, indicating the potential hot spots for possible development of slope instability.

Landslides and slope failure along the drainages in the higher constricted mountainous terrain often block the drainages. These have cascading effects downstream, as evidenced during the 2013 Kedarnath disaster and 2021 Chamoli disaster (Uttarakhand). It is, therefore, essential to assess the *hotspots* for the occurrence of large slope failures. Thus, the present study evaluates the possible slope failures along the drainages that might create landslide dams. Their stability was assessed using geomorphic indices like the morphological obstruction index and hydromorphological dam stability index (HDSI). These *active landslide hotspots* and the potential sites for *developing landslides* must be considered for landuse planning for the sustainable development of the area.

Landslide Risk Reduction: Developments and Issues for Preparedness

Debi Prasanna Kanungo
CSIR-Central Building Research Institute, Roorkee – 247667, Uttarakhand
Email: debi.kanungo@gmail.co; dpkanungo@cbri.res.in

Landslide disaster is one of the major recurrent concerns in Himalayan terrain during monsoon season. Such disasters pose risk to lives and all sorts of vital infrastructures such as human settlements, roads, rails, tunnels, hydro-power projects etc. All the existing and sustainable developmental infrastructures in hilly terrain need proper attention and integration towards landslide risk reduction. The present lecture aimed towards landslide risk reduction stresses upon some of the pertinent developments and issues on vulnerability-risk assessment, debris flow hazard assessment and early warning system for better preparedness. This will help the society in reducing landslide risk with a vision of sustainable infrastructural development in difficult terrains.

Climatic variability and landscape development along the southern Thar Desert margin: Insights from late Quaternary sequences

L. S. Chamyal
Department of Geology, The M.S. University of Baroda, Vadodara - 390002, Gujarat
Email: lschamyal@yahoo.com

The ubiquity and diversity of sediment records and morphological expressions in different hydroclimatic regions of India provide clues to the landscape development and climate-tectonic variability on longer Quaternary time scales. Rivers play a significant role in shaping the landscape, eroding and depositing sediments in the pathways with varied response time. From uppermost catchment regions to the downstream, lowland areas in the fluvial systems, sediment sequences give insight into the environmental changes, sediment supply and flood discharge, hillslope and soil formation processes across the late Quaternary. In the Southern Thar Desert Margin (STDM) region, the landscape evolution is manifest as distinct geomorphic surfaces attributed to the collective role of climatic, tectonic and sea level changes that have occurred since the late Pleistocene. The fluvial systems have responded to major climatic perturbations and changes in the southwest monsoon regime during the late Quaternary. Investigations on the sediment records have revealed a major change in the late Pleistocene and the Holocene fluvial landscape such that the form and dimensions of present-day rivers are very different as compared to their Pleistocene counterparts. The extremely variable climatic regimes during the late Quaternary are reflected in the aggradation -incision events and switch over between meandering to braided channels. The sedimentary sequences and characteristic facies exposed along the major west flowing rivers viz. Narmada, Mahi and Sabarmati and their tributaries suggest that floodplain aggradation occurred during wetter phases corresponding to the enhanced southwest monsoon at around >100 ka, 98 ka - 69 ka and 49 ka - 30 ka. Post 30 ka, the STDM witnessed a phase of regionally extensive aeolian activity followed by a phase of high precipitation, rapid rise of sea level and tectonic uplift during early Holocene. The estuarine-tidal to fluvial valley-fill sedimentation suggests phases of aggradation at 6.6–4 ka with an unstable monsoon regime and post-2 ka until the Medieval Warm Period (MWP), also substantiated by high magnitude flood records clustering at 3-2.2 ka, 1.8 ka-1.2 ka and 0.6-0.45 ka. The sediments are being incised, reworked and deposited in different fluvial domains in the present-day ameliorating southwest monsoon. However, the response of fluvial systems in other regions (Himalaya, Indo-Gangetic Plain, Peninsular India) to climatic variability during late Quaternary has been varied as compared to the STDM records. There appears to be a synchronicity in fluvial response till around 30 ka to strengthened monsoon phases that persisted for longer time across the geographical boundaries. After 30 ka an overall decrease in monsoon has been inferred however, the geomorphic response was variable related to hydrological instability and frequent fluctuations in monsoon intensity.

The recent disasters in the Uttarakhand Himalaya: a cryosphere response to climate change?

Navin Juyal
Formerly with Physical Research Laboratory, Ahmedabad
Email: navinjuyal@gmail.com

Frequent disasters in Uttarakhand Himalaya are red-flagging events which are constantly warning us about the vulnerability of the region. Given the fact that climate change become a reality, it is high time that a concerted efforts are required to investigate the climate sensitive valleys in Uttarakhand Himalaya. Perhaps the most critical region which is going to respond too sensitively and aggressively is the Himalayan cryosphere. Since the termination of Little Ice Age around A.D. 1850, glaciers worldwide showing variable recessional trend. As a consequence, large amounts of poorly consolidated sediment prone to slope failure and debris flows are being exposed. Some of the largest debris flows in recent years have had sources in newly de-glaciated areas.

Enormous emphasis is being put on understanding the paraglacial sediment dynamics. A recent study warned

that the stability of paraglacial zones both in terms of volume and timing of water delivery and unexpected sediment fluxes is going to increase under the warm earth scenario. The study cautions that these sediments are likely to fill up the reservoirs and would cause dam failures. In Uttarakhand we have already witnessed the impact on infrastructures due to the increasing paraglacial sediment mobilization in the recent decades. Needless to say, that given the numerous vulnerable valleys and multiple triggering factors, predicting the extreme weather events and protecting the people/infrastructure from their impact is a challenging task. However, armed with a fairly good number of scientists and related departments dedicated to combat the disaster, a concerted effort can certainly reduce the vulnerability and minimize the human suffering and economic loss. In this presentation, I will try to provide a summary of the work that our team did over the last two decades in the Uttarakhand Himalaya with emphasis on understanding the extreme weather events and its impact on the terrain and the people.

Glacial Hazards and Plausible Mitigation through AI/ML-based Warning System

Kalachand Sain
Wadia Institute of Himalayan Geology, Dehradun – 248001, Uttarakhand
Email: kalachandsain7@gmail.com

The mighty Himalaya is the world's youngest and most rugged mountain chain, which was initiated to evolve by the collision tectonics at an early Eocene age. The sediment-water transmits from the glaciers, snow fields and rivers system have made the Himalaya as the center stage of settlement for agro-economy and socio-cultural development. But the Himalaya is stressed by subsurface processes like crustal shortening, complex geodynamics, convergence, tectonics, neo-tectonics, rock deformation, exhumation, as well as surface processes such as weathering, erosion, solid/liquid precipitation, elevation-dependent warming, etc. The stresses have been further aggravated by the climate-induced phenomena and developmental activities. All these processes are responsible for the changes in landscape and geomorphology of the Himalaya, which in turn, control the damage pattern during a catastrophe caused by glacial avalanche and/or glacier lakes outburst flood. It has been observed that the glaciers are shrinking and glacial lakes are expanding and being formed, which pose threat to lives, livestock, structures and properties in the downstream. The ground-based hydro-meteorological data along with seismological data and remote sensing data provide useful information in understanding the glacial dynamics and characterization of glacial lake(s). Such natural phenomena cannot be stopped but their impact can be definitely reduced by developing an alert system through establishing a network of stations in the field, transmitting multiple data sets in to a centralized monitoring center, real-time processing/analysis and integration of data, developing warning system followed by alerting against such disaster. With the dense network of high-resolution data sets, availability of fast computing system, advancement of modelling approaches, integration of data using AI/ML, it is possible to develop an integrated warning system (IWS). The investment on monitoring and development of IWS would be much more cost-effective than the cost we pay for the rehabilitation, restructuring and loss of lives. We would be discussing issues related to glacial hazards and their plausible mitigation by developing an alert system based on AI/ML based approaches with a view to build a disaster-resilient society for sustainability and secured living in the Himalaya and adjoining regions.

Melting glaciers and its implications for hydrology and hazards in the Chandra Basin, Western Himalayas

Thamban Meloth*, Parmanand Sharma, Bhanu Pratap, Lavkush Patel, Sunil Oulkar
National Centre for Polar and Ocean Research, Headland Sada, Goa-403804
**Email: meloth@ncpor.res.in*

Himalayan glaciers are unique in many respects, with complex environmental settings of immense socio-

economic importance. To generate long-term in situ data and to answer critical questions related to the interplay of glacier mass balance, its impact on downstream hydrology and glacio-hydrological hazards, NCPOR initiated a long-term integrated programme on Chandra basin in Western Himalaya. Based on factors like the topographic regime, length, size, aspect, debris cover and presence of lakes, six glaciers (Sutri Dhaka, Batal, Samudra Tapu, Bara Shigri, Gepang and Kunzam) covering 306 km^2 glacier areas of Chandra basin were selected for the long-term studies. NCPOR has also established a high-altitude field station to achieve the above objectives in this basin. Five AWS systems have been operating at altitudes between 4000 and 5000 m across the basin, providing reliable in situ hydrometeorological data and enabling us to undertake reliable modelling studies. Further, several automated Water Level Recorders were installed across the basin to continuously quantify the river discharge data.

Our studies have revealed that most glaciers in the Chandra Basin have experienced a continued loss of ice mass during the last eight years (2013-22). The highest melting is observed over Samudra Tapu (mean annual smb: -1.20 ±0.24 m w.e.), a relatively large glacier, and lowest over Kunzam glacier (-0.1 m. w.e), a small glacier. Interestingly, the rate of ice mass loss is also higher in the Gepang glacier, a lake terminating small glacier. The study revealed a 15% increase in the river discharge over a 1°C rise in air temperature during the ablation period. Our study, combining field observations and a physically-based model, suggests that the mass balance of glaciers in the Chandra basin is less sensitive to changes in the precipitation phase (snow / rain), mainly because most precipitation falls as snow during the winter. Since retreating glaciers create many potentially vulnerable lakes in a warming climate, we have also mapped the lakes in Chandra basin. Among the nearly 166 glacial lakes mapped in the basin, about 30 lakes are larger than 10,000 m^2 area. While a majority of them are supra-glacial lakes, there exists many moraine-dammed, bedrock-dammed and ice-dammed lakes, many of which are continuously expanding in tandem with the retreat of the glaciers. Among these, the glacial lakes Samudra Tapu and Gepang Gath glaciers have been expanding dramatically since the last decade and may turn hazardous in future.

The Himalayan Springs: need for protection and unravelling their thermal potential

Sudhir Kumar, Soban Singh Rawat
National Institute of Hydrology (NIH), Roorkee, Uttarakhand
Email: sudhir.nih@gmail.com

The Himalayas has the biggest reserves of water in the form of ice and snow outside the polar regions. It is the source of ten of the largest rivers in Asia, and is popularly known as the “Third Pole”. These large river systems support irrigation in lakhs of hectares of agricultural land and provide drinking water to millions of rural and urban populations. However, studies indicate that about 75 % of the Himalayan glaciers are retreating at an alarming rate which is severely affecting the availability of water in the downstream areas and endangering the sustainability of water use in the earth's most crowded basins. Declining trend of water availability can be seen in the observed records of Central Water Commission (CWC) as well as remote sensing data available through GRACE satellite. Central Water Commission's 2017 data shows that between 1984-85 and 2014-15 water in the Indus River dropped by 27.78 billion cubic meters (BCM) whereas in the Brahmaputra and Ganga, it was dropped by 95.56 and 15.5 BCM, respectively. Notably, NASA's Gravity Recovery and Climate Experiment (GRACE) satellites have revealed that the Indus Basin aquifer, a source of fresh water for millions of people across India and Pakistan, is the second-most overstressed on the planet.

In the lower Himalayas, springs are the main source of water for drinking as well as for domestic usage. As per NITI Aayog report 2018, there are as many as 3 to 5 million springs in the country which can be categorized into five classes, viz., Depression, Contact, Fracture/Fault, Karast and Hot or Thermal springs. The declining glaciers extent have lesser impacts on the springs especially in the lower Himalayan region as springs are majorly dependent on the monsoon rains. In such circumstances, wherein the glaciers are retreating due to rising temperature, the role of springs in maintaining the base flow of the Himalayan Rivers is gradually

becoming more vital. Of late, the Govt. of India acknowledged the importance of springs in maintaining the demand of more than 200 million indians and constituted a working group on "Inventory and Revival of springs in the Himalayas for Water Security" for the sustainable development and management of springs.

Hot or Thermal springs are special case of springs as heating source is normally present at great depth, sometime few kilometres beneath the earth surface. Hot water, generally, appears on the earth surface through a major fault or fracture. The 'Geothermal Atlas of India' prepared by the Geological Survey of India (GSI) in 1991 described about 340 hot spring sites in seven key geothermal provinces throughout India. Besides the religious significance, since antiquity, the Indian thermal springs are also known for their curative values owing to their ability to heal certain diseases such as eczema, arthritis, rheumatoid, etc. Survey by the GSI revealed that about 113 out of 340 thermal springs hold an estimated total resource potential for generation of 10,600 MW electricity. The development of geothermal potential, especially, in high altitude areas would provide for the base load needs especially in the winter months when the regions' hydro-power stations might struggle to function efficiently due to freezing of the water supply. These thermal springs water can be directly used for maintaining the greenhouse temperature for vegetable cultivation and in small industries e.g., cold storage plant, wool washing, drying of farm products, etc. However, there is still much research needed to develop more understanding about the existence and extent of the geothermal reservoir at depth, the nature of the heat source, and the actual temperature of the fluids in the subsurface before unravelling the commercial utilization of these God's gifted resource.

Geothermal Energy in India : An overview, current status and future opportunities

Vishal V. Sakhare
Geological Survey of India, Central Region, Nagpur
Email: vishalsakhare1709@gmail.com

There are around three hundred seventy-six (376) thermal manifestations localities in India. These localities have been grouped into geothermal provinces/sub-provinces. On the basis of enthalpy characteristics, the geothermal systems in India can be classified into medium enthalpy (100-200 °C) and low enthalpy (less than 100 °C) geothermal systems. Medium enthalpy geothermal systems are associated with: Younger intrusive granites as in the Himalayas, viz., Puga-Chumathang, Parbati, Beas and Satluj geothermal fields. Major tectonic features/lineaments such as, the West Coast of Maharashtra; along the SONATA lineament zone, Tatapani in Chhattisgarh and Rajgir-Munger in Bihar, Surajkund in Jharkhand. Rift and grabens of Gondwana basins of Damodar, Godavari and Mahanadi valley. Low enthalpy geothermal systems are associated with: Tertiary tectonism and neo-tectonic activity. The deepest exploratory boreholes have been drilled up to a depth of 1000 m at Manuguru, Telangana, 728 m at Tapoban, Uttarakhand, 700 m at Manikaran, Himachal Pradesh, 643 m at Tatapani, Chhattisgarh, 500 m at Unapdeo, Maharashtra, 385 m at Puga, and 220 m at Chumathang, Ladakh, Jammu Kashmir. Thermal water discharges at a temperature of 70-97 °C from these boreholes. The geothermal reservoirs at Puga (Ladakh) in the northwest Himalayas and Tatapani (Chhattisgarh) fields in Central India hold the potential to be used for either geothermal power projects or direct heat applications on an industrial scale. Manikaran (Himachal Pradesh), Tapoban (Uttarakhand), Bakreshwar (West Bengal), Unhavre (Khed) (Maharashtra), Surajkund (Jharkhand), are the other potential sites for direct use of geothermal energy.

The ONGC Energy Center implementing a 1 MW geothermal power generation plant in the Puga valley, Ladakh. GSI and CREDA proposed to establish a 100 Kw pilot plant at the existing drilled borehole TAT-23 in Tatapani, Chhattisgarh. The SCCL in collaboration with the Shriram Institute for Industrial Research, is presently working on India's first indigenous geothermal power generation pilot plant of 20 Kw at Manuguru, Telangana. At present, India is at the nascent stage of harnessing geothermal resources mainly due to the cheap availability of coal, lack of technical expertise for geothermal power generation and high capital cost for exploration. However, with increasing environmental problems and the threat of climate change due to

excessive use of fossil fuel which may affect the survival of mankind, it is the need of the hour to harness all the available renewable energy sources.

Hydrocarbon Exploration in the Himalayas: Challenges and Opportunities

S.N. Chitnis
Executive Director, HoI, KDMIPE, ONGC
Email:chitnis_sn@ongc.co.in

Most of the Fold Thrust Belts are under-explored due to complex geology and challenging environment for exploration. Early drilling endeavours did prove occurrence of gas at Jwalamukhi but subsequently after drilling of 16 wells, commercial success was still elusive. Exploration and exploitation techniques used to evaluate the hydrocarbon potential of fold–thrust belts have in many respects evolved substantially over the last few decades. Seismic imaging and interpretation tools have improved significantly.

Fourteen Category III Indian Sedimentary basins have cumulative undiscovered risked conventional in-place of 2,481 MMtoe (DGH Report, 2019). Barring Bengal basin, the remaining 13 basins including The Himalayan Foreland and Spiti-Zanskar have no potential discovery. Under explored status, yet to find reserves and promise of good accumulation justifies further exploration in the Himalayan Fold Thrust Belt.
Himalayan Foreland Basin is having good potential on analogy with oil and gas discoveries from the Paleozoic-Mesozoic- Cenozoic sequences in the adjacent Kohat-Potwar Basin of Pakistan. Numerous Gas and oil shows in drilled wells & surface seepages indicate existence of a working petroleum system. Subathu (Paleocene to Eocene age) and Bilaspur Limestone (Neoproterozoic age) are envisaged source rocks. Based on electrolog and sedimentological studies of the well datasets in the frontal belt, it is evident that good reservoir facies are developed both within the Siwaliks, Dharamsala and Subathu Formations. Structural and strati-structural traps are likely entrapment. The envisaged entrapment styles include anticlinal structures, overthrust, decollement structures, sub- thrust, pop-up structures in the sub-surface. Four Plays viz., the Neo Proterozoic-Infra-Cambrian to Paleozoic play, Paleocene to Mid Eocene Play (Subathu), Oligocene to Early Miocene Play (Dharamsala), Mid Miocene to Pleistocene Play (Siwalik) have been identified in this Basin.

Hydrocarbon exploration in Spiti-Zanskar Basin has not been initiated yet. Though geochemical studies indicate low TOC but it is envisaged to have well preserved and complete succession of the Palaeozoic-Mesozoic sequences which are the major hydrocarbon producing formations elsewhere in the world. Drilling of a deep parametric well may throw good light on petroleum systems elements.

Broadly three types of prospects viz: Tertiary in Frontal Belt, Tertiary - Pre Tertiary in J&K Foot Hills and Lesser Himalayas beyond MBT can be envisaged in Outer Himalaya. Thick Palaeozoic - Mesozoic below the Karewa sediments are expected to have good source and reservoir facies. Second order anticlines formed by buried hinterland thrusts may be interesting for hydrocarbon exploration.

From a global perspective, Fold–thrust belts still host substantial undiscovered hydrocarbon. Though the challenges are many, it is prudent to look at opportunities which have shown glimpses of potential.

Linked mineralization and the basinal fluid systems; particular reference to the Himalaya

Rajesh Sharma
Wadia Institute of Himalayan Geology, Dehra Dun – 248 001
Present address: 164, Phase-1, Engineers Enclave, G.M.S. Road, Dehra Dun – 248 001
E-mail: rajesh_fluid@rediffmail.com

The basinal fluid systems with formation waters as major component have been invoked as the ore forming fluids, and are also found to have critical linkages with the hydrocarbons. Several studies carried out globally, including from Himalaya, signify that the distinct fluid flow systems can characteristically govern the precipitation of ore minerals even in different geological environments. The established mineralization models linked to the basinal fluids point that the diagenetic-hydrothermal systems are broadly responsible for significant mineralization, wherein the migration and precipitation of ore minerals may be a result of various processes such as the change in physicochemical conditions and mixing of the two or more fluids. Conclusive evidences from Himalaya attribute genetic linkages of basinal fluids with the sulphide occurrences mainly of Pb-Zn- (Cu) in the plateform type carbonate sequences of Lesser Himalaya, the synvolcanosedimentary mineral systems in Lesser Himalayan crystallines, the formation of semi-precious mineral in Kumaun, uranium mineralization in Himachal and for the widespread industrial minerals. A large amount of fluid inclusion and Raman spectroscopy data obtained from the sulphide assemblages as well as from the magnesite and talc mineralization, both hosted by the Lesser Himalayan Proterozoic carbonate sequences revealed that the ore forming fluids were basinal H2O–NaCl–KCl±MgCl2±CaCl2 in composition, and support the fluids mixing model. Alongside, its corroboration by the mineral chemical data of the ore minerals and their δ34S signatures also rule out the magmatic source. The reducing condition favourable for mineralization can be envisaged with the natural carbonaceous material that is not uncommon in the mineralized host rocks, eg. with the sulphides and uriniferous quartzite from the Largi-Rampur window. Another contemplation proposes leaching of the constituents both from the quartzites and overlying crystallines for the mineral localization of semi-precious stone, lazulite, in the vicinity of Main Central Thrust. Overall, the basinal burial and the recrystallization fluids are important to episodically deposit and remobilize the ores. Similarly, the understanding of the diagenetic basinal fluids is found significant in oil exploration program. They may consist of hydrocarbons, and are important for the success rate in the geological exploration.

Climate variability and Landscape evolution

Precipitable water vapour derived from GPS measurements for the analysis of heavy rainfall and severe cyclonic storm in Indian shield region

Anshuman Pandey[1*], V.K. Gahalaut[1], J.K. Catherine[1], N. Puviarasan[2]
[1]GPS and Geodesy Group, CSIR-National Geophysical Research Institute, Hyderabad
[2]Regional Meteorological Center, India Meteorological Department, Chennai
[*]Presenting author: anshuman.bhu.geo@gmail.com

The present study is an attempt to analyze GPS-derived precipitable water vapour (GPS-PWV) which has the potential for predicting and tracking heavy rainfall and cyclonic storms. GPS precipitable water vapour is a measure of the inflow and outflow of water vapours in a vertical air column above the GPS site. CSIR-NGRI is operating 13 permanent GPS stations along with the meteorological sensor in the Indian shield and central region. We also used data from IMD stations. Using the GPS positional and meteorological data for each station for a time duration of five-year (2013-2017), total wet and zenith delay are calculated which leads to deriving GPS-PWV values. We found a good correlation between PWV values and rainfall in a region. An accelerated value of GPS-PWV is observed during heavy rainfall and severe cyclonic storm. We observed an increase in PWV before the heavy rainfall of 202-315 mm/day. The corresponding PWV is in the range of 25-58 mm before the heavy rainfall event which decreases after the rainfall. Encouraged by these correlations, we studied the PWV signatures of the OCKHI-2017 cyclone through data from three stations that are close to the cyclone track (KYKM, MCOY, and TRVM). The PWV value is observed as 13.53-18.13 mm corresponding to the cyclone-induced rainfall of 19.55- 43.6 mm/hour at the time of the cyclonic storm at KYKM and MCOY sites. In conclusion, we found a good correlation between the rainfall, humidity, PWV values, and GPS positional error at the considered stations as the cyclone approaches.

Characterizing spatial variation in the landscape along the Indo-Burmese range: understanding the role of tectonics and climate in evolution

Arindom Gogoi[1,2*], Anand K. Pandey[1,2], Prabha Pandey[1,2]
[1]CSIR-National Geophysical Research Institute, Hyderabad - 500007
[2]Academy of Scientific Innovation and Research, Ghaziabad - 201002
[*]Presenting author: arindom.gogoi9@gmail.com

Indo-Burmese Range resulted from the oblique convergence of the Indian plate and Eurasian plate. The northward motion of the Indian plate is being accommodated into the Indo-Burmese Range (IBR) at a rate of ~17mm/year and gives rise to a mountainous topography with structurally and geomorphically distinct litho-tectonic units, namely basement core, bounded by steeply dipping transpressional reverse faults with dextral shearing (Kabaw Fault) towards East, followed Westward in the form of Inner and Outer structural wedges with progressive thin-skinned tectonic setup. Within the IBR, the core experiences seismicity with focus at intermediate depth (70-200 km), and the focus gradually becomes shallow (0-30 km) towards the outer wedge. The entire landscape is dominated by a structurally controlled trellis drainage pattern, where the bedrock channels respond to different base levels, and controlled by Central Myanmar Basin across Kabaw Fault at ~120 m for the east-flowing rivers, while west-flowing river drains to Sylhet trough at ~50m. Drainage network reorganization or capture is the most observed feature of the west-flowing rivers. We analyzed SRTM 90m DEM and TRMM annual average rainfall data using the Stream Power incision Model (SPIM) to understand the climate and tectonic coupling in landscape evolution. We observed a clear change in transient signature from north to south along the IBR. The topographic and precipitation swath profiles indicate the orographic barrier controls the precipitation pattern. In the Naga zone, precipitation and relief show significant clustering, suggesting precipitation has strong control over landscape evolution. In the middle (Arakan-Yoma) and lower (Ramree) sections, where accretion and oblique subduction to collision regime is evolving, the precipitation-tectonic coupling is low, and the later has dominant control on the

landscape evolution. We further analyzed transient erosional signal/drainage divide stability using Chi analysis, which transforms the horizontal river long profile into chi coordinate, to understand drainage capture and reorganization. It is found that the main water divide is stable in the Naga zone, while in the Manipur region along the CMF the divide is unstable, and it will migrate towards the West. In the Ramree region, the divide seems stable.

Spatio-temporal variation of DIC and DOC in river water and groundwater in the lower basin of the Cauvery river

Keerthan L*, Ramya, Priya R, Elango L.
Department of Geology, Anna University, Chennai
**Presenting author: keerthan38@gmail.com*

Rivers play an important role in the global carbon cycle by linking the land and ocean systems, spatio-temporal variations of the carbon fluxes are essential for the global carbon budget. The present study was carried out to determine the spatial and temporal variation of DIC and DOC in river water and groundwater in the lower Cauvery river basin. The samples were collected from river and groundwater from May 2018 to August 2021 thrice a year and the sampling period was categorized as dry (May & March) and wet season (September, December & August) based on monsoon. The samples were analyzed for EC, pH, major, and minor ions, DIC, and DOC. Rock water interaction is the dominant process that controls the chemistry of both river water and groundwater. Generally, the DIC is found to be higher in groundwater in comparison with the river water, whereas DOC was found to be higher in river water. The temporal variation suggests that DIC concentration in river water is low during wet seasons and is high during dry seasons, whereas it was vice versa for DOC. This indicates that the flow of the river is the most significant factor in controlling the dissolved fluxes concentration. The DOC concentration in groundwater was high during the wet season than the dry season, whereas for DIC the temporal variation was found to be similar. It is evident that DIC could be derived due to the weathering of both silicate and carbonate rocks, whereas DOC could have evolved from soil carbon, along with the primary production and microbial effects in the river. Hence, this study is necessary to understand the variation of the carbon flux in the lower basin of Cauvery.

Palaeoenvironmental reconstruction through granulometric analysis of the Bhikiyasain palaeolake deposits, Kumaun Lesser Himalaya

Manmohan Kukreti
Kumaun University, Uttarakhand
Presenting author: manmohankukreti12@gmail.com

Grain size analysis is an essential tool for classifying sedimentary environments. The main aim of the current research is to use granulometric analysis of the Bhikiysain palaeolake sequence along the Ramganga river to describe changes in the depositional environment within the lake during the late Quaternary. The granulometric analysis was conducted using a laser particle size analyzer on 32 samples, collected at 10 cm intervals in a vertical palaeolake profile, at Bhikiyasain (Ramganga Basin). The results of the grain-size analysis indicate that the size distribution of the sediment is unimodal. The unimodal size distribution of the sediment suggests that the sediment was supplied via fluvial action. The Bhikiyasain Basin (29°43.106' N; 79°15.682' E**)** experienced tectonic activity around 44.2 ka, resulting in the ponding of the Ramgangariver and the formation of the palaeolake deposit. The ternary plots suggested the dominance of silt in the Bhikiyasain profile followed by sand and clay. Based on grain size analysis, and variation in the colour of the sediment and lithofacies, the entire profile has been divided into 6 different zones (zones1-6).Silt had the highest concentration in all the zones except for zone 1 and zone 3. Zones with high silt concentration are

inferred to represent low-energy depositional environments and high rainfall or wet climatic conditions in the catchments during the time of deposition. The higher amount of sand concentration in zone 1 and zone 3 represents the higher energy depositional environment and less rainfall or arid climatic conditions in the catchments. For the whole profile, the sorting of the samples varies between 1.1-2.0 which indicates the samples are poorly sorted. The poorly sorted sediment in all six zones represents limited transportation of sediment in the catchment and also suggests the sediment was deposited in a low-energy environment. Skewness values range between 0.1 to 0.5 which indicates that the samples are symmetrical to very finely skewed. The variability in the skewness values may be due to changes in the intensity of wind and hydrodynamic conditions of the lake. The kurtosis value range between 0.9-1.4, indicating the samples are platykurtic, leptokurtic, and mesokurtic in nature. The variability in the kurtosis value may be due to changes in the flow characteristics of the depositional medium.

Application of Bio-Argo float in understanding denitrification in the North Indian Ocean

Mohammed Munzil P.C.
Indian National Centre for Ocean Information Services, Hyderabad /
Kerala University of Fisheries and Ocean Studies, Kochi
Presenting author: munzil.pc@incois.gov.in

N* is a tracer introduced by Gruber and Sarmiento to study the effect of denitrification and nitrogen fixation in the ocean in 1997. It uses phosphate to correct the nitrate portion of its distribution due to nitrification reaction. N* describes the combined effect of denitrification and nitrogen fixation or remineralization of the nitrogen-rich organic compound. This process is spatially well separated and can be understood whether the process from the signals is either coming from one or different processes.

$$N^* = N - 16.\ P + 2.9\ \mu mol/kg$$

Here N* is the nitrate concentration in µmol/kg, and P is the concentration of the phosphate in µmol/kg. The distribution of N* has been analyzed for the northern Indian Ocean, both the Arabian Sea (AS) and Bay of Bengal (BoB), using data derived from two Bio-Argo floats. The average value of N* at denitrification depths are ~ -12 µmol/kg and ~-5 µmol/kg in AS and BoB, respectively. In concurrence with the previous studies, this study also confirms that AS is a strong denitrification basin, but BoB is not. It is mainly due to the slight difference in oxygen level between the Arabian Sea and the Bay of Bengal: BoB is slightly more oxygenated than AS. Also, we found that N* decreases exponentially in the AS when the oxygen concentration is less than 2 µmol/kg; N* is as low as ~-20 µmol/kg in the core of the AS Oxygen Minimum Zone (OMZ). Along the Oman coast, which is outside the core of OMZ, N* shows large negative values (~-10 µmol/kg). This indicates that the Oman coast is also vulnerable to denitrification. In BoB, N* in the coastal Ocean is considerably low compared to the open ocean, which implies coastal BoB is also vulnerable to denitrification in the near future.

A statistical approach for temporal disaggregation of daily precipitation data in the Himalayan region

Nibedita Samal*, Sanjeev Kumar Jha
Indian Institute of Science Education and Research, Bhopal - 462066, MP
**Presenting author: nibedita18@iiserb.ac.in*

The Indian Himalayan region (IHR) has shown an increasing trend in heavy precipitation, leading to frequent floods. IHR has a complex and fragile topography, making it difficult to establish rain gauges, radar instruments, or weather stations at multiple sites. Hence, the available meteorological and field datasets in the

IHR region are not adequate for monitoring weather events such as extreme precipitation, cloudbursts, flash floods, and avalanches. For accurate monitoring and routine issuance of warnings of heavy precipitation events, precipitation data with a high temporal resolution is necessary. Hence, this study applies the statistical approach of temporal disaggregation of point precipitation to generate future hourly precipitation data using 20 years of daily and hourly hindcast precipitation data at several stations in the Himalayas. The approach uses the nearest grid point precipitation to the station data for finding the disaggregation factor and multiplies it with the daily reanalysis data to produce hourly precipitation data. The disaggregation factor is calculated by dividing the hourly observation of precipitation by the daily aggregate. This factor is multiplied by the daily reanalysis data to calculate the hourly reanalysis at the required station. The daily and hourly precipitation datasets used in this study are obtained from the High Asia Refined Analysis version 2 (HARv2) at 10×10 km spatial resolution for the monsoon season (June, July, August, and September) of 2000 to 2020 years. The observed data used is from the Integrated MultisatellitE Retrievals for GPM (IMERG) available at the 30-minute interval and will be aggregated to get both hourly and daily data. The disaggregated data are compared with observed hourly data from IMERG at those weather stations. The hourly data obtained from this approach does not show any gap in the data and is found to be reliable through different error statistics.

Comparative water accounting of river basins using open access satellite observations and water accounting plus framework

Nirmal Kumar[1], Sudhir Kumar Singh[1*], Pankaj Chauhan[2], Kalachand Sain[2]
[1]K. Banerjee Centre of Atmospheric & Ocean Studies, IIDS, Nehru Science Centre, University of Allahabad, Prayagraj - 211002
[2]Wadia Institute of Himalayan Geology, Dehradun - 248001
[*]Presenting author: sudhirinjnu@gmail.com

The estimation of total water consumption is useful for watershed management aspects such as for the development of agricultural and environmental services. The data scare regions need open access satellite observations for mitigation of the watershed problem. The freely available open-access satellite observations viz. CHIRPS and PERSSIAN precipitation were evaluated with India Meteorological Department (IMD) precipitation for two different river basins. The CHIRPS dataset is more significant with the observed precipitation than PERSIANN. The value of R^2, RMSE, NSE, and PBIAS were 0.87, 45.22, 0.86, and -0.91%, respectively for the CHIRPS. Water Accounting Plus (WA+) and open-access earth observation datasets were applied to quantify beneficial and non-beneficial water consumption.The maximum average water yield in the Ghaghara River basin was accounted as 125mm/month for CHIRPS. Further, CHIRPS showed a higher value of average water yield of 60 mm/month in the Betwa River basin. CHIRPS, showed the total water consumptions in the basin for 2013–14 (wet year) and 2015–16 (dry year) are 106.3 and 101.8 BCM/year in the Ghaghara river basin, while 25.4 BCM/year (dry year) and 29.5 BCM/year (wet year) in the Betwa River basin. The findings have depicted that the non-beneficial component of total water consumption was higher than the beneficial part. Among the satellite observations, CHIRPS precipitation data is more suitable over the central Himalayan and central Indian River basins for the study of the hydrological processes.

Expanding Episodes of Anthropogenic Brutalization of the Himalaya: Geology as A Tool for Mitigation Measures

O.P. Varma
Indian Geological Congress, Roorkee – 247667, Uttarakhand
Presenting author: igcroorkee@gmail.com, igcroorkee@ymail.com

Advancing progressively along the series of articles and editorials in the Jour. Ind. Geol. Cong. on a variety of

issues of climate change and its deteriorating impacts on the environment and biomass, the author in this paper primarily draws upon the brutalizations and atrocities committed against the Himalaya, particularly the western Himalaya, by anthropogenic villainous activities. In addition, the results of the growth, development, and diversification of geology to its current status have been compiled in an evolutionary flow diagram that is flashed only to show the advent of the Anthropocene Era, which is closely moving with the climate change phenomena, the author views.

Evoked are, then, disasters placed into two groups – natural hazards and anthropogenic (man-made) disasters. A non-conventional discussion ensues with optimum focus on the Western Himalayan region – the gorgeous landmass with the environment, mostly pure and pristine, but most prone to disasters. Both types of disasters pose serious threats to the existence of mankind and atmospheric & societal turbulence. Natural hazards, also called geo-hazards, are inflicted by the nature and have to be accepted as they occur. They, by & large, include earthquakes, landslides, volcanoes, fiercest wildfires, glacier-melting, severe and flash floods, heatwaves, cyclones, tsunamis, cloud bursts, lightning, avalanches, and a few others. In contemporary times, these are occurring three times more than 50 years ago. Data from the past three decades is presented for mitigation purposes. While 59% of the land-mass of India is prone to quakes; aghast! a forecast of a major quake that may displace 40% of Kumaun Himalaya – a region of tough geography and rich biodiversity – remains at risk of permanent displacement by co-seismic landslides.

Anthropogenic disasters, countless in number with umpteen indicators, arise from vices and practices of our fellowbeings against nature, which is run by an autopilot system. They are primarily responsible for climate change scenarios, and are mainly, spoilers of the atmosphere, such as hot days & heatwaves, and also zoonist diseases, generated from wet markets, intense factory farms, and large-scale deforestation in India.

Unresolved though, the current pandemics' origin shows that modern wet markets have moisture, moist water, mud & slash favorable for the generation of pathogens-viruses, bacteria & others. They spread epidemic & pandemic diseases to insinuate human suffering. Of late, Covid-19, and now monkeypox, spread over eighty countries by Sept. 2022, while India, fortunately, logs reduced new cases of Covid-19 at about 8000 daily. Re-emergence of the polio in London, for the first time since the 1980s, referred to with other zoonist diseases and monkeypox, is a sad commentary. At home, people scared of epidemic diseases, migrated to hilly areas generating large-scale pollution and waste generation and above all wildfires widely; the state of Uttarakhand, hasa 71.05% forest area, reported 12,985 wildfire incidents between Nov. 2021 and June 2022, and they are found having direct link with tourism.

Thence, the paper takes a turn to fathom the reasonings, but only the major ones, behind the fast-growing plethora of anthropogenic vices, brutalizing this part of the Himalaya, being seriously detrimental to the upkeep of the land, are discussed factoring in the linkage – "*Population explosion (pressure on earth's resources) concretization, damn corruption, civil constructions, contractual commissions, political swindlers and smugglers, degraders of cleanliness and civilized behaviour."* We debate on the linkage, thread-bare with stark examples.

Having recourse to Indic spiritual and festivals yatras, massive congregations, and pilgrimages, such as Amarnath Yatra (in June), Kavad Yatra (in July), Char Dham Yatra (Oct.-Nov.), imbibing the largest movement of people in the world, are objectively considered, and caution is given that if these are not monitored with full proof remedies, they may come out as introducers of climate change – connected to anthropogenic disasters, and spreaders of infectious diseases, and global wildfires, shocking examples of which are not uncommonly reported.

Mitigation emergences of Kavad Yatras' hazards are dealt with adequately. The worst kinds of hazards have been known to emerge from management shortcomings in the conduction of the Kavad Yatra. It calls for very strict monitoring of the epidemiological profile of part-takers. In addition, the greening of routes and public transport is absolutely essential. The roots of mitigation measures are in culture, religious, administrative

politics, and administrative tie-ups with illiteracy, poverty ignorance, religious & civic bigotry, and lack of awareness among people; these be eliminated from the people as much as possible.

The soul is then searched on how academic bodies in the field of geosciences can really perform the services to help reduce ills arising from such events. In this connection, critical analysis is made of the main objectives of the scientific societies, like IGC & FIGA, that is to provide effective solutions to societal challenges and make recommendations for policy implementation at national and international levels. The ingredients of the objectives are not vague, but meaningful objectives.

Rummaging the objectives of this paper, the author concludes that each & every scientific association ought to move with the times and step out for achieving the objectives. They should be audited by day-to-day service to the community. Any consideration of those geoscientists who have spent glorious years of their life with trust and excellence be suitably rewarded. Corruption and dereliction of duty must be dealt with heavy hands. In the case of natural hazards, there is nothing that we can do except taking them for granted, but mitigation devices, in advance, must be underway in man-made disaster-prone regions. Nodal agencies, at the same time, are expected to deliver the needed funds without any consideration other than the bright performance of NGOs. Environmental geology in school and college be made compulsory.

Gas hydrate dissociation in the Krishna Godavari basin due to the progression of bottom water temperatures post-glacial maximum

Palle Jyothsna[1,2*], Nittala Satyavani[1]
[1]CSIR-National Geophysical Research Institute, Hyderabad, Telangana
[2]Academy of Scientific and Innovative Research, Ghaziabad 201002, Uttar Pradesh
[*]Presenting author: jyo.sarika@gmail.com

The 3D seismic data from a small region in the Krishna Godavari basin is examined in the present study to understand the dissociation mechanism of the gas hydrates. The seismic interpretation shows many structural features such as faults, slump zones, slope failure features, etc. Faults are the primary migration pathways for the advection of fluids/free gas in the study area. The bottom simulating reflector (BSR), which is an indicator of the gas hydrate stability zone, is seen shoaling upwards due to the focused fluid flow in the region. The historical sea surface temperature (SST) studies reveal an increase in SST by 3°C relative to the present SST since the last glacial maximum, due to which the thermodynamic stability is altered. Hydrate is more sensitive to temperature than pressure resulting in its dissociation. The results obtained from the study area indicate that the bottom water temperature is the major contributing factor that might have triggered gas hydrate dissociation. Based on the in-situ borehole temperatures and bottom water temperatures in the past and present, we infer that the shallow hydrate in the study area is dissociating, and the released overpressure (water and gas) is migrating through the pathways, creating large slumps in the continental slope, as is also observed from the seismic data.

Significance of morphometric analysis for obtaining its structurally controlled terrain of Mahi River Basin, India

Hrushikesha Pasham[1*], Sakram Gugulothu[2], Ratnakar Dhakate[3], Anand K.Pandey[4]
[1]Department of Geology, Andhra University, Andhra Pradesh
[2,3,4]CSIR-National Geophysical Research Institute, Hyderabad - 500007
*[*]Presenting author:*hrushipasham45@gmail.com

Drainage network quantification contributes a vital sign of tectonic, geomorphic, hydrologic, and denudation

aspects of the area. To understand the evolution of the Mahi river basin, we have extracted and analyzed the morphometric parameters using SRTM and LANDSAT data in the ArcGIS environment. Morphometric analysis of the Mahi River Basin has been reported as an 8th-order drainage basin, with an area extending 28844.4 km^2. The higher bifurcation ratio of the Sub-basin (SB8) shows structurally and geomorphologically disordered, and high Sinuosity leads to large meandering. The SB7, SB8, SB12, and SB13 show a hike in those positive interdependence parameters such as drainage density (Dd) and stream frequency (Sf) leading to high permeability, high runoff, flat top, and gentle slope. The shape parameters such as form factor (Rf), circulation ratio (Rc), elongation ratio (Re), shape index (Sw), and, lemniscates (K) determine the basin is elongate, youth stage, long duration with late and slow discharge peak, and large lag time. The relief parameters of the basins are portrayed by high relief with a steep slope, but due to the presence of a higher lineament zone, the discharge rate is been controlled in the higher relief SB1, and SB2. The above studies of these basins intimate that the drainage evolution of the study area is advanced well beyond the young stage. Lineaments and relief have the main influence on the drainage progress in Mahi basins. Basin morphometry, landform processes, erosional characteristics, and hydrological responses are useful for watershed management and development.

Hydrology of data scarce Himalayan River Basins

Pragati Prajapati, Akshay Singhal, Sanjeev Kumar Jha*

Indian Institute of Science Education and Research Bhopal, Madhya Pradesh

**Presenting author: sanjeevj@iiserb.ac.in*

The availability of observed hydrological data is scarce in the Himalayan region. Due to complex topography, harsh weather, and insufficient manpower, ground-based observatories such as stream gauges and rain gauges are sparse. As a result, researchers have to look for alternate sources of data that are not as reliable and accurate as ground-based observations. The alternate sources can be satellite-derived precipitation estimates which are available at fine spatial and temporal resolution. In terms of stored water availability, the Himalayas have a vast spatial distribution of glaciers from where several rivers originate. Over the past few decades, various studies have found that the streamflow of rivers has drastically reduced, frequency of flash floods has increased along with accelerated and seasonally shifted water abstraction and tectonic activities. The absence of long-term meteorological data, soil-moisture cover, rapidly changes in land use, varied geology, etc. requires analytical tools to characterize rainfall- runoff behavior of complex mountainous basins. Hydrological models such as SWAT hydrological modeling, streamflow simulation, remote sensing in hydrometeorological models, SRM (Snowmelt Runoff Model), and VIC (Variable Infiltration Capacity) provide a platform to simulate these data and help us to understand the water balance, streamflow generation and enabling us to develop fast and efficient prognosis of flood events or to create early warning against droughts. Hence, it is clearly evident that for a better understanding of mountain hydrology these hydrological models are an indispensable component. We need to develop a model of less error with improved accuracy followed by reducing deficiencies of the previous models. In this regard, we setup a full-distributed hydrological model and observe the changes in the water balance in different land use classes in one decade. The work is in progress and the results will be presented at the conference.

Tectonic-Climate interplay from intraplate landscape of Gujarat, Western India

S.P. Prizomwala

TCEE Group, Institute of Seismological Research, Gandhinagar – 382009

Presenting author: prizomwala@isr.res.in

The arid to semi-arid landscape of Gujarat is a seismically active intraplate region with a considerable

Quaternary landscape, which provides an opportunity to reconstruct the roles of climate and tectonics at various temporal timescales. Employing geomorphology, and detailed sedimentology supported by geochemistry and optical dating, we integrate the fluvial to fluvio-marine and aeoline records to evaluate the potential of dryland environments in archiving the palaeo-events. The Quaternary records from Kachchh show excellent sedimentary signatures of past events since the later part of MIS-3, which have also responded in kind to climatic fluctuations. The Mainland Gujarat records comparatively span a much older timescale doing as back as MIS 5e, and have archived signals of climate and associated sea level changes. Contrastingly, the Saurashtra landscape has thin Quaternary cover mostly in form of Miliolitic deposits, which also show strong signatures of past tectonic as well as climatic fluctuations. Out of all the Holocene records have been well studied in all three domains and illustrate an intricate behaviour of landscape response to external forcing changes, which also were observed in human–landscape relationships during the Middle to Late Holocene period. Overall the rich geological library in form of terrain features in Gujarat showcases excellent archives and examples of longterm climate-tectonic perturbations.

Spatial and Temporal Analysis of Air Pollution in Dehradun and Haridwar During 2019-2021

Ritika Saini[1*] Pankaj Chauhan[2]

[1]Department of Earth Sciences, Banasthali Vidyapith, 304022, Rajasthan

[2]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehradun,248001

[*]Presenting author: ritikasaini5678@gmail.com

Air pollution is the concentration of air pollutants that are present in the atmosphere. It has become a global problem. We have presented a comparative study for air pollution in two cities i.e., Dehradun and Haridwar for three years 2019-2021. The air pollution data obtained for this analysis has been gathered from the Uttarakhand Pollution Control Board (UPCB). We have also discussed the impact of meteorological conditions on the air pollution of a particular area for which the data was obtained from the Indian Meteorological Department (IMD). The analysis was done on the basis of three pollutants i.e., PM10, Nitrous oxide, and sulphur dioxide. In this present analysis, we have discussed the effect of industrialization, urbanization, and vehicular emission on ambient air quality in Haridwar and Dehradun City. In this study, we observed that the air quality of Dehradun was poorer as compared to that of Haridwar. This study is an attempt to analyze the air quality status and air quality index (AQI) in both cities. The average AQI value for Haridwar is 80.52 where as that of Dehradun is 100.2. Elaborating on the reasons why commercial areas of Dehradun registered poor air quality levels the topography of Dehradun is such that it is surrounded by the Shivalik range on one side and ridges on other side which makes it difficult for suspended particulate matter to escape. Secondly, being a capital city, there is the ongoing construction of several projects which contribute to pollution. Thirdly, the vehicular traffic in the city has increased drastically. In this, we have also discussed the lockdown period in the year 2020 and observed that the concentration of air pollutants has decreased to a greater extent during this period as there was extremely less vehicular emission and no industrial activities going on during this period. Therefore, lockdown presumes to be the effective alternative measure to be implemented for controlling air pollution and the present work includes the degree of air quality change during lockdown at a spatial scale.

Seasonal variability of thermohaline structure and associated biological response in the Eastern Equatorial Indian Ocean: An Argo study

Trishneeta Bhattacharya[1,2]
[1]*Indian National Centre for Ocean Information Services, Hyderabad*
[2]*Kerala University of Fisheries and Ocean Studies, Kerala*
Presenting author: trishneeta@gmail.com

The Equatorial Indian Ocean is known to exhibit complex dynamics in response to remote forcing from the equatorial belt of the world oceans. The seasonal variability in the thermohaline structure of the water column therefore can significantly impact the biological state of the upper ocean. We examine the time-series observations of temperature, salinity, chlorophyll-a, and dissolved oxygen obtained from four autonomous biogeochemical (BGC) Argo profiling floats deployed in the Eastern Equatorial Indian Ocean (EEIO) to study this variability in the upper 200 m of the water column. A good correlation (0.58-0.78) between thermocline and sea level anomaly (SLA) along the track of the BGC floats establishes the fact that thermocline variability is indeed modulated by the equatorial waves in the EEIO. The propagation of upwelling (downwelling) equatorial waves characterized by negative (positive) SLA leads to shallower (deeper) thermocline variability in the EEIO. Satellite observations and BGC Argo profiles of chlorophyll-a reveal that the enhancement of near-surface chlorophyll-a is modulated by the equatorial waves during the seasonal change in the direction of the prevailing, or strongest, monsoon winds in this region. Further, the analysis reveals that a shallow thermocline in the EEIO corresponds to positive surface chlorophyll-a anomalies while deeper thermoclines are consistent with negative anomalies. The depth of oxycline closely follows the depth of the thermocline exhibiting the same seasonal pattern of variation as seen in the case of the thermocline. The correlation coefficient for thermocline and oxycline depth is seen to be within 0.5-0.8 in the case of all the BGC Argo floats indicating moderate to high correlation. Intense apparent oxygen utilization across the water column below the depth of oxycline, ranging between 225-260 µmol/kg in the study region corresponds to high biological productivity further establishing the enhancement of chlorophyll-a in the near-surface EEIO during seasonal reversal of monsoon winds.

Trans-Himalayan Spiti Sandwich – Ingredients: Tectonics, Climate, Relief and Lithology

Uday Sharma[1,2*], **Yogesh Ray**[1], **S.J. Sangode**[2]
[1]*National Centre for Polar and Ocean Research, (Ministry of Earth Sciences, Govt. of India)*
Headland Sada, Vasco Da Gama– 403804, Goa
[2]*Savitribai Phule Pune University, Pune, 411007, Maharashtra*
[*]*Presenting author: udaysharmaofficial@gmail.com*

The temporal and spatial landscape evolution in terrestrial environments depends on weathering, erosion and subsequent depositional processes. These processes are controlled by the conjugated effect of local and regional tectonics, climatic conditions, local relief and lithology.The Trans-Himalayan Spiti basin lying in the rain-shadow zone, famous for its continuous palaeozoic-mesozoic sedimentary record, makes an interesting case to study the coupled effect of the above-mentioned processes influencing the dynamics of this extensional basin.

The Spiti basin extending from N-W to S-E is sandwiched between Main Central Thrust to the south and the Karakoram fault system in the northeast. The high relief and cold-arid climate in the present day results in >50% of water influx in the basin through glacial melting. This study attempts to understand the Spatio-temporal landscape modifications influenced by climatic and tectonic activity across the late quaternary, with the help of sedimentological and geomorphological studies; through lithofacies association, clast-fabric

studies and GIS-based analysis. The presence of alluvial fans, scree, and colluvium cones are some of the significant geomorphological attributes resulting from para-glacial and peri-glacial processes operating in the region. The upper part of Spiti showcases a braided channel profile, whereas deep incision in the lower part beyond Mane Bridge has resulted in the formation of meandering belts.

In the past, the basin has been influenced by multiple glacial surges during cold phases and intense monsoon activity during warm regional climatic conditions. The sediments deposited during aggradation phases due to para-glacial processes become vulnerable during the intense monsoon phases and result in various landslides which in the past have blocked the trunk channel. It has resulted in the formation of lacustrine deposits at multiple locations in the lower reach near the trunk channel. These depositional units are also further affected by numerous neo-tectonic events evident from the soft-sedimentary deformations/sesmites visible at various locations. Though poorly preserved, the glacio-fluvial sediments in the upper reaches give an idea about the past glacial direction and extent of paraglacial and peri-glacial activity.

CO_2 Injection in Geological Formations to Reduce Global Warming

V. P. Dimri
CSIR-National Geophysical Research Institute, Hyderabad - 500007
Presenting author: vpdimri@gmail.com

The excess of CO_2 is considered to increase atmospheric temperature. There are different sources of CO_2 emission. Coal, oil, gas, cement, and flaring contribute 40%, 34%, 19%, 6%, and 1% respectively. The average global air temperature near the earth's surface increased around 0.6°C during the last 100 years ending 2005. The climate model projections summarized by the Intergovernmental Panel on Climate Change (IPCC) indicate that average global surface temperature will likely rise a further 1.1 to 6.4°C during the twenty-first century. Yet, the Paris agreement seeks to limit planetary warming to well below 2°C, urging nations to pursue an even stricter target of 1.5°C. To put this in perspective, the average global temperature has already risen 1°C since the start of the industrial revolution. India ratified the Paris Agreement on climate change on the 147th birth anniversary of Mahatma Gandhi.

There are major consequences of global warming such as sea level rise, and increasing intensity of extreme events e.g. cloud bursts, effects on melting of glaciers, etc. So, sequestration of excess CO_2 is one option. There could be several potential CO_2 traps such as basalt formation, shale formation, saline reservoir, non-economic coal seams, abandoned hydrocarbon reservoirs, and brown oil fields.

Public awareness of the detrimental effects of global warming and its mitigation steps is a vital part to overcome the increasing carbon dioxide. The plantation is one such solution and it should be strictly implemented.

Indukurpet Mandal Decision Support System (IMDSS) by Using Geospatial Technologies for Rural Community Development, SPSR Nellore District, Andhra Pradesh

Vamshi Krishna Reddy P.[1], Bangaku Naidu. K[2*],Anji Reddy. M[1],Sakram. G[3]
[1]Centre for Environment,Jawaharlal Nehru Technology University Hyderabad-500085,Telangana
[2]Department of Geology, Sir. C.R. Reddy Degree College, Eluru-534007, AP
[3]CSIR-National Geophysical Research Institute, Hyderabad 500007, Telangana State
[*]Presenting author:naidu0756@gmail.com

Geospatial technology has developed at a significant pace over the last two decades and will play a key role in

the development of the nation, particularly in the agricultural sector. Agriculture and horticulture are the main occupation of the people of the SPSR Nellore district of Andhra Pradesh in general and the present study Mandal area, Indukurpet Mandal in particular. The Indukurpet Mandal is one of the cyclone-prone areas of Andhra Pradesh State and is affected by several previous cyclones. In view of this, a detailed study is conducted to evaluate the land and soils for their suitability to various cropping patterns and also to provide an early warning system to minimize the damage to crop yields. The spatial database consists of a drainage map, hydrogeomorphology map, land use/land cover map, classification of soils, soil quality data, and agrometeorological data on the ArcGIS platform. The spatial data is analyzed with special reference to the suitability of land for different crops. Based on the agrometeorological data and the data obtained from automatic weather stations located in Mypadu village of Indukurpet Mandal, location-specific advisories are suggested. A method, of disseminating the information to the farmers as and when required, is also developed. this work helps to create the archival of the digital data of all the 14 villages in the Mandal which can be used for micro-level planning and decision-making process by administrators. Geospatial technologies are found to be a technique that provides greater flexibility and accuracy for handling a digital spatial database. The combination of remote sensing and GIS and field data proves that it is a powerful combination to apply for land-use suitability analysis and to evolve an early warning system for reducing the damage to the crop yield. The suitable crops identified are like Paddy, Green gram, Black gram, Banana, Mango, Coconut, and Sapota. This decision support system can also be used to evaluate the carrying capacity of the area for its shortcomings and therefore to improve productivity.

Generating future skillful ensemble forecasts by relating forecast and satellite precipitation data over the northwest Himalayas

Akshay Singhal[1], Athul Cheriyamparambil[1], Nibedita Samal[1], Sanjeev K. Jha[1*]
Indian Institute of Science Education and Research Bhopal, MP
[*]Presenting author: sanjeevj@iiserb.ac.in

Skillful quantitative precipitation forecast (QPF) is highly desirable for hydroclimatic studies in the Himalayas. The available deterministic raw forecasts often contain bias as obtained from the numerical weather prediction (NWP) models. In this work, we take into account the spatial inconsistency between a QPF and observation data to set up a stochastic model based on the concepts of multiple-point geostatistics (MPS). The MPS model simulates the 'observation' data by using the corresponding forecast data obtained from the NWP model. The approach co-simulates the spatially connected precipitation patterns between two different sources of precipitation by constructing multivariate training images. Several covariates are also used to assist in the identification and resampling of patterns. In the previous works which apply MPS, the spatial patterns of model output and observation data are more or less similar. However, in the case of a precipitation forecast, such an ideal condition may not exist since the NWP models are based on several assumptions. To account for that uncertainty, the inconsistency in the spatial scales of the two datasets is dealt with by blending the approach of MPS with the 'spatial downscaling and bias correction (SDBC)'. Results show that the MPS approach (along with SDBC) generates skillful forecast ensembles by taking into consideration the slope, aspect, and other topographical variables, along with the NWP model output and observation data. The model generates 25 ensemble forecast members at the selected avalanche and glacier sites at the daily temporal scale. The study presents a novel method for stochastically generating a cost-effective and reliable precipitation forecast in complicated regions around the world such as the Himalayas. The results from the study will be presented at the conference

Hydrology, lake-level fluctuations and paleoclimate from the Ladakh Himalaya since 3ka

Anil Kumar[1*], Sumit Sagwal[1], Choudhurimayum Pankaj Sharma[1], Pradeep Srivastava[1,2], Shravi Aggarwal[1,3], Ravi Bhushan[4]

[1]Wadia Institute of Himalayan Geology, 33, G.M.S. Road, Dehradun, Uttarakhand – 248 001
[2]Department of Earth Sciences, Indian Institute of Technology, Roorkee - 247667
[3]Hemvati Nandan Bahuguna Garhwal University, Srinagar, Uttarakhand –249 161
[4]Physical Research Laboratory, Ahmedabad, Gujarat – 380 009
[*]Presenting author: akumar@wihg.res.in

The development of a large number of lakes in the Trans-Himalaya and Tibetan Plateau (TP) is the consequence of global warming and climate change. An increase in the lakes area and their scattering are warning about the deteriorating health of the water tower of Asia (the Himalaya). Understanding the lake-level changes and their hydrological imbalance may provide a relationship of climatic dynamics over the high reaches of the Himalaya. Pangong Tso, ~140 km long, transboundary, and a hypersaline closed basin shared between India and China, is highly sensitive to the minute changes in the air temperature, precipitation, and snow-glacier melt. The incised tributaries exposed the classical Gilbert-type deltaic sequences that made the present-day landscape of the Pangong Tso periphery. We undertook sedimentological, chronological, stable isotope (Sclerochronological analysis of gastropod molluscs) and diatom concentration to delineate hydrological fluctuations of lake level. Based on the sedimentological studies that include the lithologs and sedimentary structures, two major facies were identified in the studied sections that are (1) deltaic and (2) fluvial deposits. We collected molluscs shells from topset of the different sections that are recognized as the *Radix brevicauda, Radix lagotis, Valvata piscinalis*, and *Gyraulus* species of freshwater origin gastropods having habitat in the littoral zone. In this study, we identified three phases of lake level changes over the past 3 ka. The height of the gastropod shell-bearing layers from the present-day lake-stand and their stable isotope study supports the higher lake stand at ~2.8 – 2.0 ka. A sharp decline is measured up to 1.7 ka which is followed by again a high stand of the lake from 1.7 – 1.1 ka, when the salinity was dropped to 2-6 ppt and the concentration of freshwater loving diatoms increased. The 3rd phase is identified as the rapid fall in the lake level (~6m) which can be recognized by the incision of the deltaic sequences in the last 1 ka. The rapid lake-level fall might be the effect of an abrupt rise in aridity in this region. A review of the palaeoclimate record available from the region suggests that late Holocene fluctuation in lake level might be the consequence of the interplay between the Indian Summer Monsoon (ISM) and westerlies.

Microfabrics and architectural elements as means to understand cave carbonate growth

Dipanwita Sengupta[1,2*], Som Dutt[1,2]

[1]Wadia Institute of Himalayan Geology, Dehradun-248001, Uttarakhand
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-20102, UP
[*]Presenting author: sgdipa13@gmail.com

While oxygen isotopes are being exhaustively used as palaeoclimatic proxies from speleothems, microfabrics and speleothem architectural elements are two of the less utilized proxies. An understanding of the paragenetic history of speleothems is fundamental for comprehending how other proxies and radio-isotopes are preserved in them. There is also a need to decipher the physico-chemical cave conditions, hydrology, nature of drip that deposits the laminae, etc., and how these factors affect crystallization and lamina stacking. This can be achieved by the study of speleothem petrography and architectural elements and it provides reliable support to isotopic data, help to interpret sources of error, and estimate the chronological limit of a sample. In this study, we have focussed on a speleothem sample from the north-western Himalaya

(BD) and another from the Shillong plateau, north-eastern India (KMS 6). Sample BD has accreted through the growth of columnar crystals, microsparite, and micrite, developing a flat-topped stacking pattern. Significant coherency exists between its isotopic signal, microfabrics, and architecture showing a direct response of speleothem growth to precipitation variability. Prominent columnar crystals have developed in increased precipitation phases and microsparite and micrite are observed in suppressed precipitation phases. Sample KMS 6 consists of columnar crystals, mosaic calcite and a minor amount of micrite, and a flat-topped to globular stacking pattern. Although the isotopic pattern shows variability, the stacking pattern is majorly aggradational indicating a steady driprate and homogeneous calcite supersaturation irrespective of climatic perturbations. The microfabrics also support the stability of drip, and shows diagenesis at some parts and the presence of detrital quartz explains the age uncertainty of the sample. A comparative study of these samples re-emphasizes the importance of the petrographical and architectural study of speleothems for the complete understanding of palaeoclimate, depositional process, and its controlling factors.

Assessment of glacial lake under the threat of climate change in Bhilangana River Basin, Garhwal Himalaya, India

Pawan Patidar[1,2*], Amit Kumar[1, 2], Kalachand Sain[1, 2] Akshaya Verma[1]
[1]Wadia Institute of Himalayan Geology, Dehradun
[2]Academy of Scientific & Innovative Research, Ghaziabad, Uttar Pradesh
[*]Presenting author: pawanpatidar28@gmail.com

Climate change is a global phenomenon and its effect is variable in different regions. In recent decades Himalayan glaciers are retreating and glacial lakes are increasing in number and size. The expansion of glacial lakes increases the probability of Glacial Lake Outburst Floods (GLOFs). Glacial lakes are dynamic and vary in dimensions and types in time and space. Keeping in view, the different lakes, we have identified one lake, i.e., Masar Tal in the glaciated catchment of the Bhilangana river, which is a major tributary of river Bhagirathi. The study is done by using multi-temporal satellite imageries (Landsat TM, Landsat ETM, Landsat OLI, Sentinel 2, etc.) and a high-resolution Digital Elevation Model (DEM). In the present study, Normalised Difference Water Index (NDWI) method is applied to differentiate glacial lakes in the basin. After applying all the GLOF parameters (like surface area, damming characteristics, surroundings, etc.) the Masar Tal is found potentially dangerous while other nearby glacial lakes found stable for the past 2-3 decades. The lake was found completely frozen throughout the year until 1975, while a minor fraction was seen melted during the August and September months up to 2001 but the percentage of meltwater has significantly increased during the study period (1975-2021) also snow cover change is observed in this period. Presently, the lake remains melted during most of the ablation period where maximum liquid precipitation occurs. The freezing and melting patterns changed a lot during the study period in Masar Tal. The peak discharge of the lake has been calculated using different empirical equations at different stages of evolution. For 2021 lake volume was found ~7594397 m^3 and the estimated peak discharge was found ~31856 m^3s^{-1}. A huge amount of water along with debris could be released from an altitude of ~4726 m.asl with an accelerated rate may be disastrous for 2 hydropower plants and other infrastructures in the downstream region.

Late Holocene wild-fire record from the Ladakh Himalaya in response to climate variability and anthropogenic impact

Sumit Sagwal[1,2*], Dipanwita Sengupta[1,2], Anil Kumar[1,2], Som Dutt[1,2], Pradeep Srivastava[3]
[1]Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand - 248001
[2]Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh- 201002
[3]Department of Earth Sciences, Indian Institute of Technology, Roorkee - 247667
[*]Presenting author: sumitsagwal123@gmail.com

Wildfire is an integral component of the terrestrial ecosystem which regulate the vegetation cover and plays an important role in landscape dynamics. To determine the role of wildfires in the development of ecosystems and landscapes in the recent past, it is required to reconstruct the occurrence and intensity of paleofire events. The wildfire records are being stored in the lacustrine, peat, or marine sedimentary deposits which provide temporal information on fire activity along with climatic variables prevailing on a local as well as regional scale. A ~2.8 m long peat sequence from Stagmo Nala, Indus Valley, Ladakh Himalaya was studied for charcoal microfossil contents along with sedimentological characteristics to investigate fire regimes and to reconstruct the wildfire history. The charcoal count (CC) method provides a suitable method for investigating the role of climatic and vegetation changes on fire occurrence with possible human intervention. The results depict the interaction of fire with vegetation and human activity in the Ladakh Himalaya during the past ~ 2.8 cal kyr BP. Three distinguished events of wildfire were identified. The first event of high CC from ~2.8 -2.55 cal kyr BP, indicates a high fire frequency. This first high charcoal flux phase could be explained as the natural response of dense vegetation growth along with human interruption. This event likely corresponds with the time of the bronze age expansion and the Tibetan Plateau's immediate human occupation. The second phase of relatively low CC is identified from 1.65 to 1.54 cal kyr BP and is supported by the high fuel availability during a transitional phase from cold to warm climate. The third phase of the moderate charcoal flux of wildfire in Ladakh Himalaya is identified at ~ 1.38 cal kyr BP. During this phase in the later historic age, an aggravated ISM intensity with the more favourable climatic condition for biomass and the human role in modifying the vegetation is recorded from the archaeological settlement of Ladakh.

Low-frequency climatic variability in Northwest Himalaya and its forcing mechanisms

Shruti Mandal[1,2*], Chhavi Pandey[1], Dipanwita Sengupta[1,2], Som Dutt[1,2]
[1]Wadia Institute of Himalayan Geology, Dehradun-248001, Uttarakhand
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-20102, Uttar Pradesh,
[*]Presenting author: shrutimandal@wihg.res.in

Lakes can be open or closed hydrological systems, are very much sensitive to climate change, and preserve a variety of proxies. Therefore, they are used for the reconstruction of palaeohydrological and palaeolimnological changes with climate variability and vice-versa. In this work, we present a statistical approach of analyzing various multi-proxy parameters (e.g. pollen record, grain size analysis, etc.) to understand the climatic perturbations that influenced the lakes of Northwestern Himalaya since the Last Glacial Maxima (LGM). We have focused on four lakes- Tso Moriri, Tso Kar, Pangong Tso and Chandra Tal, and two paleolakes Khalsi and Saspol. This study is an attempt to understand the factors that influenced lacustrine primary productivity, geochemical and mineralogical studies, pollen record studies, etc. which will further help to comprehend the behaviour of the Indian Summer Monsoon and westerlies in the past over the northwestern Himalaya. Results suggest significant variations in the regional climate with the forcing of solar changes, ENSO activity, and sea surface temperature in the Indian and North Atlantic Oceans.

Earthquakes: Genesis and Mitigation

Evaluation of Seismic Hazard in the Central Seismic Gap Region of the Himalaya based on Site Effects and Simulated Accelerograms

Anjali Sharma[1,3*], Dinesh Kumar[1], Ajay Paul[2], S.S. Teotia[1]
[1]Department of Geophysics, Kurukshetra University Kurukshetra, 136119
[2]Wadia Institute Himalayan Geology, Dehradun, 248001
[3]Ministry of Earth Sciences, Borehole Geophysics Research Laboratory, Karad, 415105
[*]Presenting author: anjali.11587@gmail.com

The seismic hazard in the Central Seismic Gap (CSG) region between the unruptured zones of 1905 Kangra and 1934 Bihar-Nepal earthquake of the Himalayas is very high due to the increase in population density, built environment as well as urbanization in the Himalayas and adjoining Ganga plains. It has been estimated the 100-year and 50-year (beginning the year 1999) probability of occurrence of a great earthquake is 52% and 31% respectively in the Central seismic gap region of the Himalayas. This region has stored so much strain energy that it needs multiple earthquakes (M ≥ 8) to release this energy. The 2015 Gorkha Nepal earthquake (M 7.8) that occurred on the eastern edge of CSG has been expected to release energy from this edge. The energy accumulated at the western end of CSG is yet to release indicating the severe seismic hazard in the region.

The simulated strong ground motions due to earthquakes play an important role in the evaluation of seismic hazards in the region. The present study uses a modified hybrid technique to generate the accelerograms due to a future great earthquake (M 8.5) in CSG, Himalaya. The modified hybrid technique is a blend of two techniques i.e., the composite source technique and the semi-empirical envelope technique. The technique involves the random distribution of sub-events of varying sizes on the fault plane. The site response functions and High-frequency decay parameter (kappa factor) have also been incorporated into the hybrid technique. The waveforms have been simulated at more than 430 points using the site response function estimated from empirical accelerograms at recording stations located in the CSG of the Himalayan region. Peak ground acceleration (PGA), and duration parameters have been estimated. The simulated PGA values have been converted into intensity values to generate a synthetic intensity map. The accelerograms have been simulated for three scenarios by assuming three nucleation points. The PGA value at Delhi and Saharanpur varies from 0.06g to 0.19g and 0.17g to 0.8g respectively depending on the start of rupture on the fault plane. It has been found that for some cities like Delhi, Shimla, Bhagpat, and Saharanpur the simulated PGA values are comparatively low in one scenario but the duration is more as compared to the other two scenarios. The synthetic intensity maps for three scenarios have been presented which show that area covered by high-intensity values is different for different scenarios. These maps give an idea about the damage scenario due to a great earthquake in CSG, Himalayas. It is expected that the Delhi region may witness MM intensity of VI-VII due to a great earthquake in the CSG region of Himalaya. The scenario hazard maps prepared in the present work provide important information to mitigate the seismic hazard of different cities of the region. This kind of study may help to mitigate the earthquake hazard and to design earthquake-resistant structures and buildings in the region.

Complexities of ground motions of a Himalayan earthquake – a case study

R.K. Chadha
Raja Ramanna Fellow, CSIR: National Geophysical Research Institute, Hyderabad-500007
[*]Presenting author: rajen0555@gmail.com

Understanding strong ground motions and their propagation from the Himalayan earthquakes is a key to earthquake hazard assessment and mitigation in the adjoining Ganga Basin housing a large population and infrastructure of the country. An analysis is presented based on strong ground motion recordings of the 2015

Gorkha earthquake sequence by the CIGN network in the Indo-Gangetic Plains (IGP). Peak Ground Accelerations (PGAs) of the M_w 7.9 mainshock were found to be marginally greater than those of M_w 7.2, the largest aftershock but the Peak Ground Velocities (PGVs) and Peak Ground Displacements (PGDs) were nearly equal or even smaller. A comparison of PGAs of the M_w7.2 first aftershock and the third largest aftershock of M_w 6.7 showed similar values but the higher PGVs and PGDs. Because PGAs in the IGP during the Gorkha earthquake sequence occurred at f ~ 4 Hz, and PGVs and PGDs at f ~ 0.1 Hz, it is inferred that the source spectra of the mainshock and the M_w 7.2 aftershock had similar amplitudes at f ~ 0.1 Hz, and the source amplitudes of the M_w 7.2 aftershock and the M_w 6.7 aftershock were nearly equal at f ~ 4 Hz. Both spectral ratios and moment-rate spectra support these inferences. Spectral ratios at IGP stations and teleseismic moment-rate spectra do not support directivity as the cause of this complexity but point to a deficient radiation at intermediate frequencies (0.04–0.3 Hz) during the mainshock with respect to the Mw 7.2 aftershock as the principal reason.

The 2015 Gorkha earthquake caused great destruction in Nepal but in comparison to the high magnitude of M_w 7.9 the damage was less than expected and the PGAs were relatively low, i.e., less than 1/4g above the rupture area in hard and soft sedimentary sites in and around Kathmandu basin. This brings in the importance and role of sites effect in near and far fields of the earthquake source region, especially in the IGP. It has been observed worldwide that areas located in sediment-filled basins in the far field are prone to severe damage due to the amplification of seismic waves at lower frequencies that resonate with the natural frequencies of the tall structure. A few examples are Northridge (1994, M_w 6.7), Kobe (1995, M_w 6.9), Loma Prieta (1999, M_w 7.0), Turkey (1999, M_w 7.4), Puebla-Morelos (2017, M_w 7.1) and Bhuj (2001; M_w 7.7). Several critical structures like Nuclear Power Plants and Dams are planned and under construction in several states in the Ganga Basin, to meet the energy needs of the country. It becomes necessary to plan Strong motion networks and initiate such studies around the proposed structures to predict strong ground motions at the site through a modeling approach.

Strain budget and seismic hazard in the Koyna-Warna seismic zone

Anup Kumar Sutar[1*], Sukanta Roy[1], V.M. Tiwari[2]
[1]Ministry of Earth Sciences, Borehole Geophysics Research Laboratory, Karad
[2]CSIR-National Geophysical Research Institute, Hyderabad
[*]Presenting author:anupseismo@gmail.com

The Koyna-Warna region in western India is well-known around the globe for recurrent reservoir-triggered seismicity. Several geophysical investigations have identified two distinct seismic zones, namely, Koyna Seismic Zone (KSZ) and Warna Seismic Zone (WSZ). To understand the seismic potential of the region, the strain budget has been estimated using published GPS velocities and the earthquake catalogue of the region. The estimated result suggests that the rate of strain accumulation in KSZ (2.55E+16 Nm/y) is ~11 times larger when compared to WSZ (2.29E+15 Nm/y). KSZ releases only ~20% of the accumulated energy per year, however, WSZ releases most of the accumulated energy in the form of earthquakes. The difference in the strain accumulation and release rates for the two regions may be attributed to spatial variability of the medium properties such as density, elastic constants and fracture density. Gross strain estimates suggest, KSZ has accumulated enough strain post the 1967 M6.3 Koyna earthquake to generate an event of M_w5.8, provided the accumulated strain is released in a single event. The seismic hazard scenario in terms of peak ground acceleration (PGA) due to a potential M_w5.8 event has been estimated using the stochastic simulation technique. The simulated result suggests that ~40km distance from the source zone may experience PGA ranging between 0.08 - 0.26g with an expected intensity of V-VII. The acceleration response spectra corresponding to the natural period of single-storey (T=0.1s), double-storey (T=0.2s), 3-4 storey (T=0.5s), 5-6 (T=0.8s) storey and very tall structures (T=1s) for the potential M_w5.8 event has been estimated. The maximum response spectral acceleration at the centre of the mezoseismal area for the M_w5.8 event

corresponding to the natural period of a single-storey, double-storey, 3-4 storey, 4-5 storey, and tall structures have been found to vary as 0.65g, 0.49g, 0.30g 0.15g and 0.12g respectively. The result of the present study will be useful in various engineering applications and help reduce the loss of lives and damage to infrastructure due to any future strong events in the region.

Identification of earthquake signatures from geomagnetic data from Kutch

Archana R.K[1*], Kusumita Arora[1], K.M Rao[2]
CSIR-National Geophysical Research Institute[1], Hyderabad
Institute of Seismological Research[2], Gandhinagar
[*]Presenting author: archanamgp.ngri@gmail.com

Geomagnetic data from Kutch, Gujarat area has been studied for a decade (2009-2018) to identify the anomaly related to earthquakes. Different methodologies have been applied to the data set to identify the signatures associated with earthquakes. The methods involve (i) Analysis of the geomagnetic Z component for quiet time to characterize the seasonal pattern, if the amplitude variations in daily Z are double the standard deviations from the quiet day seasonal mean, then is considered as an anomaly; (ii) the large differences in the time of occurrences of peak values of Z compared to seasonal mean is considered as an anomaly; (iii) the polarization ratio has been a calculated for all quiet days for midnight hours and identified the anomaly (iv) geomagnetic pulsations are identified for quiet days and calculated polarization ratios.

Comparative analysis of SSR and HVSR method for Site Response analysis of National Capital (Delhi) Region, India using strong motion data

Prince Saini, Sakshi[*], Neeru, Himanshu Mittal
Department of Geophysics, Kurukshetra University, Kurukshetra
[*]Presenting author: princesaini5520@gmail.com

Delhi the national capital of India is highly populated where approximately 10 million people live. Delhi falls under seismic Zone IV and so the probability of earthquake occurrence is high. It lies approximately 200km from the Main Boundary Thrust (MBT) and 300 km from the Main Central Thrust (MCT), the two most active thrusts of the Himalayas.

Every earthquake has main three parameters- source, path effect, site effect. In seismic hazard estimation, site response plays an important role. To estimate the site effect in the Delhi region, we used two spectral methods, HVSR (horizontal to vertical spectral ratio) and SSR (standard spectral ratio). HVSR is a single-station technique and in SSR we need a reference site. So, each technique has a different result for the same site. So, for a better interpretation, we compare these results with regional geology.

We estimated site amplification at different sites in Delhi using data from different earthquakes using the Standard spectral ratio method (SSR) and Horizontal to Vertical Spectral Ratio (HVSR) method. For the SSR method, the reference site is IMD ridge (NDI) is taken on the basis of geology. The data that we use is strong motion data. The quantification is attempted in terms of site amplification. We compare the two methods under study. strong-motion recordings of earthquake events have been considered in this study for the SSR and HVSR methods respectively. The results provided by both techniques are comparable.

Statistical relationship between Shear Wave Velocity and Standard Penetration Resistance for Gorakhpur City, Northern India

Pawan Kumar Yadav*, Uma Shankar
Department of Geophysics, Institute of Science, Banaras Hindu University, Varanasi-221005
**Presenting author: pawankryadav12345@gmail.com*

Earthquake mitigation and soil investigation for seismic hazard analysis in the potentially active seismic zone around the southern Himalayan region are very important concern. Since the alluvium soil deposits have a significant effect on the amplitude of ground motion during earthquake energy propagation. Soil dynamics characteristics and microzonation studies are determined by essential geophysical parameters such as shear wave velocity. The shear wave velocity (SWV) is not possible to measure at all sites then standard penetration resistance (SPT) N value can be used. The objective of the study is to focus on establishing a relationship between shear wave velocity and SPT-N value using power regression analysis. The microtremor array measurements (MAM) data acquisition was carried out at 22 sites and 8 boreholes drilled up to a depth of 30m with Standard Penetration Test (SPT) N values. The soil samples were collected for the study of index properties in the laboratory. The lithology drawn from drilled borehole has observed clay of low plasticity with dominant silty sand followed by a medium to fine sand to a depth of 30m. For deeper strata follow wellbore data has been taken from the published report over a depth of 100m. Among, 4 sites of statistical data were used to develop a correlation between SPT-N and shear wave velocity. Using the SPT-N value, the predicted shear wave velocity was established with an uncorrected N value strongly correlated with a correlation coefficient (R^2) is 0.71 for all soil types. To validate our correlation compared with existing correlations in published literature was found well match. As per the National Earthquake Hazards Reduction Program (NEHRP) soil classification, the study area falls under class D. A new empirical relationship was established between SWV and SPT-N value in the Indo- Gangetic Plain (IGP).

Analysis of Shear wave velocity structures of Varanasi city, Uttar Pradesh using microtremor array measurements

Sangeeta Kumari*, Uma Shankar
Department of Geophysics, Institute of Science, Banaras Hindu university, Varanasi
**Presenting author: sangeetakumari816@gmail.com*

In the Varanasi city, microtremor measurements are used to evaluate the site properties for seismic hazards. The present study provides a shear wave velocity model for Varanasi city using microtremor array measurements. The S-wave velocity structures of Varanasi city are investigated using the array records of microtremors at twelve sites. Dispersion curves at these sites are calculated using the frequency–wavenumber (F–K) spectrum method. The S-wave velocity structures in Varanasi city are then estimated by employing the surface wave inversion technique. Harder strata sites have higher phase velocities than softer sites. The Phase velocity dispersion of the Rayleigh wave is calculated from an array using the SPAC method, and a 1-D shear wave velocity structure is determined by means of inversion processes. The top layers up to 50 m show shear velocities between 280 and 320 m/s and the velocities of the underneath layer vary between 600 and 1600 m/s to 100 m of depth. The inversion results are also in good agreement with borehole data. The study concludes that a microtremor array measurement is a useful tool for estimating S-wave velocity structure. In addition, at 115 single stations, data are acquired to investigate the HVSR and observe the frequency and amplitude at each station. The predominant frequency value lies between 0.38 Hz - 0.65 Hz and the amplitude value lies between 4.5 - 16.5. This indicates that the deep thickness of the upper soft soil at about several hundreds of meters. Such a huge amount of sediment deposition sources could be associated with the fluvial rivers system in the area and sediment drain from Himalaya. The average peak frequency (~0.5) may reflect the Quaternary-Tertiary boundary. The objective of

this study is to use the properties of the ambient seismic noise to study the site response for hazard analysis and to understand the subsurface structure at each recording site in Varanasi city with Vs. Using all the dynamic properties of soil we prepared the frequency, amplitude, and velocity maps for the city.

Coseismic deformation field and source modelling for the Mw 6.1 Afghanistan earthquake of June 21, 2022 by means of Seismic waveform and InSAR

Sanjay K Prajapati[1*], Rajkumar[2], Auchitya Pandey[1], Partha Sarkar[1], O.P. Mishra[1]
[1]National center for Seismology, Ministry of Earth Sciences, New Delhi
[2]Indian Institute of Technology (ISM), Dhanbad
[*]Presenting author: sanjaynecessary@gmail.com

On June 21, 2022 at 20:54 UTC, a Mw 6.1 magnitude earthquake struck in the Afghanistan-Pakistan boundary region, with the epicenter located close to the village of Gardez. The mainshock was followed by a few aftershocks of the M > 4.0. The earthquake was widely felt in Pakistan and some parts of western India, and severe causalities have been reported in eastern Afghanistan and western Pakistan. It was the deadliest earthquake in Afghanistan since 1998. The analysis of Broadband seismic waveform data from the Indian station suggests the epicenter lies close to the Gardez fault which is seismically less active. The moment tensor inversion calculated from the 10 nearest (~500 km) seismic station data indicates a left lateral strike-slip fault having a 204-degree strike with an 81-degree dip. Descending and ascending sentinel interferograms show a maximum range change of 30 cm, which is due to the coseismic ground displacement associated with this strike-slip earthquake. The SAR data was modeled by using an analytical elastic dislocation model, with the fault plane geometry and rake estimated using a non-linear inversion algorithm (without any external constraint) and the slip distribution obtained through linear least-square inversion with a positivity constrain. The slip model suggests that the majority of fault slip appears to be located below a depth of about 5-10 km and there is limited slip towards the surface. If the fault plane is geometrically extended to intersect the surface, its trace runs parallel and very close to the trace of the Gardez fault system, suggesting that possibly strike-slip Gardez fault might be associated with mainshock which did not rupture over a decade. The models are also coherent with the few aftershock distributions, especially for the northern segment, although the relocated seismicity seems to highlight the geometrical complexities not fully recovered by the coseismic models due to a few aftershocks of the mainshocks event.

Study of attenuation characteristics for Saurashtra and Mainland regions of Gujarat

R. Chaitanya Kumar[1,2*], Santosh Kumar[1], Ketan Singha Roy[1]
[1]Institute of Seismological Research (ISR), Gandhinagar, Gujarat
[2]Gujarat University, Ahmedabad, Gujarat
[*]Presenting author: chaitugeophy@gmail.com

Physiographically, Gujarat can be divided into three parts, viz., Kachchh, Saurashtra, and Mainland Gujarat. Kachchh region of Gujarat is one of the seismically active intraplate regions and experienced an earthquake of Mw7.7 in 2001. The Saurashtra and the Mainland Gujarat regions have witnessed the seismicity of the level of M~6.0 in the past, and are also seismically active.

The high-frequency attenuation parameter 'kappa' governs the decay of high frequencies significantly. It may differ depending on the source, path, or site, or a combination of these parameters. In the present study, 'kappa' values for the two parts of Gujarat, i.e., Saurashtra, and the mainland of Gujarat have been determined using

local earthquakes of M3.0-5.3, recorded by the Institute of Seismological Research. The acceleration time histories have been converted into a spectrum using a conventional Fast Fourier transform technique. The spectral decay parameter is determined by performing linear-least square fits to the acceleration spectrum on a log-linear plot.

The 'kappa' values vary between 0.001 to 0.045 for the two regions of Gujarat with average 'kappa' values of 0.0221, and 0.0212 for Saurashtra, and mainland Gujarat regions respectively. Dependency of 'kappa' has been observed on distance, and site for all three regions. The estimated high-frequency attenuation parameter 'kappa' is essential in seismic hazard assessments and can be employed during the simulation of strong ground motions.

Tectono-geomorphic and paleoseismic investigations along the foothill zone of Kumaon, central Himalaya, India

Mohd. Azhar Ansari*, Javed N. Malik, Mitthu Dhali
Indian Institute of Technology Kanpur
**Presenting author: amohd@iitk.ac.in*

Fault growth, related folding, and propagation of fold in the frontal and lateral directions are usually observed in fold-and-thrust belts of the Himalayas. The process of active faulting and associated fold growth, lateral propagation, and fault segmentation as well as a linkage in many tectonically active regions have influenced the shaping of the landscape. In a tectonically governed landscape, fault-related-fold growth generally includes various geomorphic markers like the diversion of the river from its original course and formation of wind gaps (Jackson et al., 1996; Burbank et al., 1999), and such geomorphic markers can be utilized in the reconstruction of deformational events in tectonically active regions (Bès de Berc et al., 2005). To understand the phenomenon of lateral propagation of fault in a tectonically active region, numerous researches have been conducted in different parts of the world (Jackson et al., 1996; Burbank et al., 1999; Keller et al., 1999; Friend et al., 2009; Champel et al., 2002; Malik et al., 2007, 2010a, 2014; De Sarkar et al., 2014).

From the Central part of the Himalayas, studies carried out by Malik et al. (2014) indicate that the Kaladungi fault (KF) has displaced the distal part of the Kaladungi fan surface resulting in the formation of a south-facing active fault scarp with variable heights along the front. The Kaladungi Fault is a splay thrust fault of the Himalayan Frontal Thrust system in the Ramnagar area of Uttrakhand which provides an excellent example of forwarding and lateral propagation of fault and related folding in both directions along the strike of the fault. The northwest and southeast propagation of KF along the strike has resulted in the diversion of the Dabka and Baur rivers respectively. The diversion of the Dabka and Baur rivers can well be justified by the existence of palaeo windgaps through which these rivers flowed earlier during the recent past. The lateral propagation of the fold along KF has resulted in the diversion of the Dabka river to the west and the Baur river to the east. This is justified by the existence of the Dabka river wind gaps DW1, DW2, DW3, and DW4, through which it flowed earlier during the Recent geologic past. Similarly, the Baur river is shifted from west to east marked by two paleo wind gaps, BWG1 and BWG2.

Till now no attempt has been made to know the rate of lateral propagation of the Kaladungi Fault which has resulted in the formation of wind gaps of the Dabka and Baur river. To achieve the target we have collected the OSL samples from the youngest terrace of wind gaps. The age that will obtain gives the age of abandonment of the channel after which it becomes dried and shifted to the newer path. Finally, river terraces are frequently used as geomorphic markers to demonstrate active tectonic deformation (Molnar et al., 1994; Rockwell et al., 1984; Lavé and Avouac, 2000).

Numerical Modelling of tsunami wave to assess the possible environmental impacts along the western coasts of India

Babita Dani[1], V. Srivastava[1], A.P. Singh[2], R. Bhatla[3*]
[1]Department of Geology, Institute of Science, Banaras Hindu University, Varanasi
[2]National Centre for Seismology, MoES, New Delhi
[3]Department of Geophysics, Institute of Science, Banaras Hindu University, Varanasi
[*]DST-Mahamana Centre of Excellence in Climate Change Research, Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi
[*]Presenting author: babitadanibhu@gmail.com

Numerical modeling of tsunami waves has been made for the western coasts of India at a few locations along Gujarat, Mumbai, Goa, Karwar (Karnataka), and Mangalore using the TUNAMI N2 code. The fault parameters are considered from earlier published literature. Bathymetry data and possible tsunami generation locations have been obtained from the ETOPO2 (Global Relief Model) and General Bathymetric Chart of the Oceans (GEBCO) satellite data. For tsunami run-ups, the land topography data Shuttle Radar Topographic Mission (SRTM) is used. The present simulation consists of a duration of 6 hours (360 min). Possible arrival time with amplitude at various locations has been estimated. Possible impacts on the environment have also been studied and reported from the published literature. The paper also analyses the changes in the directivity of the generated tsunami waves towards the western coasts of India by changing the dip and strike angles as different scenarios. Time series and height along the different parts of the Gujarat coast and hourly travel-time chart of the tsunami wave are also discussed. After the earthquake and initial tsunami wave generation, it reaches at all the locations along the Gulf of Kachchh (Gujarat) in nearly 2 hrs to 5.30 hrs with amplitudes from 1 to 2.5 m, Mumbai in around 4.45 hrs with amplitude of 2 m, Goa in around 3.08 hrs with amplitude 1 m, Karwar (Karnataka) in around 3.12 hrs and Mangalore in around 3.36 hrs with amplitudes 1 m each. The authenticity of the estimated tsunami phases of the 1945 tsunamigenic earthquake along the MSZ is corroborated with the available reports and published literature.

Evidence of distinct plate fragments in the Sumatran-Andaman subduction zone based on P-waves

Bhaskar Illa[*], Prakash Kumar
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad-500007
[*]Presenting author: bhaskar.illa1992@gmail.com

The Sumatra-Andaman subduction zone has been the site of the world's most disastrous earthquakes, and a few of them have triggered deadly tsunamis. The Sumatran earthquakes of 26 December 2004 (Mw 9.2) and 28 March 2005 (Mw 8.6) occurred on a multiple plate junction comprising India, Burma, Australia, and Sunda plates. To understand the rupture dynamics in the mega-thrust subduction zone, high-resolution velocity and anisotropy are crucial parameters, especially in the sub-moho depths where the hypo-centers of mega earthquakes are mostly nucleated. We imaged the uppermost mantle structure by inverting high-quality 41,354 Pn arrivals from 5725 regional events recorded at 316 stations to understand the significance of regional-scale structural heterogeneity due to the lateral propagation of Pn waves. Our results suggest a strong variation in velocity and fast polarization in the entire study region. The presence of a cold and rigid ocean slab (8.25-8.4 km/s) associated with positive velocity anomalies is subducting beneath the relatively weaker and less dense Burmese and Sunda plates (7.8-7.95 km/s). There is clear evidence of mantle anisotropic direction with the age of the oceanic plate, i.e., the trench-parallel fast polarization has a higher crustal age than the trench normal directions, with a much higher spreading rate of greater than 100 mm/yr. Based on the change in fast polarization directions from trench parallel to trench perpendicular, our result clearly demarcates Andaman and the north of Sumatra as two distinct tectonic plates where the mega events of 2004

and 2005 occurred. Such delimitation of two distinct plates controls the rupture dynamics of the region. Further, the presence of low Pn velocity anomalies beneath the east Andaman segment and west of transform faults indicates the existence of a magma reservoir caused primarily due to the steep dip and the tearing of the Indian slab, which is also reflected in the discontinuous high-velocity anomalies in the Pn tomography in the Andaman region.

The 3G Investigations for Seismic Microzonation and Site-specific Hazard Assessment

B.K. Rastogi
President Ind. Society of Earthquake Science, 1-2-63/3 Habsiguda, Hyderabad- 500007
Presenting author: bkrastogi12@gmail.com

The Institute of Seismological Research has the unique expertise of carrying out various aspects of seismic microzonation and site-specific earthquake hazard analysis including Geotechnical, Geological, and Geophysical (3G) investigations. Such investigations are being carried out in Gujarat and different parts of the country. The geology of the area is studied to understand basic earthquake hazards. The seismicity of the Gujarat region is monitored by a dense network of 60 broadband seismographs and 55 acclerographs. In other areas of investigation, a network of mobile seismographs is run for a year or more to identify possible active zones. Seismicity and tectonics are studied up to 300km distance from the site and in more detail within a 50 km radius. To know the nature of soil layers and drainage pattern a geomorphological map is prepared by remote sensing and ground check. The depth and seismic shear velocity of near-surface soil/rock layers is estimated by drilling as well as geophysical methods like MSWA, analysis of seismograms, microtremor array surveys and PS-logging. Depth to the water table and major near-surface soil layers are also studied by the resistivity method. Overall, faults have been mapped in Gujarat. However, the exact location and orientation of geological faults as well as soil/rock layers of deep basins are estimated by Transient EM, Resistivity Imaging, seismic reflection, gravity, and magnetotelluric geophysical surveys. Ground Penetrating Radar is sometimes used for detecting near surface layers and faults.

The Geotechnical investigations are done through numerous boreholes usually to 50m depth and sometimes to a shallower depth of 30 m or deeper depth of 90 m. Different types of physical and mechanical soil properties including dynamic properties (by Tri-axial-Cyclic Tests) are measured in a well-equipped ISR geotechnical lab. The boreholes are drilled at grid intervals of a few tens of m for an individual site and up to 2 km intervals for large areas. SPT-N values are measured at every 2m and disturbed soil samples are collected along with that. Undisturbed samples are also collected while drilling at regular intervals. PS-Logging is done for P and S-wave velocities of individual layers. The SPT-N values are correlated with Vs at that depth derived from Engineering Geophysics. The location and elevation of geophysical measurement points are measured by Land Survey with Total Station & RTK-GPS. Based on geotechnical data as well as from geophysical surveys the depth to Engineering Bed Layer (EBL) is assessed in the whole area which is having a Vs ~500m/s. The institute has made a pioneering contribution in using engineering geophysics for geotechnical modeling, thereby distributing uniformly in an area the information obtained in boreholes. The 3D soil profiles are prepared for the area using geotechnical data from which soil modeling is done.

The strong-motion time history is estimated at the EBL for near and far field earthquakes based on global relations for expected magnitudes along the possible faults. The soil models are prepared using 30 to 90 m deep boreholes at a 2km grid. The EBL may be estimated, say at depths of 15 to 60 m for the seismic velocity of ~ 500 to 760 m/sec with SPT N-Value of 80-100. The soil models are prepared based on soil classification and SPT N-Value above EBL. Based on the soil profile estimated from borehole data, SPT N-Values, soil properties, and Vs of different layers above the EBL the time history at the EBL is migrated to the surface using the SHAKE Program which estimates amplification due to each layer. The 1D ground response

analysis is conducted through SHAKE and strong-motion parameters are estimated at the surface.

The time history is converted into the Response Spectra and Design Basis Ground Motion required by structural engineers. The PGA maps and spectral acceleration (Sa) maps for 0.1 to 1.25 sec are also prepared on a grid pattern with a spacing of 0.5km. The soil amplification estimated for different shallow layers is used for suggesting foundation design. Liquefaction potential is estimated using soil properties, depth to the water table, and ground acceleration. The safe Bearing Capacity of the soil is also estimated.

ISR has done *seismic microzonation studies* at Dwarka, Gandhidham-Kandla -Anjar area, Dholera SIR, Bhuj, Ahmedabad, Gandhinagar, Surat, Bharuch, GIFT City (which is the 1st smart city of India and is planned to have a cluster of skyscrapers of up to 100 storied buildings) and some others. Seismic micozonation for eight different cities in India, sponsored by MoES is under rapid progress. ISR reviewed Seismic Microzonation of Guwahati City and its Town-Planning. *Seismic Hazard Assessment at Individual Sites was done* for the 182 m tall Sardar Patel Statue of Unity, LNG Storage Terminal sites at Mundra and Dahej, some Nuclear Power Plant sites, a 13-storied *V. S. Hospital building*, the 17 (+3 basement)-storied *"The Capital"* building at Ahmedabad, *E-City* site (a multistory residential complex of Essel Group) at ISCON circle, Ahmedabad. Vs30 and response spectra have been worked out for these sites. *Specific region* study includes vulnerability Assessment of Ports of Gujarat and for the two planned religious complexes: (i) *Devni Mori*, about 100 km northeast of Gandhinagar and near Mesow dam where a world-class Buddha statue and temple is planned (ii) the *Sant Nagri,* about 100 km north of Gandhinagar near Dharoi dam which is going to have temples for 108 saints, both in Sabarkantha district.

It may be noted that the two high-rise buildings of Ahmedabad referred above and the buildings of the GIFT city have been designed based on our suggestions of the seismic safety factor. For two buildings of 28 floors, the foundation depth and type were also designed to ward off any liquefaction effect as per our suggestion.

An important finding of seismic microzonation is that the low-rise buildings of 3-5 stories need to have 50-100% higher seismic factor than that recommended in the National Code up to a distance of 20km from Narmada and Cambay faults while up to 40km from Kachchh faults. The same recommendation is being accepted for designing the important buildings of Gujarat.

The Deccan Volcanic Province (DVP) of India hosts three different types of earthquake sequences

Harsh K. Gupta
CSIR-National Geophysical Research Institute, Hyderabad
Presenting author: harshg123@gmail.com

Earthquake sequences are broadly classified into 3 categories by Mogi (1963a, b) namely Type 1, 2, and 3, respectively. Type 1 earthquake sequence is the one when the material is homogeneous, and the stress is uniformly applied. In this type, a mainshock occurs, with no foreshocks, and the aftershocks follow. Type 2 earthquake sequence is observed when the material has a rather heterogeneous structure and/or the applied stress is not uniform. In this case, the main shock is preceded by foreshocks, and the number of aftershocks as well as the duration of the occurrence of aftershocks increases. Type 3 of the earthquake sequence is observed when the material is extremely heterogeneous and/or the applied stress has different concentrations, then there is no main shock, and a swarm kind of activity occurs where the number and magnitude of shocks increase with the passage of time and then decreases after some time. The Deccan Volcanic Province (DVP) of India witnessed earthquake sequences belonging to Type 1 (Latur earthquake of M 6.2 on 29 September 1993), Type 2 (Koyna earthquake of M 6.3 on 10 December 1967), and Type 3 (Palghar earthquake swarm 2018-2020). It has been proposed that the change in the mechanical properties in the shallow crust due to the

loading of the water reservoir has caused the change from Type 1 to Type 2 earthquake sequence for Koyna. Similarly, intense rain is considered to cause the change to Type 3. However, how these changes occur is not well understood.

There is a need for understanding the cause leading to three different characteristics of earthquake foreshock-mainshock-aftershock sequence for a single geological domain, which is the DVP. It is hoped that the detailed near-field studies of earthquakes being undertaken at Koyna through a 3 km deep pilot borehole in the immediate vicinity of the Donachiwada Fault hosting the reservoir-triggered seismicity (RTS) will provide an explanation.

The Coda wave attenuation characteristics for the Saurashtra region, Gujarat, India

Indu Bala[1,2*], Manisha Sandhu[2], Santosh Kumar[1], Dinesh Kumar[2]
[1]Institute of Seismological Research, Gandhinagar Gujarat
[2]Department of Geophysics, Kurukshetra University Kurukshetra
[*]Presenting author: indubala1920@kuk.ac.in

Attenuation study for the seismic waves is pretty much important for the estimation of source parameters and seismic hazard assessment. Seismic attenuation is measured by a dimensionless quantity, known as the Quality factor (Q) which is obtained by frequency-dependent Q relation ($Q = Q_0 f^n$). In the present study, we used the single backscattering method for Coda Q estimation (Aki & Chouet, 1975). The data of the Gujarat State Seismic Network has been used which is being operated by the Institute of Seismological Research (ISR) Gandhinagar, Gujarat. We have used 327 velocity time histories of 100 local earthquakes which are recorded at seismic stations of Saurashtra, Gujarat during the year 2007-2010. The earthquake magnitude range is 2.5 to 5.1, and the epicentral distance is up to 70 km. 'Q' has been evaluated at five central frequencies (1.5, 3, 6, 12 and 20 Hz) using 20s and 30s window lengths.

The average Qc relations $Qc = 137\ f^{0.85}$ & $Qc = 141\ f^{0.88}$ have been found for horizontal & vertical components respectively considering the 20 s window length of the coda wave. Similarly, Qc relations $Qc = 205\ f^{0.75}$, $Qc = 226\ f^{0.74}$ have been found for horizontal & vertical components respectively considering the 30 s window length. The obtained Q_C values show that the attenuation is strongly frequency-dependent (as the frequency increases, attenuation will be increased) which is related to the heterogeneity of the medium. The estimated attenuation values can also be used to understand the tectonic stability and medium heterogeneities of a region.

Location of Earthquake using SEISAN software

Ishika Aggarwal[*], Abhishek[1], Ajay, Saurav Deep
Department of Geophysics, Kurukshetra University, Kurukshetra, Haryana
[*]Presenting author: ishika.aggarwal@kuk.ac.in

The recorded earthquake waveform data provides valuable information about the source mechanism. The waveforms can be analyzed using the open source or commercial program codes available in different languages. An open-source software "SEISAN" has been widely used around the world by local seismic networks, volcanic observatories, and/or individual researchers. In the present study, SEISAN software has been used to analyze the recorded waveform data and its functionality has been demonstrated.

It provides all essential tools needed for the basic processing of earthquake data to obtain the location,

magnitude, source parameter, and fault-plane solution. This study focuses on some of the processing tools of the SEISAN on real-time recorded data. The SEISAN has been used to relocate some of the earthquakes that occurred in the NCR region. It has been found that different modules of the SEISAN are mainly useful in locating earthquakes and understanding the source mechanism of the region.

Site Characterization using Strong Motion Data in the North-West Himalayan Region

Mansheetal Singh*, Krati Gupta, Khushboo
Department of Geophysics, Kurukshetra University, Kurukshetra
**Presenting author: mansheetalsingh84@gmail.com*

The Uttarakhand state is situated between the India-Nepal border in the east and, Himachal Pradesh in the west, and is referred to as the Garhwal-Kumaun Himalaya. The region is fed by several perennial rivers such as Yamuna, Ganga, Ramganga, and Kali, which are potential sources of hydroelectric power generation. The Himalayan arc is the manifestation of a convergent plate boundary between the Indian and Eurasian tectonic plates. The continuous subduction of the Indian plate beneath the Eurasian plate below Tibet is the cause of the current seismicity in the Himalayan arc. The Himalayan seismicity is that most of the epicenters are distributed between the MBT and MCT, which is known as the Himalayan Seismic Belt (HSB).

Site effect estimation using recorded ground motion is an effective approach used for the estimation of precise seismic hazards of a region. Keeping this in mind, an endeavor is being made to study the local site effects at different locations in the North West region of the Himalaya through analysis of recorded strong ground motion data provided by the Program for Excellence of Strong Motion Studies (PESMOS). The strong data of six earthquakes recorded at fourteen sites has been used. Site response parameters such as predominant frequency (F_{PEAK}), site amplification (A_{MAX}) at different frequencies, and shear wave velocity up to a depth of 30m (V_{S30}) were estimated using the Horizontal to Vertical Spectral Ratio (HVSR) method. From the V_{S30}, the relative subsurface layer thickness has also been estimated at all the sites. Based on the analysis, the maximum velocity VS30 is 804 m/s estimated at the Munsiari site consisting of Schist and granite. Maximum site amplification 5.5 is estimated at a frequency of 4.3 Hz at the Kapkot site which consists of dolomite.

Study of Shear-Wave Velocity Models in and around North-East India Using Rayleigh-Wave Dispersion data

Nongmaithem Menaka Chanu[1*], Naresh Kumar[2], Sagarika Mukhopadhyay[1], Amit Kumar[3]
[1]*Department of Earth Sciences, IIT Roorkee, Roorkee - 247667*
[2]*Wadia Institute of Himalayan Geology, General Mahadeo Singh Road, Dehradun - 248001*
[3]*National Institute and Ocean Research Centre, Goa- 403804*
[*]*Presenting author: menaka.nongmaithem@yahoo.in*

Rayleigh wave dispersion data of moderate magnitude (Mw 5.4) earthquake of Assam, NE India, is used to retrieve regional shear wave velocity (VSV) models. The earthquake that occurred in NE India is well recorded by 10 broadband seismic stations situated on the Indian, Eurasian and Burmese plates. Group velocities are estimated for the fundamental mode Rayleigh waves using the Multi-Filter Technique. Data from 10 stations form two main groups based on epicentral distance ranges. They are an outer group of 6 stations and an inner group of 4 stations. The ray paths from the event to the stations pass through different parts of the geotectonic features of plates in and around NE India. VSV models of paths from the outer group that passes through the part of Brahmaputra River Basin, Siwalik Himalayas, Eastern Himalayas, and a large part of the Lhasa block suggest the Moho at ~70 km depth. Whereas, the path that passes through Mikir Hills,

the central Indo Burma Ranges, Burma Microplate, Sagaing fault, and Eurasian plate suggests the Moho at 45 km depth. One of the paths in the Indian Plate has enough data to suggest an increasing velocity of up to 70 km and Moho at 45 km. For the inner group formed by the nearby stations in NE India, the path to the station passing through Mikir Hills and Upper Assam Valley shows the Moho at 45 km depth. The other two paths pass through Bengal Basin and Tripura fold belt and show low-velocity medium in the top 18 to 20 km depth indicating the presence of a thick sedimentary layer up to such depths in the Bengal basin. The fourth path goes through the border of the Shillong Massif and the Brahmaputra River Basin. The top layer velocity is much higher compared to the previous two paths due to the presence of the Granitic basement at a much shallower depth. A velocity of 4.3 km/s is observed at a depth of 21 km. This indicates the presence of a thin crust in this region. We found that those paths that pass through the northern part of IBR and along the western side of IBR are not able to identify the Moho discontinuity. This could be because of the steep angle at which the Indian Plate subducts below the Burma Plate. Moreover, in the northern part of the Indo Burma Subduction zone, the subsurface structure shows repeated underthrusting of low-velocity material from the downgoing plate and over thrusting of high-velocity material from the overriding plate.

Earthquake swarm activity in the Western DVP – Magnetotelluric results from the Bhatsa and Palghar seismic zones

N.N. Chakravarthi[1,2*], G. Pavankumar[1,2], A. Manglik[1,2]
[1]CSIR-National Geophysical Research Institute, Hyderabad, Telangana
[2]Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh
[*]Presenting author: nalluru.ngri21j@acsir.res.in

The Deccan Volcanic Province (DVP) is a major geological domain of the Indian peninsular shield. Though the region is considered to be seismically stable, it has experienced some significant intraplate earthquakes, e.g. the Koyna (1967, M6.8, ~15 km) and the Latur (1993, M6.2, ~10 km) earthquakes, as well as swarm type earthquake activity at Bhatsa, Silvasa, Navsari, Nasik, Valsad and more recently at Palghar. Geophysical studies of these regions broadly inferred highly heterogeneous crust along with the role of water and reservoir that possibly altered the stress state of the region leading to such activities. Here, we present Magnetotelluric results along two traverses in the western part of the DVP covering the Bhatsa and the Palghar earthquake swarm regions. Geoelectric models of these two regions obtained by two-dimensional inversion of MT data depict strong resistivity contrast suggesting that the crust below the basalt cover is fragmented. The zones of fragmentation are coinciding with the major pre- and post-eruptive tectonic structures, e.g. the West Coast fault, the Pavel Flexure, and the Kurudwadi rift. By combined analyses of the models with existing geophysical and geological information, we postulate that intersections of local structural trends with these regional tectonic features are the locales for stress concentration. The stresses are increased either due to internal tectonic processes within the fractured crustal blocks or by stimulation of the weak zones.

Identification of Karstic caves using Multichannel Analysis of Surface Waves (MASW) technique- A case study from Cuddapah Basin, South Indian Shield

P. Siva Sankar[*], K. Satish Kumar, K. Swapna Sri, P. Pavan Kishore, B. Laxman, M. Shri Hari Rao, D. Mysaiah
CSIR-National Geophysical Research Institute, Hyderabad
[*]Presenting author: sivamarine007@gmail.com

The collapse and subsidence nature of "Karstic caves" in Carbonate rocks are hazards for human lives and existing infrastructure. The mapping of these caves not only provides the impact of hazards but also provides

clues to underground drainage resources for agriculture and treasure for the archaeological monument. The mapping of these Karstic caves using geophysical methods is still challenging due to the complexity of the near-surface material and the limited resolution of the techniques. Multichannel Analysis of Surface Waves (MASW) is one of the emerging shallow seismic techniques useful to map the subsurface discontinuities like faults, shear zones, fractures, and cavities in terms of shear wave velocity. An experimental MASW study was conducted along the two orthogonal profiles (400 m and 150 m) over the known Belum caves area, Cuddapah Basin, India with a close station interval of 2.5 m to compute shear wave velocities of the formations and their variations. The study aims to establish the standard methodology to delineate the underground cavern system by using the MASW technique in the Indian environment. It is inferred from the MASW study; two distinguished layers are delineated up to the depth of 30 m. The top layer with a velocity of 750 m/s to 1500 m/s represents the massive limestone with a porous/might be cavern zone. This layer is underlain by a very high-velocity layer that varies from 1700 m/s to 2500 m/s. This high-velocity layer might be the bottom of the cavern zone. The thickness of the cavern system is estimated as ~10m partially saturated.

Geomagnetic Precursors of Himalayan earthquake

Rahul Prajapati*, Kusumita Arora*
CSIR-National Geophysical Research Institute
**Presenting author: rahulphy007@gmail.com*

We present a study on the investigation of ground-based geomagnetic (H, D & Z) and electric field (Ex & Ey) data to identify the EM signatures associated with medium to large earthquakes in the Himalayan region. The location of the recording site of the geo-electromagnetic field is near the Main Central Thrust (MCT) in Patiyasar, Kumaun Himalaya, India. The objective of the study is to find the robust anomalies in the geomagnetic and electric field which can be a prominent signature before an earthquake. We used the constrains of seasonal effects on geomagnetic and electric field data from several months to find robust signatures. Although we have considered the effect of seasonal variation on data, we have also verified the anomalies by comparison with the magnetic field of H-component which reduces the ambiguity in the anomalies that can be due to the ionospheric activity. The patterns of anomalies are correlated with the moderate earthquakes ($3.5<M<5.0$) that occurred within a 250 km radius of our site. We suggest that the electromagnetic signatures may be the promising precursors of an earthquake during its preparation.

Determination of Strain accumulation rate in Kachchh Paleo rift using GPS measurements

S. K. Rajewar*, V.K. Gahalaut
GPS and Geodesy Group, CSIR-National Geophysical Research Institute, Hyderabad
**Presenting author: shubhamrajewar@gmail.com*

Within the Indian plate the prominent failed rift regions, namely, the Narmada Son, Kachchh, and Godavari have produced major and moderate magnitude earthquakes in the past few decades causing considerable loss of human lives and property. In the past 200 years, the Kachchh paleo-rift in western India, a plate interior region, has witnessed an unusually large number of strong earthquakes, namely, the 2001 Bhuj (Mw 7.6), 1956 Anjar (Mw 6.0), 1845 Lakhpat (Mw ~6), and 1819 Allah Bund (Mw ~7.7) earthquakes.

Here we estimated the strain accumulation rate from 23 GPS measurements which provide constraints on long-term tectonic deformation in this region. We have estimated the site velocities in the Indian Reference frame using the Euler pole. These site velocity estimates show predominantly north-south motion, leading to compression in the Kachchh region. We calculated the two-dimensional strain rate with ($0.5^o \times 0.5^o$) gridding,

using the site velocity estimates in the Indian reference frame where we calculated dilatational, second invariant, principal axes, and maximum shear strain and dextral-sinistral motion using a Python-based Strain-Tool software. For this purpose, we used the least square method proposed by. We found that the principal axes of strain exhibit N-S compression with an average rate of 4 nstrain/yr in the Kachchh region but as we move closer to the failed rift region it increases to 7-9 nstrain/yr. Maximum shear strain rate in this region is 2-5 nstrain/yr and the Second Invariant component is in the range of 2-10 nstrain/yr. The dilatation strain rate (negative) shows a convergence strain rate of 4.5 nstrain/yr. All these parameters imply that Kachchh failed rift is reactivated as a reverse fault. Although the current strain rate is high, it may not continue to remain at the same level as such regions show large variations in strain rate with time.

Estimation of earthquake hazard parameters for the Himalayan Seismic belt

Rajiv Kumar[1*], R.B.S. Yadav[2], Himanshu Mittal[1]
[1]National Center for Seismology, Ministry of Earth Sciences, New Delhi
[2] Department of Geophysics, Kurukshetra University, Kurukshetra
[*]Presenting author: tomargp18@gmail.com

In the present work, using the maximum likelihood method, we investigated the spatial distribution of seismicity and earthquake hazard factors for the Himalayan seismic belt (HSB). This technique allows the use of either historical or instrumental data or a combination of both. Using this method, the maximum regional magnitude (M_{max}) mean seismic activity rate (λ), well-known a & b-values of the frequency-magnitude G-R relationship, return periods (RP) and probabilities of different earthquake magnitudes are estimated along the (HSB) bounded by 25^0-35^0N,72^0-98^0E. A catalog of earthquakes from 825 B.C. through 2019 A.D., homogenized for Mw and declustered from dependent events is used for shallow depth (0-25 km) earthquakes. The hazard parameters are calculated in 34 seismic source zones corresponding to shallow depth (0-25km), which are identified by their seismicity level, focal mechanism, and seismotectonic setting. The determined hazard parameters have been geographically mapped in all different seismic source zones to analyze the spatial variation of localized seismicity parameters. The source zones 16, 18, 26, 29, and 33 exhibit M_{max}≥8.0 and have the potential to generate M_{max} 7.0-7.7 earthquake. The estimated RP of earthquake for M_w 7.0 show low RP (35-94 years) for zones 1, 5, 6, 15, 19, 22, 23, 26, 31, and 33, whereas, the probability of the occurrence of M_w 7.0 in 100 years is observed to be high (>0.70) in these zones. In nutshell, the low return periods and high probabilities are observed in zones 1, 5, 6, 15, 26, 31, and 33 for the studied depths (0-25km). It is perceived that the seismic hazard level changes spatially and reveals high-level crustal heterogeneities and seismotectonic complexity in the inspected regions.

Geometry of the Main Himalayan Thrust in Garhwal Himalaya

Sandeep Gupta[1*], P. Mahesh[1,2], K. Nagaraju[1,3], K. Sivaram[1], Ajay Paul[4]
[1]CSIR-National Geophysical Research Institute, Hyderabad 500007
[2]CSIR-National Institute of Oceanography, Dona Paula - 403004, Goa
[3]Pondicherry University, Puducherry - 605014
[4]Wadia Institute of Himalayan Geology, Dehradun- 248001
[*]Presenting author: sandeepgupta@ngri.res.in

Objective assessment of seismic hazard and understanding of the Himalayan arc's tectonics requires detailed information on the crustal structure and geometry of the under thrusting Indian Plate beneath the Himalaya. We use seismic waveforms recorded at 41 seismological stations operated during 2005-2008, and determine the seismic crustal structure beneath the Garhwal Himalaya using teleseismic receiver function modeling and 3-D local earthquake tomography. We integrate these results with earlier studies (magnetotelluric and Lg

attenuation etc.) and propose that the Main Himalayan Thrust (MHT), having a flat-ramp-flat geometry, lies at the base of fluid (saline-rich aqueous fluid/partial melt) zones present in the upper-crust. We also argue that the earthquake occurrence in the Kumaun–Garhwal Himalaya is largely controlled by the geometry of the MHT and crustal lithology.

Insight on shallow crustal configuration of the Himalayan Frontal Thrust using an integrated active and passive seismics

Shashank Narayan Verma*, Dibakar Ghosal, Anubhav Mukherjee
Indian Institute of Technology Kanpur, Kanpur – 208016, UP
**Presenting author: snarayan@iitk.ac.in*

The Himalayan Frontal Thrust (HFT) system ruptured in the past outbreaking multiple earthquakes and is highly vulnerable to any future earthquakes. To properly assess the risk associated with future earthquakes, a thorough investigation of the regional subsurface structure is critical. We carried out active and passive seismic studies to obtain the appropriate velocity model and geometry of the HFT system in the Kumaon Himalayas near Pawalgarh, Uttarakhand. By analyzing the ambient noise data, we found the Rayleigh wave group velocity to vary between 320 m/s and 1334 m/s, having an average velocity of 750 m/s. This study speculates the onset of the HFT following the average velocity contours from the region. We then carry out the travel time tomography studies of the seismic thumper generated data recorded in remote acquisition unites (RAUs) and 5 Hz geophones and observe the low-velocity layer of 1200–1800 m/s (P-wave velocity) of about 100 m thick to overlie the Siwalik Formation. Seismic imaging reveals the geometry of the HFT and Kaladungi Fault (KF) dipping 33° and 30° at the surface towards the north, respectively. Our results further show the thickness of the Upper and Middle Siwalik ~1.2 km and 1 km having an average interval velocity of 2.82 km/s and 3.23 km/s, respectively. Finally, we estimate the possible horizontal shortening across HFT and KF of ~1.23 km and 0.84 km, respectively. Measured parameters can play a crucial role in modeling the ongoing tectonics of the region and provide key input information for geotechnical studies for an efficient hazard assessment.

Seismological monitoring of Donichawadi fault associated with the 1967 M6.3 Koyna earthquake towards setting up of Fault Zone Observatory at depth

Sunil Rohilla*, Anup K. Sutar, G. Srihari Prasad, Himanshu Chaube, Digant K. Vyas, Sukanta Roy
Ministry of Earth Sciences, Borehole Geophysics Research Laboratory, Karad 415105
**Presenting author: sunil.rohil@gmail.com*

The Koyna region in western India is characterized by recurrent seismic activity over more than five decades. The seismicity is largely confined within a 20 km × 30 km area and extends down to a depth of ~10 km. The largest earthquake in the region was the *M* 6.3 Koyna earthquake of December 1967, which caused more than 200 casualties. The event formed a ~NNE-SSW trending surface rupture known as the Donichawadi fissure zone, which was originally mapped by the Geological Survey of India in the wake of the earthquake, over a length of ~4 km and a width of ~200 m between Nanel and Kadoli. Geophysical, geochemical, and seismological investigations combined with drilling studies show that the fissure zone is the surface manifestation of a deeper crustal fault. Detailed seismological monitoring in the Koyna-Warna region since 2005, including a 5-station local network deployed in the vicinity of the fault zone in January 2022 confirms that the Donichawadi fault is seismically active even 55 years after the 1967 earthquake. During January-June 2022, approximately 745 microearthquakes with magnitude range -0.5 to 3.7 and extending down to a depth of 10 km have been recorded by the local network, besides several thousand events recorded by the other stations. Existing velocity models of the Koyna region are being tested to locate earthquakes with improved

accuracy. Deep drilling down to 3 km at Gothane, ~5 km to the south of Kadoli, reveals that the majority of the fractures strike along NW-SE to NNE-SSW, consistent with the Donichawadi fissures, and dip steeply in the range 40-75°. These observations support the extension of the Donichawadi fissure zone to deeper levels and drilling at this site may cut across the fault zone. Accurate locations of events using the enhanced broadband network will be helpful in determining the potential trajectory of the deep borehole for setting up a Deep Fault Zone Observatory in the region.

Geological, Geo-electrical resistivity and Geochemical studies on gem tracts in parts of Eastern Ghats, Visakhapatnam District, Andhra Pradesh, India

P. Trinadha Rao
Hon. Professor, Department of Geophysics, Andhra University, Visakhapatnam.
Presenting author: trinadhrao2004@gmail.com

The occurrence of gem minerals is a rare phenomenon and in the same way, the geological information, geophysical and geochemical information are also very rare.

Visakhapatnam District of Andhra Pradesh state in India, located in parts of the Eastern Ghats comprising valuable mineral resources, especially gem minerals. The precious and semi-precious stones of Alexandrite, Chrysoberyl, Chrysoberyl cat's eye, Garnets, Tourmaline, Sillimanite, and a variety of quartz groups are known to occur in this region. The gemstones are very much engulfed within the pegmatite both in the primary and secondary stages.

The geological studies on exploration, mining, and environmental planning have shown very promising results, where the gem mineral resources were estimated to a depth of 15 mts. from the surface. Geo-electrical resistivity surveys have been utilized and the results are favorable and correlated with the surface geological features.

The geo-chemical investigation was carried out for the host rocks and the associated gem-variety stones and analyzed for their major and minor elemental concentrations. Geochemical analysis of the petrological members of gem-bearing tracts of the region was carried out by ICP-MS and elemental concentrations were determined. A few of the samples were processed for XRD analysis.

The following important points are noted in (i) Invaluable gem minerals are found in association with the Khondalite suite of rocks, as per their geochemical evaluation. (ii) The secondary pegmatitic body indicated all the mineralogical characteristics of the primary pegmatites in a deeply altered stage (iii) The colluvium forms the target of explanation for the gem minerals in this region. (iv) The study shows that the element fluorine is endangered to the local rural people, which may result in fluorosis in parts of this region.

1-D regional Vs-structure from inversion of group velocity dispersion Measurements of Love and Rayleigh waves – application to the Uttarakhand Himalaya

Abhishek Kumar Gupta[1,2*], Prantik Mandal[2]
[1]Wadia Institute of Himalayan Geology, Dehradun-248001
[2]CSIR-National Geophysical Research Institute, Hyderabad - 500007
[*]Presenting author: abhishek9162687550@gmail.com

We study surface wave group velocity dispersion characteristics and average 1-D regional shear velocity (V_s) structure of the Indian part of the Himalayan region, using digital waveform data of twenty-one regional

Indian earthquakes of M_w 5.0-6.2, which occurred during 2018-19, from 17 three-component broadband seismographs of the Uttarakhand Himalayan seismic network of the National Geophysical research Institute, Hyderabad, India. First, we measure fundamental mode group velocity dispersion data for both Rayleigh and Love- waves in the period of 6-73 s and then invert these dispersion curves to estimate the average 1-D regional crust and upper Mantle Vs-structure below the Kumaon-Garhwal (K-G) Himalaya. Our best model in Uttarakhand Himalayan region, India, reveals an 8-layered crust with a mid-crustal low-velocity layer (approximately a drop of 1.5-2.3% in V_s) between 8 and 20 km depths below the vicinity of the Main central thrust (MCT) zone. In the upper crust (0- 20 km depths), our modeling suggests shear velocities ranging from 3.1 to 3.9 km/s while shear velocities in the lower crust (20 – 45 km depths) are modeled to be varying from 3.7 to 4.69 km/s. The Moho depth is modeled to be at 45 km depth below the K-G Himalaya while the Vs in the upper mantle is found to be 4.69 km/s. Our modeled mid-crustal love velocity layer possibly could be attributed to the presence of metamorphic fluids in the fractured main Himalayan thrust (MHT), resulting from the weakening of the crustal material at the interface between the overriding Eurasian plate and the upper part of the under-thrusting Indian plate.

Reconstruction of Paleodietary and Paleoehabitat of late Miocene Siwalik herbivore mammals from Nurpur, Himachal Pradesh, India

Abhishek Pratap Singh[1,2*], Ramesh Kumar Sehgal[1,2], Ningthoujam Premjit Singh[1], Aditya Kharya[1,2]
[1]Wadia Institute of Himalayan Geology, Dehradun-248001
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh-201002
[*]Presenting author: abhishekpratap@wihg.res.in

Here we present the five (75 serial samples) fossil tooth enamel stable carbon and oxygen isotope data of late Miocene (Dhok Pathan) herbivore mammals from Nurpur Himachal Pradesh, India. Stable carbon isotopes from fossil mammalian dental enamel provide evidence of the past dietary habitat, whereas stable oxygen isotopes reflect the past temperature and precipitation. We also correlate our dental enamel data to published late Miocene fossil tooth enamel data in order to understand the trend of expansion of the C4 plant. The $\delta^{13}C_{enamel}$ values of five herbivore fossil mammals are -11.29 ±0.63, -12.01 ±0.47, -12.97 ±1.11, -13.30 ±0.71, and -12.68 ±0.49‰, respectively and the mean value is -12.2 ±1.09 VPDB. This indicates that the mammals were mainly C3 diet from close canopy forest to woodland, whereas the very less abundance of C4 grasses was also noticed in their diet. The $\delta^{18}O_{enamel}$ mean value -7.81 ±1.92‰ VPDB, with an average oxygen isotope ratio of -8.85 ±1.71, -10.65 ±0.23, -8.26 ±1.92, -5.83 ±0.85 and -7.86 ±0.62‰ respectively suggested the existence of humid/wet climatic conditions in the area during the late Miocene. The occurrence of the same trend of the C4 vegetation expansion at around ~8-7 Ma is shown by integrating the data of late Miocene herbivore mammals from Pakistan, Afghanistan, the Tibetan Plateau, Greece, India, and the present data. Overall, the present stable isotopic data represent forested and woodland environments with patchy grassland and water likely to be derived from local sources such as ponds or streams.

Vertebrate coprolites—a key to reconstruct ancient ecosystems

Nibedita Rakshit[1*], Sanghamitra Ray[2]
[1] Department of Earth Sciences, IIT-B, Powai, Mumbai- 400076, Maharashtra
[2] Department of Geology and Geophysics, IIT-K, Kharagpur – 721302, WB
Presenting author: nibedita18@iiserb.ac.in

Coprolites are fossilized excretory materials of prehistoric organisms comprising pulverised undigested or partly digested food material that had passed through an animal's digestive system and subsequently defecated. These coprolites provide direct insights into the digestive processes, diet, prey-selection

behaviour, and physiology of their producers and constitute tools for deciphering ancient biodiversity and animal interaction in palaeoecology. More than 400 vertebrate coprolites were found embedded in a calcirudite unit of the Upper Triassic Tiki Formation of the Rewa Gondwana Basin in close association with varied micro- and mega- vertebrates. Morphologically these coprolites show wide variation and can be broadly categorized as non-spiral cylindrical (without any internal structure), spiral (external appearance resembling a ribbon coiled around a long axis, but internally consisting of stacked and spiraling cones), and scroll (similar to a rolled sheet of paper). The non-spiral cylindrical types were mostly produced by a wide variety of tetrapods whereas different morphologies of the spiral and scroll coprolites were attributed to different groups of dipnoans, actinopterygians, and chondrichthyans that prevailed in the Late Triassic Tiki. A detailed study of these coprolites exhibits a wide variety of inclusions in the forms of teeth, ganoid scales, and other skeletal remains of both aquatic and terrestrial animals. The study shades light on the predator-prey relationship and connectedness between these coprolite-producing animals and reveals a dynamic and highly diverse Late Triassic animal community. The community proliferated across the inter-realm boundaries that existed in a fluvial setting. This study highlights the importance of vertebrate coprolites in reconstructing and understanding ancient ecosystems.

Conservation of Geoheritage sites in Himalaya: Siwalik Fossil Park, a case history

V. P. Mishra
Secretary, Palaeontological Society of India, Lucknow
Presenting author: mishravijayp@gmail.com

Siwalik rocks forming the foothills in the Indian subcontinent are famous worldwide among geoscientists for the large variety and number of vertebrate fossils mainly mammals entombed in these sediments. In addition to mammalian fossils, fossils of fish, a few amphibian, snakes & birds, crocodiles, tortoises, molluscan shells, leaf impressions & fossil wood have also been recovered from Siwalik rocks. Several sections mainly in the Markanda valley, north of Chandigarh, south of Nalagarh, around Nurpur, Uttarbaini, and Ramnagar in H.P., Haryana, and J. & K. states are richly fossiliferous.

A geosite in Siwaliks at Saketi in the Sirmaur district of Himachal Pradesh was established as Fossil Park way back in 1974. Siwalik Fossil Park, Saketi has been developed by the Geological Survey of India, in collaboration with the Himachal Pradesh Government, which is a significant step towards the preservation of prehistoric animal sites, restoration of their natural environment and utilization of the same for scientific, educational and recreational purposes. The museum at the Siwalik Fossil Park, Saketi displays a large number of Siwalik vertebrates. A number of life-size models of Siwalik vertebrates have also been erected at the locations from where their fossils were recovered in the park. The Siwalik Fossil Park has been designated as National Geological Monument in 2001 by the Geological Survey of India.

In addition to fossiliferous sites, Siwaliks exhibit exemplary sedimentary structures, tectonic features, and even neotectonic activity. At least some of these sites also need to be conserved and preserved for future generations. Several more fossiliferous Siwalik geosites are needed to be preserved in the Jammu region, Himachal Pradesh, Haryana, Uttarakhand, West Bengal, and Arunachal Pradesh.

During the last several years only one fossil park / geosite in the Siwaliks of northwestern Himalaya could be established. Since the land of the geosites belongs to the States, the state authorities need to be informed/sensitized/provoked/guided in conserving and preserving of certain Siwalik geosites having features of special interest/fossil locations. This may be of help in the future to declare more geo-heritage sites/monuments in Indian Siwaliks. Since the Siwalik foothills do preserve several cultural, religious, and heritage sites, the geosites may also be included in tourist circuits.

Seismicity and Focal mechanism solution study in Eastern Himalayan Syntaxis using waveform Inversion

Ashish Pal[1,2*], Dilip Kr. Yadav[1], H.C. Nainwal[2]
[1]Wadia Institute of Himalayan Geology, Dehradun-248001
[2]Hemvati Nandan Bahuguna Garhwal University, Srinagar Garhwal-246174
[*]Presenting author: ashish@wihg.res.in

The Siang Valley of Arunachal Pradesh is one of the seismotectonically very active regions which lies in the eastern Himalayan Syntaxis, we have investigated seismicity and fault plane solutions in this region using the data obtained from eight broadband seismic stations (BBS) by the Wadia Institute of Himalayan Geology in 2019. We have analyzed 350 local and regional earthquake events in the magnitude range ($3 \leq ML \leq 5.9$) in the region during the period from January 2019 to May 2020. From the distribution of local seismicity, it is observed that the concentration of seismicity is in Namcha Barwa, western and eastern flanks of Siang Valley respectively. The depth distribution of seismicity extends up to a focal depth of 45 km with a higher concentration in the upper crustal part. Further, we determined eight numbers of fault plane solutions (FPS) using wave form inversions (ISOLA) for the events having magnitude between 3.5 to 5.9. The waveform inversion has been performed for those events which have maximum azimuthal coverage. The frequency band used for inversion is in the range of 0.02–0.10, which corresponds to the maximum signal-to-noise ratio. An accurate crustal velocity structure, hypocentre location, and a proper frequency band have been used for obtaining reliable fault plane solutions. The FPS obtained for the shallow focused events shows Thrust as well as Normal type of mechanisms with a little amount of strike-slip components. The compressional axes orientations of the thrust fault plane solutions show a north-easterly direction and the tensional axes of the normal fault mechanism show NW-SE. High seismic activity in the region is due to the northward movement of the Indian plate towards Eurasia and its eastward subduction with the Burmese plate.

3-D Seismic Velocity Structure of the Kinnaur region of NW Himalaya based on Local Earthquake Tomography

Javed Raoof[*], Naresh Kumar
Wadia Institute of Himalayan Geology, Dehradun, India
[*]Presenting author: rjaved@wihg.res.in, rjavediitk@gmail.com

Traveltime tomography images the heterogeneous velocity structure beneath the Kinnaur region of NW Himalaya using earthquake data recorded by a local seismic network of 12 broadband stations. The data of 928 local earthquakes were used from 2008 to 2012 with a magnitude range of 1.0 to 4.5. The seismicity is mainly confined in the upper crust (~25 km depth) with a majority of earthquakes located up to 35 km focal depth. The dataset consists of 5655 P–rays and 5602 S –rays on an average of 12 picks per earthquake. To check the reliability of our results we have performed a checkerboard test with different anomaly sizes and amplitudes at different depth sections of the crust. The anomaly size of 30×30 km^2 is well resolved with an amplitude of ± 10 percent. The results are well resolved up to ~35 km depth. The tomographic image shows a high-velocity body at a shallower depth from ~ 0-5 km comprising of thrusted hard and rigid crystalline rocks. Whereas low-velocity anomaly patterns at shallower depths reflect the tectonic features. The tomograms showing low-velocity body up to ~25 km depth represents the underthrusted crustal part of the Indian plate comprising of the sedimentary wedge. The S-wave velocity tomograms have more contrast and lower velocity strata compared to P-wave velocity. The seismicity pattern corroborates well with the observed seismic velocity anomaly patterns and tectonic features. Most of the Seismicity occurs at/or near the junction of the two anomalous zones of high/low seismic velocity patterns. This pattern is more governed by the Vp/Vs images suggesting structural heterogeneities. The patterns of the observed low-velocity anomalies may correspond to the alignments of faults and the high-velocity anomalies may represent the rigid blocks. We

postulate that there is a variation in the strength of the underthrusting Indian plate along with the major structural trends in the Himalaya. This may be due to the presence of heterogeneities and complicated subsurface architecture resulting from crustal level folding and faulting phenomena and rotation of the Indian plate during the Indo-Asia Collison process. The new results were obtained for the first time in the study region which may be useful for seismic hazard and related studies.

Shear wave crustal velocity structure in the Northwest Himalaya based on noise cross-correlation of Rayleigh wave

Naresh Kumar*, Sanjay K. Verma, Devajit Hazarika, Ajay Paul, Dilip K. Yadav
Wadia Institute of Himalayan Geology, 33 GMS Road, Dehradun-248001, India
**Presenting author: nkd@wigd.res.in*

We investigate crustal shear wave velocity variations using ambient noise cross-correlation tomography in the central part of the northwest Himalaya. The studied region encompasses the Kali River valley in the east to Satluj valley in the west, with the adjoining Indo-Gangetic Plain in the south covering the northern part of the Delhi-Haridwar ridge. It includes the south Tibetan detachment and the southern part of western Tibet. Fundamental mode group velocities of Rayleigh waves are extracted from the cross-correlation data of 46 Broadband seismological stations from the regional seismic network of the Wadia Institute of Himalayan Geology, Dehradun. Over 600 dispersion curves in the period range of 4-40 s show a group velocity variation between ~2.2 and ~3.9 km/s. The shear wave velocity structure of the uppermost lithosphere down to ~60 km obtained by non-linear inversion of the Rayleigh wave dispersion data provides new insight into the geometry of the crust and Moho. A large variation in Vs in the range of ~2.4 to ~4.8 km/s corresponds to the tectonic deformation of the Himalayan wedge, a variety of changes in structure, and crustal thickness variations. Thick low-velocity sedimentary formations are identified beneath the Indo-Gangetic Plain and the frontal Himalaya. Anomalous low Vs zones are also observed in the mid-crust beneath the higher Himalaya and southern Tibet, indicating partial melting or the presence of aqueous fluid zones. The high-velocity anomalies may be correlated with duplex structures beneath the Lesser Himalaya and with lithospheric flexure. A Low-velocity zone is observed at ~10-15 km depth around the MCT, which is interpreted as the presence of fluid that causes micro-to-moderate size earthquakes in the Himalayan Seismic Belt. The low-velocity zone beneath Tethys Himalaya in the lower crust to the north of the ramp structure is caused by the shear heating in the ductile regime and/or decompression due to partial melting. The LVZ becomes thicker and extended to the lower crust towards the north beneath southern Tibet. In Tibet, similar signatures were reported further north through surface wave studies. Possibility of flexure in the mantle below ramp structure, high-velocity zone in the lower crust beneath Inner Lesser Himalaya. It indicates the possibility of thinner Moho due to flexuring. The flexural geometry and rheological study of the Indian plate beneath the eastern Himalaya in Bhutan has also been evaluated in previous studies.

Floods: Past and Present

Sedimentary record of paleoflood events along the western continental shelf of India

Firoz Badesab[1*], Deepak, RP[1,3], Nitin Kadam [1,2], Rajeev Saraswat[1]
[1]CSIR- National Institute of Oceanography, Dona Paula-403004, Goa
[2]School of Earth Ocean and Atmospheric Sciences, Goa University, 403206, Goa
[3]Academy of Scientific and Innovative Research, CSIR-NIO, Dona Paula-403004, Goa
[*]Presenting author: firoz@nio.org

Continental-shelf sediments are valuable archives to document the paleoflood events, magnitude, and evolution over geologic time. We employed rock magnetic, mineralogical, and geochemical methods on the sediment core retrieved from the inner continental shelf, off Goa to reconstruct the history of paleoflood events through Holocene. Two distinct paleoflood events marked by enhanced increase in ferrimagnetic mineral and calcium carbonate content followed by the presence of coarse-grained sediments were identified at ~ 6.77 – 6.43 ka and ~ 6.14 – 5.56 ka, respectively. Multi-proxy data revealed that the paleoflood events had a pronounced impact on the sediment delivery and accumulation in estuarine and shelf regions off Goa. Comparative rock magnetic analyses of source rocks, riverine, estuarine, and shelf sediments helped to delineate the source-specific sediment contribution from different tributaries. End member analysis on magnetic remanence and grain size data revealed four distinct end members (EM1 and EM3: Ferrimagnetic, EM2 and EM4: Antiferromagnetic) based on the coercivities and their contributions towards the bulk sediment record varied over time. We attribute that the temporal variation in the sediment (fine and coarse-grained) contribution during paleo-flood events can be linked to a major change in climatic conditions.

Changing land use to Coastal Flooding in parts of Krishna River delta, Andhra Pradesh, India

M.V. Ramana Murty[1*], K. Mruthyunjaya Reddy[2], K.V. Swamy[3]
[1]AP Space Applications Centre (APSAC), Labbipet, Vijayawada - 520010
[2]National Remote Sensing Centre, Balanagar, Hyderabad- 500037
[3]Dept. of Geosciences, Adikavi Nannaya University, Rajamahendravaram - 533296
[*]Presenting author: moidavrm64@gmail.com

The deltaic plains are bestowed with lush coconut gardens, extensive croplands, evergreen mangroves, etc. These plains are prone to various natural disasters like cyclones, tsunamis, and associated flooding. Tropical storms claim several lives, damage croplands, destroy infrastructural facilities, disrupt communication networks, etc., depending upon their intensity. Some of the cyclonic storms that affected the Krishna river delta region on the east coast of India include October 1779, November 1864, October 1949, November 1977, May 1990, etc. However, the loss of human lives during the recent event is gradually reducing mainly due to the improved dissemination system and timely evacuation. The Earth observation from space enables us to address various issues on land resources and disaster management. Satellite-derived flood inundation maps produced in near-real time provide valuable information to identify the affected areas. The interpretation of land use/ land cover classes before the event provides insight into likely damages. Further, the coastal land forms like tidal flats and mud flats support mangrove vegetation, which protects the coastal population from the constant threat. The land use category like aquaculture is likely to amplify the flood vulnerability, as it obstructs the free flow of retreating floods. In the present study, land use/ land cover classes and the extent of flood inundation between May 1990 and September 2016 are analyzed. The standing flood waters in agriculture lands are observed behind the beach ridge & swale complex in the deltaic plain between Bapatla and Ponnuru in the Guntur district. The extent of mangrove vegetation within the sanctuary is improving, while outside the boundary there is some degradation. Thus, the land use/ land cover patterns along with geomorphic setup play an important role in assessing the flood response in space and time.

Impact of floods in a Socio-hydrological perspective with a special focus on Chennai, India

Rinisha Kartheeshwari Mariappan, Elango Lakshmanan
Department of Geology, Anna University, Chennai

About half of the world's population is residing in urban areas (UN-Habitat report, 2008). Due to the very high population density, urban floods became very common. Though the mortality rate due to floods in India has been reduced to 3-5% each decade, they cause a huge socio-economic loss in a very short period. Chennai city is one of the rapidly growing cities in the world with a population of about 85 lakhs, which is growing at a rate of about 2.5% per annum. The Chennai metropolitan area (CMA) was having about 470 lakes, ponds, marshlands, and swamps. Chennai city is also blessed with two major rivers (Adyar & Cooum) and an artificial (Buckingham) canal running close to the sea from north to south. Rapid urbanization has resulted in the conversion of over 85% of these waterbodies into built-up areas (The Hindu, 2018), which has resulted in reducing the city's resilience to severe monsoonal rains and associated floods. In recent years, the impact of climate change and the associated variation in the rainfall pattern is also been witnessed by the city. In the last two decades, Chennai city received excess rainfall in the years 2005, 2008, 2015, and recently in 2021 which has resulted in the inundation of many localities of Chennai. The average annual rainfall in Chennai city is 1400 mm. In the year 2021, the city received 1044 mm of rainfall in the month of November itself. Thus, the annual rainfall of Chennai in 2021 was 2174 mm which is the third-highest in the last 175 years and inundated more than 550 localities in the city of Chennai. In the past floods occurred due to natural phenomena. Contrarily majority of the recent floods occur due to poor maintenance of stormwater drains, micro water drains, canals that are encroached and clogged due to siltation, and solid waste disposal in addition to climate change. These impacts can be reduced by letting the city act as a sponge with the facilitation of bioswales, tree trenches, sidewalk planters, and curb bulbouts. While clearly assessing, that Climate change is just one of the causes of floods. Incorporating the above-mentioned way forward methods with high awareness can reduce the chaos faced by the socio-hydrology of all the cities including Chennai city.

Geodynamics, Crustal evolution, and Mantle structures

Three-dimensional seismic velocity structure and seismotectonics beneath the Sikkim-Darjeeling Himalaya

A.P. Singh[1*], O.P. Mishra[1], O.P. Singh[2]
[1]National Center for Seismology (NCS), Ministry of Earth Sciences (MoES), Lodhi Road-110003, New Delhi
[2]Geological Survey of India (GSI), 27, J. L. Nehru Road, Kolkata-700016, WB
[*]Presenting author: apsingh07@gmail.com

In this study, we attempted to establish the plausible depth of disposition of the basal décollement through 3-D seismic imaging using local earthquake tomography to understand the linkage between seismogenesis and collisional tectonics of the Sikkim-Darjeeling Himalayan region. We analyzed a total of 2105 events recorded by 42 broadband seismograph stations during 2005 – 2011. Detailed 3-D seismic imaging unraveled heterogeneous velocity structures (Vp and Vs) with low and high velocities with distinct variations in Poisson's ratio (σ) at different depth ranges. A well-resolved low-velocity zone is found to persist consistently at depth of about 20 km that corresponds to the gentle, north dipping décollement plane, exhibiting significant velocity perturbations across this interface. The geometry and depth of the décollement surface are found to vary laterally and its deepest disposition is observed at a depth of ~ 30 km. The shallower low-velocity zone up to 10 km with higher-σ suggests the presence of the Quaternary piedmont sediments with high fluid saturations while the higher velocity perturbation with low σ at the mid-crustal layer is indicative of the competent parts of the crust, where seismogenesis is related to the occurrence of earthquakes of varying strengths beneath the Sikkim - Darjeeling Himalayan region. Our seismic imaging corroborates with the past moderate earthquakes that were confined to the vicinity of high and low velocity (Vp and Vs) and σ zones whilst the strong size earthquakes (M > 6.0) occurred mostly below the décollement plane where high-velocity basement thrust exists along with Indian subducting plate. This study clearly expresses the well-defined disposition of the décollement zone that controls the nature and extent of seismogenesis.

Morphotectonic Study of Siwalik Hills region near Sirmaur district, Himachal Pradesh, India to delineate the hidden (subsurface) faults in the area

Aakanksha[*], Kirti, Sushil Kumar
Department of Geophysics, Kurukshetra University, Kurukshetra
[*]Presenting author: sharmakanksha10@gmail.com

Himalaya is a tectonically active region due to the continuous movement of the Indian plate in the northward direction. This has made the foothill terrain a high-stress and strain zone. We present a study in the Sirmaur district region in the Lesser Himalayas, commonly known as Shivalik. There are earthquakes ranging from 1 to 5 magnitudes in the recent past shows that the study area is tectonically active. In this study, the densely populated foothill zone of Shivalik Himalaya between the Markanda River and the Yamuna River in and around the Sirmaur district has been critically analyzed by morphological and geophysical techniques. The six river basins Yamuna River, Giri River, Bata River, Markanda River, Somb River, and Asan River in the study area have been morpho-tectonically analyzed. For this purpose, Resources at 1: LISS III Ortho satellite imageries and field studies have been used to assess the active tectonic setup of the terrain qualitatively. The different geomorphic indices such as the longitudinal profile, and the stream-length gradient index (SL) have been used to find the hidden faults in the study area. Electrical resistivity surveys have been used to confirm the presence of hidden faults in a particular area. The study reveals that the terrain in the Sirmaur district of Himachal Pradesh is seismo-tectonically active and proper building codes should be followed in construction activity. There is an urgent need to characterize the tectonic nature of the populated foothill region and to identify the active faults in the whole terrain that can pose a serious seismic threat.

Automated magnetotelluric data processing using SigMT python package

K.S. Ajithabh*, Prasanta K. Patro
CSIR – National Geophysical Research Institute, Hyderabad
**Presenting author: ajithabhks@gmail.com*

Manual time series editing makes magnetotelluric (MT) data processing usually a time-consuming job. Developments in MT data processing enable automation and offer minimum manual involvement in the time series editing. We introduce a new open-source python package named 'SigMT' which helps to process the MT time series to obtain MT impedances and tipper data in an automated way. Mahalanobis-based data selection tool facilitates automated data processing of the data. Also, different data processing tools such as coherency threshold-based selection and polarization direction-based selection are included in the SigMT. The robust estimation technique is used to obtain the final MT impedances. We demonstrate the application of the SigMT package in the data acquired from the NW Himalaya to show the efficacy of the package.

Upward migration of gas over the Diligent fault: Andaman subduction

Ankush*, A.K. Anirudh, P. Vishnupriya, S. Seshuganesh, Sriram G., Dewangan P.
CSIR-National Institute of Oceanography, Goa-403004
**Presenting author: ankush96@nio.org*

Forearc basins play a central role in the geodynamics of tectonic plates and help stabilize the wedges of graben-associated accretionary prisms. The Andaman Forearc Basin study area lies east of the subduction zone where the Indian Plate subducts under the Sunda Plate in the northeastern Indian Ocean. In November 2021 on RV Sindhu Sadhana (Cruise SSD-085) we conducted a high-resolution 2D Multichannel Seismic Survey (MCS), multi-beam echosounder survey (MBES), and Water Column Imaging (WCI). In the current study, evidence of a new gas flare was found on one of the ridges in the southern part of the Diligent Fault Zone (DFZ). The flare occurs at a depth of 1550 m and has an average height above the seafloor of 700 m. The mound-like feature is observed between CDPs 1020 and 1360 at seismic intervals, indicating very low-amplitude reflections from the seafloor. The lateral extension of the mound is 535 meters. Several fault-like structures are found nearby, as well as a bottom simulation reflector (BSR) at a two-way travel time of 2650ms between CDP1430 and 1920 under the mound. These types of reflectors mimic the ocean floor butexhibit opposite polarity to the ocean floor. BSR is the most common attribute used to infer the presence of gas hydrates underground. We also observed several other high-amplitude features at shallow depths. This may indicate that free gas migrated from deeper regions through cracks moving in both directions under the mound.

A comparative study of the Noa-Dihing and BurhiDihing River Basins in Assam and Arunachal Pradesh: A fluvial morphometric approach

Anwesha Dutta Hazarika[2*], Manoj Kr. Phukan[1,2]
[1]*Geoscience&Technology Division, CSIR-North East Institute of Science and Technology, Jorhat, Assam*
[2]*Academy of Scientific and Innovative Research (AcSIR), CSIR-NEIST Campus, Jorhat, Assam*
**Presenting author: anweshaduttahazarika96@gmail.com*

The Noa-Dihing and BurhiDihing River in the states of Assam and Arunachal Pradesh emerges from the common catchment areas located in Naga-Patkai Range (NPR) and Mishmi Hills. After taking feeds from numerous tributaries in the areas of NPR and Mishmi Hills the rivers started flowing through separate channels from Miao in Arunachal Pradesh. Downstream from Miao the Noa-Dihing is mainly fed by some small streams originating in the Manabhum Hill Range situated at north of the river. After flowing through a

tight meandering channel in the juncture of the Mishmi Hills and NPR, the Noa-Dihing River follows a braided course for more than 50 km in the plains, thereafter again taking a meandering course of about 35 km before it merges with the Lohit River near Dibru-Saikhowa National Park in Tinsukia district of Assam. Change from a braided to a meandering course may indicate a break in the topographic slope aspect. On the other hand, after leaving the Noa-Dihing River channel the BurhiDihing River is fed by several bigger tributaries which help in maintaining its downstream flows. Compared to the Noa-Dihingriver, the BurhiDihing river maintains a matured meandering channel. The presence of a series of large palaeochannels along the course of the BurhiDihing River, which are much larger than the present river channel, and a lesser number of palaeochannels along the course of the Noa-Dihing River may imply that previous discharges of both the channels flowed through the Burhi-Dihing River only. It may suggest that the BurhiDihing River in the past was much larger and used to transport a greater discharge. Probably, at a later stage, a significant portion of the flow of the Burhi-Dihing River was diverted to the Noa-Dihing River, which may be due to river capture/avulsion during a large flood event, resulting in a gradual decrease in size of the former. However, a tectonic cause for the same also can't be ruled out since both the river basins are situated in a very active seismic zone. The morphometric parameters of the rivers indicate active tectonics. Earthquake records of the area also suggest significant activity and several identified lineaments seem to be seismically active.

Comparison between mafic dyke swarms of Bastar and Dharwar craton: Implications from geochemical and thermo-mechanical aspects

Aurovinda Panda[1,2], Rahul Patel[1,2], Ravi Shankar[1], D. SrinivasaSarma[1,2*]
[1]CSIR- National Geophysical Research Institute, Hyderabad 500007
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201002

We present geochemical and physical evidence of thermal erosion of dyke host rocks (i.e., Granitoids) from the Bastar and Dharwarcraton. Thermal erosion or wall rock melting of host rocks influences the geochemistry of primitive basaltic magma by adding acidic components of host rocks into basaltic magma. This leads to a more complex geochemical nature of basaltic magma. Geochemically, the mafic dykes of this study are classified as basalt, and basaltic andesite in the total Alkali-Silica (TAS) diagram and are represented by the tholeiitic magma series in the AFM diagram. AFC (assimilation and fractional crystallization) trends and elements ratio plots (e.g. Nb/Yb vs Th/Yb, Th/Nb vs Nb/U, and Zr vs Zr/Y) imply fractionation and crustal contamination of magma ascending in the dykes. Several factors control the thermal erosion of host rocks such as the nature of magma, magma flow rate, heat transfer, and rate of melting of host rocks. Calculations are presented for these parameters for the 2.37 Ga mafic dyke swarms of Bastar and Dharwarcratons in India. The nature of magma flow, i.e., whether magma ascends turbulently or in a laminar manner, has a critical role to play in heat transfer to adjacent wall rocks and determines the extent of thermal erosion. Remarkably higher values for estimated Reynolds numbers for these dykes which are greater than 8000 suggest magma would have traveled turbulently. Furthermore, estimated values of magma flow rate, heat transfer, and wall rock melting rate of country rocks for upper, middle, and lower crust suggest the same.

Imaging crustal structure across the Proterozoic Aravalli Delhi fold belt, Northwest India using Common Reflection Surface (CRS) stack approach - a review

Biswajit Mandal[*], V. Vijaya Rao, P. Karuppannan, K. Laxminarayana, Prakash Kumar
CSIR- National Geophysical Research Institute, Uppal Road, Hyderabad-500007
[*]Presenting author: bisuman@gmail.com

Imaging the crustal structure of the thrust and fold belt areas is a challenging task due to lateral velocity variation. The Proterozoic Aravalli Delhi fold belt in NW India is one such area that exhibits complex

structural and velocity variations. Here, we apply the Common Reflection Surface (CRS) Stack method to image the crustal structures using the multifold crustal reflection data acquired along the Nagaur-Jhalawar transect. The CRS method is an automatic stacking process that doesn't need a precise velocity-depth model, which is essential for the conventional common mid-point approach. We have identified many geological features and tectonic boundaries which are hitherto unknown in the region. The study revealed variations in the Moho boundary and several crustal reflectors throughout the area. We imaged a domal structure in the Marwar basin and Delhi fold belt and the extension of the Jahazpur thrust from the surface to Moho depth. Further, divergent-reflection fabric representing collision zones of the Aravalli and Delhi orogens are also imaged. A gently deeping structure of the Vindhyan basin with 7.5 km thick sediments emplaced over 1.5 km of volcanic sequences is identified. We also imaged the crustal-scale Chabmal Thrust and Great Boundary thrust fault. Subduction and collision are responsible for the evolution of these thrusts implying horizontal crustal growth in the region. The crustal thickness along the transect varies from 40 to 48 km.

Synthesis of Crustal Structure of Northeast India: Seismogenic and Geodynamic Implications

B.R. Arora[1*], Sanjay K. Prajapati[2]
[1]*Former Director, Wadia Institute of Himalayan Geology, Dehradun-248001*
[2]*National Centre for Seismology, Ministry of Earth Sciences, New Delhi-110003*
[*]*Presenting author: arorabr47@gmail.com*

Receiver function formulation is applied to the recently established 19 seismological stations distributed over northeast India. Integration and validation of inverted shear velocity structure with earlier stations and their cross-validation with gravity modeling permit us to track the structural configuration of different domains and their seismogenic and geodynamic interactions with binding Himalaya and the Indo-Burmese arc. The crust beneath the Himalayan foredeep is divided into two blocks with contrasting structures and compositions. The western crustal block beneath the elevated Shillong Plateau (SP) has a felsic composition (low Poisson ratio) and thin crust (33-35 km). In addition, a 5-km thick high-velocity layer in the upper crust (<10 km), extending from the southern margin of the SP to the Lesser Himalaya, symbolizes a Pre-Himalayan structure on the Proterozoic passive margin of India. The enhanced slip rate due to part absorption of the plate convergence at the Dauki fault facilitates the uplift of the SP. As against this, a narrow strip along the upper Assam Basin in the eastern-foredeep, marked by pronounced gravity low, high Poisson ratio, and dual low-high velocity layers in the deep crust, is viewed as an intrusive slice of the oceanic (mafic) crust extending from the Indo-Burmese wedge (IBW). Further south, under the ~10 km thick IBW, northeast dipping 2-layered crust comprising 5-15 km thick delta sediments overlying the ~20 km thick basement layer of oceanic (mafic) affinity (Poisson ratio >0.26) is found to be the eastward continuation of the crust that exists in the Bay of Bengal. High pore-pressure fluids released from down-going sediments modulate the frictional coupling to nucleate large earthquakes on top of the down-going mafic crust, mapped as the seismic active plane. The collision zone between the subducting mafic slab and the overriding Burmese oceanic platelet is seen as a discontinuous shallowing of the Moho across the Churachandpur-Mao Fault.

The Shyok and Indus Sutures are one and the same

Michael Brookfield
Jackson School of Geosciences, Universiyt of Texas at Austin, Austin, TX 78712-1692, USA
Presenting Author: mbrookfi44@gmail.com

The two ophiolitic sutures of the NW Himalaya, the Shyok (or northern) suture and the Indus suture, are separated by the large Ladakh batholith complex and its volcanic cover, which are usually interpreted as a

subduction-related magmatic arc. Wondrous tectonic schemes, one of them mine, are used to explain their Mesozoic-Cenozoic relationships and development, including reversing subduction polarities. The stratigraphic successions in both suture zones are, however, practically identical, as Rai noted in 1983, and the main Ladakh batholith has adakitic magma characteristics and formed by partial melting of garnet-bearing thickened lower crust around 50 Ma during the "hard' collision of India and Asia. Such relationships are also found in southern Tibet, where an eclogite-bearing belt lies just behind the Gangdese batholiths with peak ages around 50 Ma, and also with adakitic characteristics. A clue to the evolution of these tectonically highly compressed belts is in Afghanistan, where major continental collisions did not take place and where an NW-SE 800 km long transect goes from the Asian margin at Herat, through a late Jurassic-early Cretaceous back-arc basin and magmatic arc at Kandahar, into latest Cretaceous-Paleocene arcs, bounded on the south by a thick Eocene and younger forearc sedimentary wedge.

Subsurface expressions of the Faizabad Ridge, central Ganga Basin, by a magnetotelluric study

M. Demudu Babu*, A. Manglik, M. Suresh
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad – 500007
**Presenting author: mdbabugeo7@ngri.res.in*

Geophysical studies and deep exploratory drillings in the Ganga basin for hydrocarbon exploration have revealed the presence of transverse ridges, depressions, and faults beneath the thick alluvial cover of the basin. These studies were mainly focused on the intra-basinal structure and in some places could not delineate the basement, especially in basin depressions. The Faizabad Ridge is one of the prominent transverse tectonic features in the central Ganga basin, assumed to be the NE-to-NNE extension of the Bundelkhand craton, and its extent up to the Himalayan front is debatable. We have carried out an MT study along a 50 km long NNE-SSW profile in the central Ganga basin covering the Faizabad ridge to delineate its extent beneath the sediments towards the Himalayan front. Two-dimensional modeling of the distortion-corrected impedance tensors in the period band of 0.001–25 s shows a heterogeneous basement structure. The geoelectric model reveals a very thin sedimentary cover between Chitrakoot and Allahabad. At Allahabad, the basin thickness suddenly increases to more than 2 km and a graben-type structure is obtained. At Faizabad, the basement depth is about 3.4 km, but it rapidly increases thereafter and reaches more than 8 km at the northernmost part of the profile where the Ridge signatures are not seen. We infer that the Ridge, though present till 50km north of Faizabad, does not continue to the Himalayan Foothills along the profile. The results also suggest the presence of a near-vertical weak zone of moderate resistivity in the vicinity of the Yamuna River. This region is also the contact between the buried Faizabad Ride and the rocks of the VindhyanSupergroup.

Terrain rejuvenation and landscape evolution of northeastern Indian peninsula: implications on tectonic-incision coupling during Tertiary period

Devika Maisnam[1,2*], Prabha Pandey[1,2], Anand K. Pandey[1,2]
[1]CSIR-National Geophysical Research Institute, Hyderabad-500007
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002
**Presenting author: maisnamdevika@gmail.com*

The geomorphic processes dynamically interact with the tectonic forcing causing differential uplift-incision and producing characteristic landscapes. The cratonic blocks across the Central Indian Tectonic Zone (CITZ)in the northeastern Indian peninsula, which experienced block deformation and basin formations due to the reactivation of Proterozoic structures during Gondwana dispersion, show signs of terrain rejuvenation during Tertiary. Following the Late Cretaceous-Early Tertiary Deccan (lamproite) volcanism, the

Chhotanagpur plateau shows prominent terrain growth and is experiencing flexure bulge related to Himalayan orogeny since Miocene. The mild seismicity with extensional shear sense in the Chhotanagpur plateau and Singhbhum craton along the Proterozoic structures and the growth of transient landscape suggest the region is undergoing terrain rejuvenation during the Tertiary period. We explored the transient landscape using stream power incision models along the north-flowing Son river system and the south-flowing Mahanadi, Damodar, Brahmani, and their adjoining rivers with the Ganga and the mean sea level in the Bay of Bengal as the base levels, respectively. The geomorphic indices suggest the north-flowing Son river system has high erosive susceptibility with a westward basin tilting bordered by Narmada Son Fault System. Whereas the south-flowing rivers with eastwards tilted basins show largescale drainage deflection and the channels show high erosive power with a notable incision along the Proterozoic structures suggesting differential surface uplift during Tertiary. The transient landscape is modeled to numerically constrain the spatial variability of the uplift-incision coupling and discussed their implication on evolving tectonic rejuvenation during the Tertiary period.

New insights into the crustal structure of the Delhi fold belt using gravity and seismological data

Divyanshu Dwivedi[1*], Ashutosh Chamoli[2]
[1]*CSIR-National Geophysical Research Institute, Hyderabad, 500007, Telangana*
[2]*Department of Earth Sciences, IIT Roorkee, Uttarakhand*
[*]*Presenting author: ddwivedi@ngri.res.in*

The Delhi fold belt (DFB) is a noticeable SW-NE trending transverse structure at the leading edge of the Indian peninsula. The crustal architecture of the Proterozoic DFB controls the seismotectonic behaviour of the Delhi and NCR region. We model the crustal structure of the Delhi fold belt and surrounding region using gravity data. We applied the power spectral analysis, filtering, 3D structural inversion, and the Depth from Extreme Points method to constrain the crustal model. We use boundary edge detection methods to delineate prominent edges of the sources corresponding to the geological boundaries. The outline of earthquake distribution demonstrates a close relationship with the major geological boundaries. We notice folding patterns towards the north of the Delhi-Sargodha ridge (DSR), which relates to the DSR constituents that emerged due to flexural bulging of the Himalayan foreland basin. The derived boundaries indicate NW deflection, which correlates with the WNW-ESE deflection of the SW-NE trending deep underplating material at the Moho. The shallow components of the DSR give rise to the clustering of the earthquakes in the region. We will discuss the results in light of the seismotectonics of the study region.

Advance features in monitoring of earthquakes at NCS-MOES-India

Priyanka Kumari[1*], Ram Kumar Giri[2], Sunil Kumar[2], Ravi Kant[3]
[1]*India Meteorological Department, Mausam Bhavan, Lodi Road, New Delhi*
[2]*Amity University, Rajasthan*
[3]*National Centre for Seismology*
[*]*Presenting author:* prsheshma.9@gmail.com

National Centre for Seismology (NCM), Ministry of Earth Sciences (MoES) play an important role in the real-time monitoring of seismic activities in the Indian region and neighboured. Precise and timely information reception and dissemination of seismic tremors is the key to success and mainly depends on the selection and robustness of the seismic stations. Therefore, it is essential to minimize the influence of undesirable or unrealistic vibrations and disturbances around the selected seismic stations. In this work, authors utilized a statistical method called Probabilistic Power Spectral Density (PPSD) based on the

standard spectral density plots generated through the SEISAN software program running at National Seismic Centre (NSC), New Delhi. The strength of robustness of any station depends on the increase in ambient vibration levels which can be reflected in the lower and upper tolerance limits of plots generated. This analysis is very useful in diagnosing the seismic noise in digital seismic telemetric monitoring networks and in determining the noise conditions in selected sites before establishing a countrywide seismic network in the Indian domain. PPSD analysis is useful for the long-term vibration behaviour of the selected stations or observed areas. For brevity, the authors have presented the analysis of six stations only and it has been found that the noise levels were confined within the new LNM and HNM and can be said to have good performance. However, the cultural effects cannot be ignored completely.

Structural extension of the Aravalli-Delhi Fold Belt beneath the Delhi Seismic Zone, India – Inferences from magnetotelluric studies

G. Pavan Kumar*, A. Manglik, M. Suresh, D. Nagarjuna, M.D. Babu, N.N. Chakravarthi & K. Raj Sunil

CSIR-National Geophysical Research Institute, Uppal road, Hyderabad – 500007

**Presenting author: gayatripavan@ngri.res.in*

The Delhi Seismic Zone (DSZ) in the northwest Indian shield is one of the seismically active intraplate regions with frequent occurrences of small-to-moderate magnitude earthquakes. These earthquakes occur mainly along the NE-SW-oriented Proterozoic Aravalli-Delhi Fold Belt (ADFB) and NNW-to-NW trending Delhi-Sargodha Ridge (DSR). The region is also bordered by the NE-SW trending Great Boundary Fault (GBF) in the east and Mahendragarh-Dehradun Fault (MDF) in the west. However, the detailed subsurface architecture of DSZ and its surrounding areas concealed by alluvial sediments is still unclear. To image the subsurface expressions of these tectonic features and understand their role in seismogenesis of the DSZ, we have conducted a magnetotelluric (MT) experiment along two orthogonal profiles, a 190-km-long SSW-NNE profile across the DSR, and another along a~350 km NNW-SSE traverse that cuts across major tectonic features, e.g. MDF and GBF. Two dimensional (2D) geoelectrical model along the first profile yields a resistive layer (~1000 Ω.m) down to 10-12 km in the southern side of the profile and a northward dipping electrical conductor (<10 Ω.m) down to 20-25 km in the central part of the profile. The dipping conductor shows a good correlation with the seismicity distribution both spatially and depth-wise. Interestingly, 2D geoelectrical model along the second profile in the period band of 0.0001- 100s shows a collage of nearly vertical conductive and resistive blocks and sharp resistive contrast for couple of the tectonic features. From the combined analyses of both models along with existing geophysical information, we postulate the extension of the different litho-tectonic units of the ADFB beneath the DSZ and possibly up to the Uttarakhand Himalaya. These results have significant implications for the earthquake hazard potential of both the region, the DSR, and the Uttarakhand Himalaya.

Complex tectonic setting of the Sikkim Himalaya as revealed by broadband and long-period magnetotellurics

G. Pavan Kumar*, A. Manglik

CSIR-National Geophysical Research Institute, Uppal road, Hyderabad – 500 007

**Presenting author: gayatripavan@ngri.res.in*

The occurrence of deep crustal strike-slip earthquakes in the Sikkim Himalaya is indicative of ongoing transverse tectonic deformation of the Indian plate, in addition to the N-S convergence-related deformation within the Himalayan wedge. The two dominant tectonic forces operating in this region could lead to a complex variable spatial deformation within the Indian lithosphere. Two-dimensional modeling of the

broadband (0.01-1000 s) and long period (up to 10,000 s) magnetotelluric (MT) data incorporating the NW-SE transverse tectonic trend within the Main Central Thrust zone (MCTZ) yields a lithospheric electrical resistivity structure of the region down to 100 km. By integrating the MT results with other geophysical information, seismological data, and in conjunction with a kinematic wedge model, we propose a comprehensive tectonic model for the Sikkim Himalaya that highlights the complex nature of the lithospheric structure. A major contact beneath the MCTZ separating two geologically and compositionally distinct blocks of the underthrusting Indian plate is suggested to be an NW-SE trending lithospheric-scale fault in this segment of the Himalaya. Partitioning of the stresses generated due to northward convergence along the transverse tectonic feature can explain the strike-slip nature of the earthquakes as well as the occurrence of upper mantle earthquakes in the region. The tectonic model also demonstrates another crustal-scale tectonic feature beneath the Main Frontal Thrust that demarcates a transition zone of moderately conductive crust of the Ganga Foreland Basin and a resistive crustal block beneath the Sub-Himalaya. We attribute this zone to a necking process that possibly resulted in the omega shape of the Main Central Thrust in this region.

Shallow sub-surface investigation and drainage response of active tectonics across the Himalayan Frontal Thrust in the Kota-Pawalgarh Dun region, Kumaun Himalayas, India

Jonti Gogoi[1,2,3*], Anand K. Pandey[1,2], James Macnae[3], Prabha Pandey[1,2], Gail N. Iles[3]
[1]CSIR-National Geophysical Research Institute, Hyderabad-500007, India
[2]Academy of Scientific Innovation and Research (AcSIR)Ghaziabad- 201002, India
[3]Royal Melbourne Institute of Technology (RMIT) University, Melbourne- 3000, Australia
[*]Presenting author: jontigogoi66@gmail.com

The Sub Himalayan Mountain front, south of the Main Boundary Thrust (MBT), is structurally evolving by recurrent co-seismic slip during Late Quaternary-Holocene on the decollement, which emerges to the surface along the Himalayan Frontal Thrust (HFT). The MBT-HFT wedge show lateral variation and differential deformation partitioning within the wedge along the Himalayan front. This led to the development of several Dun structures in the Himalayan front where the Kota Dun is a half dun undergoing active intra-MBT-HFT wedge deformation along out-of-sequence faults/thrusts during the late Pleistocene. The evidences of active deformation are observed in the form of characteristic landforms developed by the interaction of fluvial gradation processes with the active structures. The Kota Dun is also unique whereby the HFT has two active strands east of Kosi River showing evidences of lateral variation in deformation partitioning. The Siwalik formations to the east of the Kosi River are covered with several piedmont fans, which preserves the evidences of active deformation in the geomorphic and structural expressions. At locations, the active faults are covered under debris and forest and to map their locations and structural setup, we used Ground Penetrating Radar (GPR), which can map up to 30 m depth in different sections. The characteristic landforms are dated using the Optically Stimulated Luminescence (OSL) dating method to understand Late Quaternary – Holocene deformation in the region. We also analyzed tectonically active transient landscapes using different quantitative morphometric methods, to constrain the spatial variability of active structures. The multiparametric data is analyzed to propose a comprehensive late-Quaternary-Holocene evolutionary model of the Kota Dun.

Geochemistry of Metavolcanics from the Tsundepalle Greenstone Belt, Eastern Dharwar Craton, India: Evidence for Neoarchean convergence

K.S.V. Subramanyam[1*], D.V. Subba Rao[1], D.B. Sankar[2], S.S. Sawant[1], C. Manikyamba[1]
CSIR-National Geophysical Research Institute, Hyderabad
[1]Dept. of Geology, Sri Venkateswara University, Tirupati
[*]Presending author: ksvsubramanyam@yahoo.com

Tsundepalle Greenstone Belt (TGB) has excellent preservation metavolcanic. In the present study Niobium enriched basaltic andesites (NEBA) and rhyolites are reported for the first time from the Tsundepalle Greenstone Belt of EDC documenting the interaction between mantle wedge and slab melts in a subduction zone tectonic setting. The basaltic textures are obliterated by slightly coarse granular, holocrystalline textures in these rocks. The rhyolites have K-feldspar and quartz along with accessories of plagioclase, Cpx, and minor amphiboles.

The basalts are basaltic trachyandesites and the rhyolites are trachyandesite to trachydacites of calc-alkaline affinity. SiO_2 content of basalts has a narrow range (52-53 wt.%) whereas the rhyolites vary between 62-67 wt.%. The total alkalies of basalts are in the range of 4.0-8.5 wt.%whereas for rhyolites it varies from 7.5-9.5 wt.%. MgO decreases with increasing SiO_2 from basalts to rhyolites. Primitive mantle normalized trace elements show LILE, and LREE enrichment relative toHFSE with Nb and Ti negative anomalies. The island arc affinity along with their Nb-enriched basaltic characteristics is evident by the relationship of Sr/Y vs. Y and Nb/U vs.Nb respectively. The significant influence of the slab melts in the generation of these NEBAisevident by their high Sr contents (408-1154 ppm). The LILE-LREE enriched, HFSE depleted signatures of these rocks along with pronounced negative anomalies at Nb-Ta, Zr-Hf and Ti attest their genesis in a subduction zone tectonic setting which is further substantiated by the relationship between Yb vs.Th/Ta wherein these NEBA are occupying the field of oceanic island arcs. The identification of NEBA from TGB supports the predominance of convergent tectonics in the greenstone belt of EDC which played a vital role in the crustal recycling and gold mineralization in this part of Dharwar Craton. These studies indicate a series of accretion of arcs in EDC which played a vital role in the crustal growth.

Morphological Filtering Model for suppressing the noise and reducing the Processing time: A case study using the Land seismic data

Lakshminarayana Sigilidevi[1], Thandan Babu Naik R[2*]
[1]Summer Intern at CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad; Student of Dept. of ECE, Adikavi Nannayya University, Andhra Pradesh
[2]CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad
[*]Presenting author: thandan@ngri.res.in

Seismic images have a crucial role to play in the delineation of various geological features. The seismic images are constructed using the seismic data acquired in the field. Mostly, the seismic data is accompanied by noise, which limits the visualization of geological features. These noises come in a variety of forms such as mono response noise, random noise, erratic noise, multiples, ground rolls, etc. The minimization of noise to improve the quality of the seismic image is carried out at various data processing stages, such as pre-processing, during processing, and post-processing. The mono response noise traces are dealt with in the initial stages of processing and removed using an editing process using any standard data processing software. It is a manual process and operated on shot gather by gather, and takes a few weeks to months in eliminating mono response noise, thus extending overall processing days. In the present work, it is proposed to simplify this elimination process of mono response noise and reduce the time to execute it from a few weeks/months to a few hours by Morphological Filtering models.

The Morphological Filtering Model (MFM) is implemented in the frequency-spatial domain. MFM works on the principle of detecting morphological scale differences between the seismic signal and mono noise in f-xy domain at each frequency slice of the 3D seismic cube. In the morphological domain, the mono-response noise appears as a small-scale component in the spatial frequency domain, because of its spatial incoherency. The MFM eliminates mono-response noises by allowing large-scale components and rejecting small-scale ones, with the input seismic data with noise separated into two subspaces. Depending upon the computing machine's specifications, such as RAM and processor, etc., the MFM eliminates the mono response noise in a few hours by operating on the entire data cube. MFM saves a lot of processing days which are otherwise spent in manual removal of mono noises and thus saves overall seismic processing days. The MFM was successfully applied on land seismic cube data, eliminated mono response noise traces in a few hours, and reduced overall processing.

Characteristic of magnetic fabrics of sediments along Kolang River, Kopili fault zone, Assam, India

Md. Mujahed Baba[*], B.V. Lakshmi, K. Deenadayalan
Indian Institute of Geomagnetism, Mumbai
[*]Presenting author: mujahedgg2048@gmail.com

The magnetic fabric technique is a well-established approach for defining the orientation of sedimentary grains in three dimensions. The technique is based on the dependence of the Anisotropy of Magnetic Susceptibility (AMS) on the alignment of the long and short axes of magnetic mineral grains within the sediment. The AMS was studied along the Kolang River in the Kopili fault Zone, Shillong Plateau, India. The AMS measurements and extensive rock-magnetic studies reported here were focused on the recognition of the magnetic fabric and the identification of ferromagnetic minerals. The AMS technique documented the presence of two types of magnetic fabrics within the sampled sites allowing the determination of magnetic lineation. NW-SE magnetic lineations are predominant and minor NE-SW trends present. AMS data indicate prolate and triaxial ellipsoids with the K_{int} and K_{max} axes well-defined in the bedding plane. The overall analysis of sites in and around the Kopili region shows that the magnetic lineation is horizontal and trends perpendicular to the poles of the compressional direction. The strong correlation between the structural features and the AMS orientations suggests a tectonic origin. In contrast, the hypothesis of a sedimentary origin can be ruled out in most cases, because the orientations of magnetic lineations and those of depositional fabrics (paleocurrents, sediment supply directions, and even slumps) are oblique at a variety of angles.

Uncertainties in crustal and lithospheric thickness and its tectonic implications

Muthyala Prasad[1,2*], Chandra Prakash Dubey[1]
[1]Solid Earth Research Group, National Centre for Earth Science Studies, Thiruvananthapuram-695011
[2]Department of Marine Geology and Geophysics, Cochin University of Science and Technology (CUSAT), Kochi- 682022
[*]Presenting author: prasadgoud333@gmail.com

The crust and lithospheric variations are the key parameters that can help to understand the internal structure and geodynamic evolution processes of tectonic plates and uplifted long surface topography. Global studies on lithospheric thickness reveal that the nature of the rigid outer part of the earth is quite variable throughout the different tectonic and lithological regions. The uncertainty component in derived crust and lithosphere is a common parameter and it arises in all geophysical applications from multiple inevitable causes. Like, inconsistency in during the data acquisition, processing, and interpretation with humans or machines, limited

available data, resolution, constraints and insufficient physical parameters knowledge, etc. compared to the subsurface heterogeneity of the structure. It is essential to estimate uncertainties in the corrections that can be made to the geophysical data to reproduce reliable subsurface geological structures for the final decision-making interpretation. To understand these uncertainties, we selected the poorly covered regions by seismological and other geophysical studies, like the western passive continental margins of India (WPCMI). The WPCMI, the Western Ghats is a consequence of long tectonic history and one of the world's most spectacular largest escarpments. Here, we interpreted a total of 40 profiles based on a different set of gravity and magnetic anomalies, previous studies results, and available regional and global models to estimate the uncertainties of crust and lithospheric thickness. We reported uncertainties for the crust and lithospheric average ±8 km and ±24 km approximately 22%, 17% respectively, in different major lithological units in south India. The observed variation of crustal thickness in its thickening/thinning reflects the misinterpretation, for example, if the region has a thick crust, it could be due to the result of a collision event or rift-related underplating and whereas, at the same time, thinner crust represents the undergone delamination or non-orogenic crust. These significant differences can be having a major influence on geodynamical analysis and tectonic evolution of the underlying lithospheric mantle. Thus, to constrain or eliminate the uncertainties, three different profiles along the Western Ghat escarpment are taken and modeled results show the thick and weaker lithosphere along the escarpment as compared to strong and thin lithosphere in far the east region. Such results may indicate the lithospheric interaction with plumes all over the Western Ghats escarpment. Thus, there is a huge gap in understanding tectonics due to the non-uniqueness of crustal and lithospheric thickness. Therefore, we need to have a unified model of these to better understand the nature and evolution of the lithosphere.

Applications of Magnetotelluric Studies in India

D.C. Naskar*, O.P. Mishra
National Centre for Seismology (NCS), Ministry of Earth Sciences (MoES), New Delhi
**Presenting author: dcnaskar@yahoo.com*

The Magnetotelluric (MT) method is one of the geophysical exploration techniques in which the conductivity structure of the earth is studied utilizing the naturally existing electromagnetic fields of the earth. The theory of the magnetotelluric (MT) method, the main branch of the EM technique, was introduced during 50's by Tikhonov (1950) and Cagniard (1953) with the natural variation of electromagnetic fields, as its source.MT surveys are mostly deployed for probing greater depths of the earth (tens of kms or even more) using very low-frequency MT signals (10^{-2} Hz to 10^{-5} Hz). From such surveys, resistivity distribution along depth is estimated. Application of this technique has grown up steadily over the years for various geological problems in India. Indian geology is quite complex with its vast cover of basalt occupied in most parts of central India, thrust regions of Himalayan terrains with collision tectonics, geothermal resource exploration, and large sedimentary basins.MT method has brought out deep crustal structures in these terrains. This leads to the mapping of (i) the electrical conductivity of the Earth's lithosphere (ii) the electrical conductivity of geothermal areas and magma chambers and (iii) lineaments/fractures/faults. Detailed MT studies are being carried out in different countries to explore the possibilities of detection of (i) olivine-spinnel transition zone, (ii) Mesozoic sediments below the flood basalts, (iii) subduction zone, and (iv) conducting zones.The audio frequency magnetotelluric (AMT) method is often used for mapping metallic mineralized zones and conductivity contrasts at shallow depths. Apart from these, continuous monitoring of MT signals to study the earthquake precursor phenomena near Koyna and also an exploration of the Antarctic continent are new initiatives. National Geophysical Research Institute (NGRI) at Hyderabad has conducted MT measurements for the first time in our country in a marine environment i.e. marine magnetotellurics (MMT).

Geological Survey of India (GSI), along with various other institutions such as the National Geophysical Research Institute (NGRI) at Hyderabad, Indian Institute of Geomagnetism at Mumbai, Indian Institute of

Technology at Kanpur, Kharagpur, Roorkee, and IIT (ISM) Dhanbad, Osmania University at Hyderabad have contributed significantly for deep crustal studies in different parts of India. In the present paper, an overview of the contributions of the technique, applied to various geological problems in India by GSI for the last two decades is presented.

Thermal conductivity at elevated temperatures, and geochemical signature for the massive rhyolite rocks of Central Bundelkhand greenstone belt, central India

Labani Ray[1,2], Nishu Chopra[1*], S.P. Singh[3], Sikha Hiloidari[1,2], S. Eswara Rao[1,2]
[1]CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad, 500007
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002
[3]Department of Geology, Institute of Earth Sciences, Bundelkhand University, Jhansi, 284128
[*]Presenting author: nishuchopra31@gmail.com

Rhyolite is a common extrusive igneous rock with high silica content which is found in different tectonic environments, like continental rifts, continental arc, oceanic islands, etc. As rhyolite is one of the important rocks in the formation of the Earth's crust, numerous studies have been carried out to understand its geochemical characteristics and petrogenesis. But the data on thermal and physical properties are meager and no data on thermal conductivity at elevated temperatures are reported yet.

The present study is an attempt to elucidate the thermal and physical properties of massive rhyolites from the Magarpur-Babina and Bansi areas, in the Central Bundelkhand greenstone belt, central India. We have investigated the thermal conductivity from room temperature (25 ^{o}C) to elevated temperatures (up to 300 ^{o}C) by a steady-state method. The petrographical, geochemical (major oxide and trace elements), and physical (density and porosity) properties have been studied to characterize the samples before the measurement of thermal conductivity at elevated temperatures.

Geochemical studies indicate that the rhyolites are high-K, calc-alkaline in nature, and show an enriched REE pattern. These are formed from low-degree partial melting of a mafic source similar to FI-type Archaean rhyolites. The average density of these samples (2637 kg m^{-3}) is higher than the reported values for rhyolite lava, breccia and porous rhyolites (1410 to 1960 kg m^{-3}) reported from the different tectonic regions and has negligible porosity. The thermal conductivity at room temperature for the massive rhyolite shows much higher values (range: 2.5 to 3.3 $Wm^{-1}K^{-1}$, with an average of 2.8 ± 0.26 $Wm^{-1}K^{-1}$) than the rhyolite lava, breccia, tuff, glassy, melt, foam and porous rhyolite (0.5 to 1.9 $Wm^{-1}K^{-1}$). The decrease in the thermal conductivity with temperature varies from 16 to 32% with an average of 23%, and the temperature coefficient of thermal conductivity varies from 0.7×10^{-3} to $1.7 \times 10^{-3}K^{-1}$ with an average of $1.1 \times 10^{-3}K^{-1}$. This study suggests that the density of these massive rhyolites is similar to their intrusive equivalent Bundelkhand granitoids, whereas thermal properties are falling between two types of granitoids, that is the values for massive rhyolites are lesser than alkali feldspar granite to monzogranite and higher than granodiorite to tonalite to quartz diorite. Expressions have been derived as $D = 13.53 \times \lambda_{RT} - 15.59$, $b = 0.81 \times \lambda_{RT} - 1.21$, which will be very useful for estimating the variation in thermal conductivity with temperature, when thermal conductivity at room temperature is known for rhyolite. Thus, the present study provides rhyolite value at room temperature and its variation with temperature, which will be the input parameter for thermal modeling.

Application of Seismic Attributes for mapping coal seams and structural features in South Karanpura Coalfield

Muthulakshmi V.[1,2*], Uma Vadapalli[1], Nimisha Vedanti[1, 2]
[1]*CSIR-National Geophysical Research Institute, Hyderabad-500007*
[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002*
[*]*Presenting author: lakshmiraj@ngri.res.in*

Seismic attributes are all the information obtained from seismic data, either by direct measurements or by logical or experience-based reasoning. A seismic attribute help in confident geological interpretation by enhancing the information that might be subtle in a traditional seismic image. The seismic image of the study area is obtained by the state-of-the-art seismic data processing of High-Resolution Shallow Seismic data from the South Karanpura field. In this area the coal seams are subtle and they are associated with some minor discontinuities. To understand the existence of smaller-scale discontinuities, we have performed the coherence attribute analysis. After discontinuity identification, we carried out structural mapping and generated the geological structural model that is consisting of three coal seams horizons and a few minor faults within the Barakar formation.

Singhbhum may not be a typical craton: Geophysical perspective

Om Prakash Pandey
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad-500007
Presenting author: pandey@rediffmail.com

The Eoarchean Singhbhum craton located in the eastern part of the dynamic Indian shield, is one of the oldest and highly complex geotectonic terrains in the world, having suffered prolonged episodes of intraplate volcanism, mafic dyke intrusions, rifting, collision and widespread sedimentation for over two billion years. The mode of its crustal and lithosphere mantle evolution and subsequent deformation and decarbonization due to sustained intraplate geodynamic forces have been a subject of intense debate. Detailed analysis of various geological and geophysical parameters in the present study indicates, (i) lower crustal-type high velocities at shallow subsurface depth of only about 4 km, (ii) removal of almost 25 km thick crust from the top and 200-250 km thick mantle lithosphere from its bottom, and (iii) strong crust-mantle thermal interaction, thick magmatic underplating, massive crustal exhumation, and topographic uplift, due to rise in mantle solidus caused by persistent mantle plume activity. In due course of time, this restructured craton has turned into more or less a mobile belt, having hardly any geophysical signatures of a typical craton, thereby challenging the prevailing notion of cratonic stability and preservation of deep continental roots in Archean terrains.

It this craton is also characterized by an unusually thin lithosphere (~60-95 km), high Moho temperatures (910°C) and also a high dose of heat flow (47mW/m^2) emanating from the mantle, which conforms with the estimated low effective elastic thickness of ~30 km. Transients effects of the paleo-thermal anomalies possibly still persist due to periodic rejuvenation of surrounding rift valleys and suture zones.

Geodetically derived Deformation studies in Gujarat, western part of the Indian plate

Rakesh K Dumka[*], D. SuriBabu, Sandip Prajapati
Institute of Seismological Research, Gandhinagar, Gujarat
[*]*Presenting author: rkdumkaisr@gmail.com*

The present study comprises three important palaeo-rift systems, Kachchh, Narmada, and Cambay towards

the western part of the Indian plate. The seismological records indicate the need for a better understanding of the deformation pattern of the region. The present geodetic study comprises almost a decade-long continuous (2009-2019) GNSS observations along with PSINSAR observations (2016 – 2020) in this part. The Kachchh is the seismically most active zones towards the western part of the Indian plate and host of three ≥ M7.0 earthquakes during the last two centuries. The GNSS results conclude that the Kachchh is presently under the influence of compressive stress from the north and south. However, the PSINSAR and GNSS result also highlight the along-strike variation of the deformation. The central part of the Kachchh region exhibits intra-basin stress, as shown by a detailed analysis of GNSS results and geological evidence. According to the analysis, the western portion of the Narmada rift system deforms at a maximum rate of 1.5 mm per year, but the Cambay rift system shows an average deformation of less than 1.0 mm per year. Additionally, the PSInSAR data from this region of the Indian plate display a good spatial distribution of deformation in the Kachchh, Narmada, and Cambay rifts. The PSInSAR rate of deformation data are corroborated by GNSS results in the area. In Ahmedabad, we discovered a sizable quantity of ground subsidence, and we came to the conclusion that this is due to an excessive amount of water extraction.

Neoarchean granitic magmatism along the north-eastern part of the Eastern Dharwar Craton, southern India: Petrogenetic and geochronological constraints

M. Ram Mohan*, Sameer Ranjan, Ajay Dev Asokan
CSIR-National Geophysical Research Institute, Hyderabad-7
**Presenting author: rammohan@ngri.res.in*

Globally, Neoarchean marks an eon of widespread voluminous granitic magmatism and the stabilization of the Archean continental crust. The Eastern Dharwar Craton (EDC) consists of Neoarchean potassic granitoids with subordinate volcanics-dominated linear greenstone belts. Based on whole rock geochemistry and zircon geochronology of granitoids from the northeastern part of the Dharwar Craton, we aim to understand their petrogenetic evolution and emplacement history. Based on the modal abundance of essential minerals, these granitoids are classified as granodiorite and monzogranites. Based on their geochemical characteristics, they are divided into High-Ca and Low-Ca granites. The High-Ca granites are compositionally similar to sanukitoids and are calc-alkaline to high-K calc-alkaline in nature, strongly metaluminous and have a relatively high Mg number (avg. Mg# = 40). They have moderately fractionated REE patterns with subtle negative Eu anomalies as well as enrichment in incompatible elements. Therefore, the high-Ca granites are likely derived from a mafic magma originating from a metasomatized mantle source. The Low-Ca granites are silica-rich, calc-alkaline to shoshonitic, peraluminous and have low Mg number (avg. Mg# = 25). They have strongly fractionated REE patterns with variable negative Eu anomalies. Their geochemical signatures attest to a heterogenous source involving both pre-existing TTGs as well as metasedimentary rocks. The zircon grains from granitoids have variable internal structures, typical igneous-like oscillatory zoned zircon as well as later fluid-assisted alteration features. Backscattered electron imaging reveals some of the grains have micro-inclusions of apatite, feldspars, quartz, uraninite, thorite, and monazite. The cathodoluminescence (CL) response of these altered zircon domains is generally low, suggesting fluid-assisted alteration and intense metamictization. The zircon U-Pb ages obtained on oscillatory zoned domains indicate that these granitoids were emplaced around ca. 2.55 Ga and are coeval with the widespread late Neoarchean magmatism related to the stabilization of the Dharwar Craton.

Thermal conductivity at elevated temperatures for the sedimentary and metamorphic rocks from the Western Himalaya, India

S. Eswara Rao[1,2*], Labani Ray[1,2], Tavheed Khan[1], Nishu Chopra[1]
[1]CSIR-National Geophysical Research Institute, Hyderabad
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002
[*]Presenting author: eswar5063@gmail.com

Thermal modeling is an essential factor to understand the geodynamics, crustal evolution, and thermal structure of the lithosphere. The thermal conductivity of rocks and their variation with temperature are important parameters for the above aspect, which is limited to the rock formations of the whole Himalayan ranges. We have collected samples from Tanakpur to Pangla transect in the Western Himalaya, India, which crosses through the Higher and Lesser Himalaya. The region comprises various metamorphic and sedimentary rocks that are formed by the tectonic activities during the collision of the Indian and Eurasian plates. The studied samples are sandstone, limestone, phyllite, and schist. We have measured the thermal conductivity of samples using a steady-state divided bar method on 20 samples ranging from room temperature (25 ^{o}C) up to 300 ^{o}C. Petrography and geochemistry were used to characterize the samples. The sandstone is composed of quartz, feldspar, mica, and chlorite and the majority of the grains are subangular to subrounded. The limestone is primarily composed of calcite, with a trace of silica and dolomite. Schist is primarily composed of quartz, feldspar, and mica in the form of muscovite and biotite, amphibole, and chlorite. At room temperature, the thermal conductivity of studied metamorphic rocks is generally lower than sedimentary rocks. The average thermal conductivity of sandstone is 4.2 $Wm^{-1}K^{-1}$, limestone 3.8 $Wm^{-1}K^{-1}$, phyllite 2.6 $Wm^{-1}K^{-1}$, and schist 3.1 $Wm^{-1}K^{-1}$. The study reveals that thermal conductivity decreases with an increase in temperature and the drop in thermal conductivity with temperature are higher for sandstone & limestone (30-32%) and lesser for phyllite and schist (20-25%). The average temperature coefficient of thermal conductivity *b* value is highest for limestone (calcite or dolomite abundance) and sandstone (quartz abundance) (1.7 $*10^{-3}$ K^{-1}), intermediate for phyllite (clay abundance) (1.2 $*10^{-3}$ K^{-1}), and lowest for schist (mica, feldspar, and quartz abundance) (0.92 $*10^{-3}$ K^{-1}). The differences in thermal conductivity at room and high temperatures for each rock variety are well correlated with the compositional change. The density of sedimentary and metamorphic rock types has similar values and varies in a wide range (2530 to 2840 kg m^{-3} and 2530 to 2730 kg m^{-3}). Sedimentary rocks have higher thermal conductivity and higher density than generally observed for these rock types. This is the first systematic study of thermal properties for Western Himalayan rocks at elevated temperatures, and it will be useful for the thermal modeling of this region.

Gravity modeling of the Garhwal Himalaya

Sandip Kumar Rana[*], Ashutosh Chamoli
Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee-247667
[*]Presenting author: rana.kr.sandip@gmail.com

We acquire a gravity dataset along ~ 205 km transect in the Lesser Himalayan Sequence from Bijnor to Gaurikund in the Garhwal region of the Uttarakhand state. The study region covers the Ganga basin, the Siwalik Himalaya, the Lesser Himalaya and the MCT zone of the Garhwal Himalaya. Three main fault systems: the Main Frontal Thrust (MFT), the Main Boundary thrust (MBT), and the Main Central Thrust (MCT) have shown implications on the crustal shortening in the Himalaya. The Garhwal region lies in the central seismic gap and has experienced two strong earthquakes: the 1991 Uttarkashi earthquake (M ~ 6.8) and the 1999 Chamoli earthquake (M ~ 6.5). All the standard corrections including terrain correction are applied in order to calculate the complete Bouguer gravity anomaly. We use spectral techniques, forward modeling and inversion to assess the Bouguer anomaly and derive the crustal density structure for the Garhwal Himalaya region. Power spectrum analysis of the complete Bouguer gravity anomaly indicates an average depth of two prominent crustal interfaces corresponding to the Moho at ~44 km and the Main

Himalayan Thrust at ~12 km depth, respectively. We apply the wavelet transform method to identify and characterize different litho-tectonic boundaries. The wavelet analysis shows useful signatures for the MFT, the Nayar Thrust, the duplex structures and the Munsiari Thrust. The geometrical constraints from the wavelet analysis are utilized in gravity modeling and inversion. We tested different Moho configurations from the previous seismological studies. The detailed density structure depicts the geometries of the litho-tectonic boundaries, the MHT ramp and the Moho for the study region. Our model exhibits good correlation with the main tectonic structures and depicts their subsurface extensions. Our modeling suggests flat-ramp-flat geometry of the Main Himalayan thrust, which relates to the long-term plate convergence and earthquake clustering in the region. We will discuss the crustal architecture in light of seismotectonics of the region and compare the results with previous geophysical studies of the region.

Alkaline to calc-alkaline magmatic suites of Mercara Shear Zone, south India

Sarbartha Shankar Mishra*, Chandan Kumar Boraiaha
Ore Research & Exploration Group (ORE-G), Department of Geology, Central University of Kerala, Kasaragod – 671320, Kerala
**Presenting author: sarbarthasmishra@gmail.com*

In this study, unmetamorphosed and largely undeformed alkaline to calc-alkaline magmatic suites from Mercara Shear Zone is reported. These Neoproterozoic magmatic rocks occur as lenses, dykes and plugs that are mostly within, or proximal to, major shear zones or trans-crustal faults. This contribution investigates the petrographic and chemical characteristics of five isolated alkaline to calc-alkaline plutons within the Mercara Shear Zone to understand their petrogenesis. All five plutons studied show an intrusive relationship with the host hornblende-biotite gneisses and/or mafic granulites. They lack macroscopic foliations and are not associated with carbonatites/ultrapotassic granites. Quartz, plagioclase and K-feldspar with minor amphibole/biotite form the major mineral phases of the studied plutons. Apatite, epidote and magnetite±ilmenite±titanite form the predominant accessory phases. Textural studies indicate that magma mixing has played a significant role in generating the studied plutons.

Earthquake hazard assessment in the Garhwal Kumaun region of NW Himalaya using GNSS measurements and seismicity

Saroj Kumar Mondal*, Vineet Kumar Gahalaut, Rajeev Kumar Yadav, Joshi K Catherine, Amit Kumar Bansal
CSIR-National Geophysical Research Institute, Hyderabad - 500007
**Presenting author: sarojbum@gmail.com*

Accumulation of elastic strain takes place along the active plate boundary region due to the continuous plate motion and thus the locked fault zones become the most potential sites for future large-size earthquakes. The Himalayan region of the continental-continental plate collision zone of Indo-Eurasia is one the most debated topic, especially the central part of this tectonic region, for the future great earthquake. Here, we utilize the dense Global Positioning System (GPS) network installed by CSIR-NGRI, in the Kumaun-Garhwal Himalayan region along with the other published data, for strain rate measurement and occurrences of past seismicity to understand the present state of stain rate and crustal stress. The horizontal resultant velocity of GPS sites in Sub-Himalaya and Lesser Himalaya are varying between 0.6±0.2 to 9.1±0.5 mm/yr in the India reference frame. Further north of Main Central Thrust (MCT) and in the Higher Himalaya, higher GPS sites' velocity range between 8.9±1 to 17.7±1.7 mm/yr. Thus, low sites' velocity is seen above the seismically active Main Himalayan Thrust (MHT) where it is locked while high sites' velocity is dominant where the MHT is slipping aseismically. Our results suggest that the average strain rate is varying along the MCT from the

north-western to the south-eastern direction along the Himalayan arc. We segregated two blocks of average low and high strain rates with high and low crustal stress respectively. The compressional strain is observed to be up to 151 nano strain/yr in the study zone. The average low strain rate block with high crustal stress is expected to be the possible zone for high seismic hazard in the future.

Active deformation in the mountain front of Nahan Salient: constrains from tectono-geomorphic analysis and GPR studies

Satish Chandra Verma[1,2*], Prabha Pandey[1,2], Anand K. Pandey[1,2]
[1]CSIR – National Geophysical Research Institute, Uppal Road, Hyderabad, 500007
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, 201002
[*]Presenting author: vschandra94@gmail.com

The narrow (< 20km wide) Sub Himalayan mountain front in the Nahan salient, between geomorphologically distinct Dehradun and Kangra re-entrant in NW Himalaya, is bordered by transverse structures, namely Ghaggar-, Kala Amb- and Yamuna- tears. A lateral variation in lithology and structure is observed from Pinjaur to Dehra duns through the Nahan salient. These spatial variations are well reflected in the geomorphic pattern and landforms, which evolved due to the coupling of fluvial erosion and active structures. We investigate the active tectonics in the Sub-Himalaya Nahan Salient during the Late Quaternary period with the quantitative geomorphic proxies constrained by field evidences, shallow sub-surface mapping using Ground Penetrating Radar (GPR), and OSL dating. We modeled SRTM-DEM (30m spatial resolution) to compute different geomorphic indices namely Hi and slope distribution and detailed analysis through river profile proxies (SL, k_{sn} & c) in conjunction with active structures mapping in the mountain front. The landscape show characteristic variation with the western and northern part being tectonically more active and experiencing river piracy. The growing anticlinal structure in the HFT zone and out-of-sequence thrusts show higher uplift. The GPR data in the HFT zone have been helpful in imaging the faults based on lithological contrast. The OSL constraints on structures and using characteristic geomorphic surfaces during the Late Quaternary - Holocene have helped in constraining the sequence of structural growth in the MBT-HFT wedge.

Rock magnetism and AMS study of Dyke swarms from the Chotanagpur Gneissic Complex: implications for magmatism and emplacement

A.V. Satyakumar[*], N. Ramesh Babu, M. Venkateshwarlu
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad
[*]Presenting author: satyageo41@gmail.com

Chotanagpur Gneissic Complex (CGC) preserved the dykes of the Deccan vicinity and Precambrian terrain. To distinguish the emplacement ages of these dykes, Rock magnetism and AMS studies have been carried out. A total of 56 oriented block samples were collected from 12 sites near Dhanbad and Dumka areas, Jharkhand, India. To determine the magnetic characteristics of dykes, samples were subjected to rock magnetic studies including magnetic intensity, magnetic susceptibility (K), isothermal remanent magnetization (IRM), hysteresis loops, backfield (coercivity remanence), and k-T (Susceptibility vs Temperature) analyses using Advanced Variable Field Translation Balance (AVFTB). To comprehend the petrofabric orientations and shape anisotropy of the dykes, conducted an anisotropy of magnetic susceptibility (AMS) analysis using MFK-1A Kappa Bridge. Results from rock magnetic studies show that the susceptibility values range from 4.89×10^{-2} to 6.01×10^{-4}, the ratio of remanence (Mrs/Ms) ranges from 0.1 to 0.27, and the coercivity ratio (Bcr/Bc) ranges from 1.82 to 4.27, indicating that the majority of the magnetic grains' sizes are in the range of pseudo-single domain (PSD) state, with few are showing multi-domain (MD)

state and magnetite as the main remanence carrier mineral. Lineation, foliation, and three principal susceptibility axes intensities are computed from the AMS investigation, and the results show three shape anisotropies that are present in the CGC dykes. The corrected anisotropy degree (Pj) of the samples was found to be low to moderate, between 1.002 to 1.081, which indicates primary magnetic fabric. The normal to intermediate and inverse magnetic fabrics connected to magma flow during the dyke emplacement are clearly defined by the magnetic ellipsoid, which is either triaxial or oblate. The principal AMS axes for samples from all sites are closely clustered on equal area plots, with the maximum susceptibility axes sub-horizontal and parallel to the dyke walls, and minimum susceptibility axes plotted near the pole of the dyke. These are considered to be the main direction of magma flow.

Complex crustal dynamics and deformation patterns beneath Northeast India and Indo-Burmese range inferred from shear wave splitting analysis: role of major tectonic structures

Debasis D Mohanty[1*], Satyapriya Biswal[2*]
Geosciences and Technology Division, Northeast Institute of Science and Technology,
[1]Council of Scientific and Industrial Research, Jorhat-785006, Assam.
[2]Academy of Scientific and Innovative Research (AcSIR)
[*]Presenting author: satyapriyabiswal8763@gmail.com

We investigated seismic anisotropy of crust beneath the Northeast region (NER) of India accompanied by Indo-Burman Ranges (IBR) from 20 broadband seismic stations employed over the major tectonic units of the region by shear wave splitting (SWS) analysis of direct S-waves. The NER possesses complex geodynamics that jawed between the Indo-Eurasian collisional boundary in the North and Indo-Burman subduction in the Northeast margin of the Indian plate. Hence, the vicinity of the region is bounded by numerous strike-slip faults, thrust faults and antithetic faults guiding crustal deformation. The Shillong-Mikir massif also plays a major role in adding complexity to the province leading to "Pop-up" tectonics. We measured SWS with the help of the splitting parameters i.e., the fast polarization direction (ϕ) and the delay time (δt) between the fast and slow components of shear waves of local earthquakes within the crustal depth ≤ 55 Km, by using an automated cross-correlation technique that chooses the good quality S-wave arrivals without being contaminated with other refracted phases. 200 local earthquake events of shallow focal depth (magnitude <5 Mw) are analyzed showing the best results of anisotropy where the ϕ in most of the cases orient in the direction parallel to the strike of the local tectonic alignments and δt show a relative variation signifying the strength of the crack density to be moderate to high. Thus, the study reveals seismic anisotropy of the crust as a result of preferential cracks and micro-cracks or pore spaces (shape preferred orientation) relating to the tectonic mechanisms aligning in the area governed by the drifting of the Indian plate towards NE and in the IBR region the presence of dextral strike-slip faults and antithetic faults infers the source of anisotropy remarking the local stress field predominantly in NE-SW direction leading to tectonic framework of the arena.

Rock magnetic signatures of the Singhbhum mobile melt and associated Dalma lavas of the East Indian Shield

Saurodeep Chatterjee[1*], Supriya Mondal[2], Debesh Gain[2], Sahendra Singh[1]
[1]Department of Applied Geology, Indian Institute of Technology (ISM), Dhanbad-826004, Jharkhand
[2]Department of Geological Sciences, Jadavpur University, Kolkata-700032, WB
[*]Presenting author: chatterjeesaurodeep@gmail.com

Petrography and rock magnetic studies were collectively applied to determine the mineralogy, magnetic parameters, and remanences of the Singhbhum mobile belt and associated Dalma lavas of the East Indian

Shield. Effects of geological processes such as oxidation, low-temperature alteration, oxy-exsolution, and weathering on the magnetic properties of the Singhbhum mobile belt and Dalma lavas are addressed in terms of various geophysical parameters. Petrographic observation revealed the presence of Ti-magnetite and minor amounts of hematite, ilmenite, sphene, and pyrite in the host schist, quartzite, and volcanic rocks, which have not yet been studied well, in terms of their magnetic characters using geophysical methods. A paucity of rock magnetic measurements has hampered petrogenetic interpretations, regional and global correlations, and their suitability for palaeomagnetic remanence studies of the history of the earth's magnetic field. In this work, the existing gaps in all those aspects are studied to infer the type, concentration, and grain size of Fe-Ti oxide minerals in this volcano-sedimentary sequence which controls their rock magnetic properties. Rock magnetic analyses included Magnetic Susceptibility (χ), Frequency-Dependent Susceptibility (χFD%), Anhysteretic Remanent Magnetization (ARM), Saturation Isothermal Remanent Magnetization (SIRM), Soft IRM, Hard IRM and their inter-parametric ratios of ARM/χ, SIRM/χ, ARM/SIRM, and S-ratio. Magnetic mineralogy indicated that the bulk carrier of Natural Remanent Magnetization (NRM) was Stable Single Domain (SSD) or Pseudo Single Domain (PSD) grains of Ti-magnetite with minor occurrences of iron sulfides such as pyrite, greigite, and pyrrhotite. This in turn made it possible to assess the mode of magnetic remanence acquisition and reliability of palaeomagnetic data obtained from these rocks. Measurements of Natural Remanent Magnetization (NRM) and its stability to Alternating Field (AF) demagnetization showed that these magnetic remanence carriers are chiefly of secondary origin, and are therefore capable of characterizing the secondary geological events in the rocks. Thus, the acquired Characteristic Remanent Magnetization (ChRM) is interpreted to be much younger than the time of formation of the rocks and records post-formation geological events.

Monitoring the Role of Temporal Land Cover Changes on Mountain Hazard Susceptibility in Beas Valley, Himachal Pradesh, India

Sayanta Ghosh[1], Renu Lata[1*], K.C. Gouda[2]

[1]G.B. Pant National Institute of Himalayan Environment, Himachal Regional Centre, Mohal-Kullu, HP

[2]CSIR Fourth Paradigm Institute, NAL Belur Campus, Bangalore

[*]Presenting author: renu15_negi@yahoo.co.in

In the last 50 years, drastic changes in the spatio-temporal variation of climate patterns have been observed over the Indian Himalayan Region (IHR) resulting increase in the frequency of Extreme Weather Events (EWE) such as cloud bursts, flash flooding, landslide, etc. The change in climate parameters has a direct impact and consequence on the Himalayan ecosystem, which in turn adversely affects the livelihood of people living in the high-altitude area. Also, alterations in Land Use Land Cover (LULC) have occurred rapidly in the already vulnerable Indian Himalayan Region (IHR) for the last few decades. Few studies have been carried out to analyze the impact of land cover changes and regional climate variability on mountain hazard susceptibility in different parts of the world. But there's a lack of the such type of study in high altitude areas of IHR. Here, we have attempted to assess the impact of regional climate variability (Precipitation, Air Temperature, Relative Humidity) as well as spatio-temporal variations in LULC on the increasing frequency of EWE in the Beas river basin of Kullu district, India. For this purpose, using multi-temporal LANDSAT data and high-resolution Terra Climate monthly data, temporal Land Cover Changes as well as climate variability over the period of 21 years, i.e., from the year 2000 to 2020 for Beas valley of Kullu district, India have been assessed. Disaster data highlights a drastic increase of 378% in the average occurrence of EWE during the present years (i.e., 2016 to 2020) than of the last 16 years (2000 to 2015). The socio-economic survey which has been carried out to study people's perception indicates that 68.6% of respondents from the disaster-prone villages in the Beas basin believe that the increase in EWE is due to changes in climate patterns. It is observed from LULC change detection that a massive increase in Agricultural land, including orchard expansion, of 123 % occurred during the year 2020 than that of 2000 in Beas Valley. Also, there's a sharp increase of 40.63 % in settlement areas which includes the tourism activities such as hotels, restaurants,

etc. during the year 2020 than that of 2000. The average rise in average air temperature is observed as 2° Celsius in the study area over the period of 21 years. Annual precipitation shows a decrease of 76 mm to 325 mm during the year 2020 than that of the year 2000. The outcome of the paper, we believe, will be helpful in better understanding the impact of land cover dynamics and regional climate variability on the increasing number of EWE which is very crucial for livelihood security as well as socio-economic development in the Beas Valley of Kullu district, Himachal Pradesh, India.

Crustal heterogeneities within the crust beneath eastern Kumaon Himalaya from L_g wave attenuation

Sudesh Kumar*, Mahesh Prasad Parija, Sandeep Gupta, Arjun V.
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad- 500007
**Presenting author: kumarsudesh77@gmail.com*

The crustal seismic attenuation structure along Tanakpur- Dharchula- Dharma transect is studied first time by using Lg wave spectra method on densely spaced 32 broadband seismographs along ~200 km long profile in the Kumaon sector of the northwest Himalaya from five regional earthquakes of M ≥4.0. The NE-SW profile extends between Indo Gangetic Plain in the southwest to Tethys Himalaya in the northeast. The lateral variability in the seismic attenuation structure is derived through the inversion of 64 high-quality two-station measurements out of total possible 94 two-station pairs. The region has Q_o estimates ranging from 63± 2 to 203± 25, with the lowest value in the Lesser Himalaya and the highest across some parts of the Indo-Gangetic Plain and Siwalik Himalaya. The strong attenuation reported consistently along the entire profile covering four different litho-tectonic units highlights the role of lesser Himalayan duplex thrust sheets present beneath the area, which imbricates small-scale crustal heterogeneities that cause strong attenuation of the Lg spectra beneath the lesser Himalaya. The presence of trapped fluids/partial melts can also be major factor responsible for strong Lg attenuation beneath the eastern Kumaon Himalaya.

2D upper-crustal P- and S-wave velocity modeling and compositions inferred from the Rewa-Shahdol 3-C seismic profile of south Rewa basin, Central India

Sudeshna Moharana[1,2*], Laxmidhar Behera[1,2]
[1]*CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad – 500007*
[2]*Academy of Scientific and Innovative Research, Ghaziabad-201002, Uttar Pradesh*
**Presenting author: smoharana@ngri.res.in; laxmidhar@ngri.res.in*

We have derived the 2D upper-crustal P-wave and S-wave velocity models (Vp and Vs) from the ray-trace inversion of seismic refraction and reflection data along the 155-km long Rewa-Shahdol 3-C seismic profile of the south Rewa basin, Central India. The south Rewa basin is an important Gondwana sedimentary basin of the Son-Mahanadi rift system having large-scale tectonic activity forming numerous faults, folds, horsts, and grabens with widespread lava flows of the Deccan basalts. The average compositions of different rock types of the south Rewa basin are constrained by the Vp/Vs and Poisson's ratio. The shallow velocity model obtained to a depth of 10-km show important geological structures with basement undulations and the presence of thick low-velocity Gondwana sediments hidden below the thin high-velocity basalts. The model represents three layered velocity structures above the basement along the profiles. The first layer represents upper Gondwana sediments with Vp (3.20-3.40 km/s), Vs (1.92-2.10 km/s), Vp/Vs (1.50-1.72), and Poisson's ratio σ (0.12-0.24). The second layer is the Deccan basalt of the Late Cretaceous period with Vp (4.85-5.10 km/s), Vs (2.70-2.85 km/s), Vp/Vs (1.78-1.83) and σ (0.26-0.28). The Deccan basalts are also exposed in some places along the profile. The low-velocity-layer (LVL) is inferred from the travel-time skips with amplitude decay observed in the first arrival seismic data of different shot gathers. The LVL mainly

corresponds to the lower Gondwana sediments with Vp (4.0 km/s), Vs (2.36 km/s), Vp/Vs (1.69), and σ (0.23). The basement is mainly granitic having Vp (5.90- 6.10 km/s), Vs (3.43-3.60 km/s), Vp/Vs (1.68-1.75), and σ (0.22-0.25). The sub-basement shows high Vp (6.45-6.52 km/s), Vs (3.70-3.72 km/s), Vp/Vs (1.73-1.75) and σ (0.25-0.26) indicates upper crustal materials. The P- and S-wave velocity models derived in the south Rewa basin show complex geological structures with wide-spread volcanic activity and different compositions of rock assemblages representing the Late Cretaceous volcanic province of Central India.

Crustal deformation analysis of active Katrol Hill Fault (KHF) in the Central Mainland Kachchh, Western India

Donupudi Suribabu[1,2], Rakesh K. Dumka[1*], K.V. Swamy[2], Sandip Prajapati[2]
[1]Institute of Seismological Research, Raysan, Gandhinagar-382009 Gujarat
[2]Adikavi Nannaya University, RajahMundary, A.P.
[*]Presenting author: rkdumkaisr@gmail.com

After the M 7.7 earthquake in 2001 (Bhuj), numerous geological and geophysical investigations on the western Indian plate turned their attention to the Kachchh rift basin. In the present study, the deformation pattern in central mainland Kachchh has been studied using the Global Navigation Satellite System (GNSS) and Permanent Scatterer Interferometry (PSI) technologies. Using the GNSS datasets from 2014 to 2021 and the PSI dataset from 2014 to 2022, we choose the east-west trending Katrol Hill Fault (KHF) as the research area and examine the crustal deformation pattern. The GNSS results show a mean deformation of roughly 2.1 mm per year, and the PSI measurements show an average LOS displacement along the KHF of 3.0 mm per year. The GPS results of this portion are well correlated with the PSI data. The parallel to the fault and the normal motion of the fault gives away the signature of the along-strike variation of the fault. The observed deformation is more pronounced in the eastern region and less pronounced in the central and western regions. The analysis of deformation and generated strain reveals that the KHF is tectonically segmented, with the eastern segment being the most active due to the dominance of compressive strain (up to a maximum of 20 nanostrain/yr). The buildup of strain along the south-dipping KHF's hanging wall side and the accumulated strain is reflected in the form of seismic activity in this part and highlights the importance of the KHF zone for seismic hazard analysis.

Effectiveness of Finite Element Method in predicting residual gravity and isostatic anomalies: Few Case-studies

A. Vasanthi
CSIR-National Geophysical Research Institute, Hyderabad
Presenting author: vasanthi@ngri.res.in

Gravity measurements on the surface of the Earth reflect the superimposed effect of deeper and larger variations of masses (regional) as well as shallower and more local variations (residual), near the point of observation. Whole Earth's large-scale gravity anomalies have been used by some experts to probe into mass/density variations deep in the Earth's interior. However, for a limited regional survey, there is a need to discriminate the regional and residual mass anomalies separately, which would enable these structures to be modeled. For this, both graphical and analytical methods being used over the decades, however, most of these techniques failed to be completely objective, since there was a need to choose the appropriate frequency range in frequency filtering, the degree of the polynomial in polynomial fitting, the choice of height in upward continuation, etc. Therefore, we developed a new analytical method, based on the Finite Element Approach (FEM), at CSIR-NGRI, which effectively computes the regional and residual gravity components, and

admiringly fills the long-standing gap. In addition, this method also computes the isostatic anomaly without explicitly invoking any isostatic model – Airy-Heiskanen, Pratt-Hayford, or Vening-Meinsz; thereby eliminating the numerous assumptions, and with that overcoming to a great degree the inherent inaccuracies and the ambiguities. In the present study, the theory, accuracy, computational procedure, and effectiveness of FEM are discussed, as applied to several case studies.

Three-dimensional Moho depth model of the Eastern Indian shield and its isostatic implications

Vikash C. Patel*, Niraj Kumar, B. Nageswara Rao, A.P. Singh
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad-500007
**Presenting author: vikash001.bhu92@gmail.com*

The Precambrian granite-greenstone terrain of the Eastern Indian shield consists Singhbhum-Orissa craton, Singhbhum Mobile Belt, Chhotanagpur gneissic complex, and Eastern Ghats Mobile Belt. This region has been and still is the focus of numerous geoscientific studies mainly because of its complex evolutionary history and rich mineralization. In this study, complete Bouguer gravity data from the second-generation Gravity Map of India (GSI-NGRI, 2006) and EGM2008 global gravity data in the Bay of Bengal (BGI: http://bgi.omp.obs-mip.fr/), were used to retrieve the three-dimensional geometry of the Mohorovičić discontinuity (Moho) of the eastern Indian shield and adjoining Bay of Bengal using inversion of gravity data. Before applying the Parker–Oldenburg inversion-based GM-SYS3D module, the Bouguer gravity data were filtered at various stages to reduce the potential bias generally expected in Moho depth determination using gravity methods with constant density contrast assumption. The 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 was applied in a way similar to the Bouguer correction using the density contrast of 0.24 g/cm^3. The complete Bouguer anomaly corrected for the sedimentary cover was used for spectral analysis to find the information about a reference level and appropriate frequency range related to Moho deflection. We used a two-layer model by taking the density contrast of the crust-mantle interface as 0.40 g/cm^3 and a reference depth of 35 km below sea level. The results of the gravity inversion reveal that the Moho depth within the Bay of Bengal is between 19 and 24 km. Over the continent, the Moho depth increases from 34 km along the coast to 38 km towards the Singhbhum Craton and Chhotanagpur Granite Gneiss Complex. Over the northern part of the area, the Moho depth increases to more than 40 km under the confluence of the Mahanadi-Damodar Gondwana basins and the Ganga foreland basin. Finally, we compare the inversion Moho and the Moho estimated using the Airy- Heiskanen model to explain the state of the Eastern Indian Shield's isostatic compensation.

Geological observations across the Pandoh Syncline of Himachal region, NW-Himalaya

Ajay Kumar Maurya[1,2*], A. Krishnakanta Singh[1,2], Paramjeet Singh[1,2]
[1]*Wadia Institute of Himalayan Geology, #33 G.M.S. Road, Dehradun-248001*
[2]*Academy of Scientific and Innovative Research, AcSIR Headquarters, CSIR-HRDC Campus, Sector-19, Kamla Nehru Nagar, Ghaziabad-201002. U.P.*
**Presenting author: ajay@wihg.res.in*

The Himalaya is one of the youngest highland topography on the Earth which is formed by the continent-continent collision between the Indian and Eurasian plates about 50 – 55 Ma ago. The kinematic evolution of the Himalaya is largely controlled by major thrust faults such as the South Tibetan Detachment System (STDS), Main Central Thrust (MCT), Main Boundary Thrust (MBT), Main Frontal Thrust (MFT), and their

associate. During the late Oligocene – early Miocene, the central crystalline zone known as Higher Himalayan Crystalline thrust over the Lesser Himalayan Sequence (LHS) along the MCT throughout the Himalayan Orogeny. Later on, the crystalline part forms the large-scale synclinal-anticlinal structures due to the compression between MCT and MBT. Now, these synclinal structures are cut-off from their root zone and named as Lesser Himalayan Crystalline (klippen) over the LHS such as Chamba-Pandoh Syncline, Jutogh thrust sheet, Almora-Baijnath-Askot klippen in the NW-Himalaya. The geological correlation of LHS and HHC in the Himachal region is very complex and we have taken a challenge to distinguish these complexities. Along the road section between Mandi-Kataula-Bajaura-Manikaran-Toss section mainly belong to LHS, Pandoh Syncline, Kulu-Rampur window, Kulu, Jutogh, and Vaikrita thrust sheets along Beas-Parvati valleys in the northwest Himalaya. In this study, we carried out our field-based studies across the Pandoh Syncline of the Himachal region of the NW-Himalaya. The section exposed between the Mandi-Kataula-Bajaura road sections represents the Pandoh Syncline and mainly contains the low-grade metamorphic rocks such as schist, Chlorite-schist, mica-schist, garnetifeorus mica-schist, gneiss and intrusive Paleozoic age granite in mandi area. Our structural studies suggest the two phases of deformation within the Pandoh Syncline. During the first phase, the quartz veins were intruded within the mica-schist and folded into open to close folds during the pre-syn collisional time of Himalayan orogeny. Similarly, the second phase indicates the post-orogenic deformation phase, the intruded quartz veins are deformed or folded and the development of recumbent or overturned folds. We also observe the shear sense markers such as thrust sense and normal sense were possibly formed during the emplacement of the Pandoh Syncline. According to a metamorphic study, the core portion of the Pandoh Syncline underwent metamorphism up to the biotite grade while both of its limbs underwent metamorphism to the garnet grade. A similar observation has been made from the Kulu Thrust sheet exposed north of the Kulu-Rampur tectonic window. Based on our observations across the Pandoh syncline, we suggest that the Pandoh Syncline represents the southern extension of the Kulu Thrust sheet and possibly thrusted over LHS during the mega-thrusting event in late Oligo-early Miocene periods.

Metamorphic evolution of the Tso Morari eclogites: a study based on breakdown reactions, symplectite formation and carbonate metasomatism

Alosree Dey[1,2*], Koushik Sen[1,2]
[1]*Wadia Institute of Himalayan Geology, 33 GMS road, Dehradun-248001*
[2]*Academy of Scientific and Innovative Research, Ghaziabad-201002*
[*]*Presenting author: deyalosree@gmail.com*

The Tso Morari Crystalline Complex (TMCC) of trans-Himalaya, part of eastern Ladakh, India underwent deep burial (≥80 km) and subsequent rapid exhumation during continental subduction, collision, and final accretion of the Indian plate with the Eurasian plate. TMCC contains enclaves of retrogressed eclogites embedded within ortho and para gneiss, locally called Puga gneiss. These eclogitic enclaves were extensively studied in the past with surprisingly different results in terms of peak metamorphic conditions from the same outcrop in the core of the complex. The presence/absence of Na-amphiboles and lawsonite is still controversial. Two retrogressed eclogite samples from the core and western margin of TMCC are investigated based on detailed petrography, mineral chemistry, Raman spectroscopy, and *P-T* pseudo section to envisage the differences and discrepancies from previous studies and to understand the transition of omphacite and its subsequent replacement. Our study suggests peak metamorphism at ~2.42-2.72 GPa and ~500-550 °C, followed by a decompression stage at ~1.1-1.75 GPa and ~550-620 °C and subsequent high-temperature overprint at 0.7–0.92 GPa and 630-740 °C. The exhumation of TMCC is characterized by the transition of omphacite into a more calcic variety, its subsequent replacement by calcic amphibole, and further formation of zoisite as a result of amphibole breakdown and formation of various symplectite colonies. Symplectite colonies of omphacite+garnet+amphibole indicate retrogression. Moreover, the presence of diopside+plagioclase symplectite indicates continued exhumation and fluid infiltration. A further

role of late-stage fluid infiltration and metasomatism is indicated by the presence of carbonates in the matrix as veins and within fractures. Lawsonite, either in pristine form or as pseudomorphs are not found in our study which negates any significant role of lawsonite in the metamorphic evolution of the TMCC.

Lateral Variation in the sedimentary structure and configuration of basement topography across the Indo-Gangetic Plain and Siwalik Himalaya inferred from receiver function inversion

Amlanjyoti Das[1*], Devajit Hazarika[1], Abhishek Kundu[1], Dilip Yadav[1], Naresh Kumar[1]
Wadia Institute of Himalayan Geology, Dehradun 248001
[*]Presenting author: amlanjyoti2000@gmail.com

The India-Asia collision and convergence produced the spectacular Himalayan mountain belt and the Indo-Gangetic foreland basin to the south which separates the Himalaya from Peninsular India. The flexing of the Indian lithosphere in response to compressive force as well as the vertical load of the thrust-fold belt resulted in the Indo-Gangetic foreland basin or Indo-Gangetic Plain (IGP) extending from the Punjab Plain in the west to the Brahmaputra Valley in the east. IGP is one of the world's most densely populated basins that experienced rapid urban population growth in the last two decades. Seismic hazards is the most significant and grave concern in the IGP and Siwalik Himalaya due to its proximity to the Himalayan Seismic Belt. Any earthquake in the Himalaya can cause considerable damage to structures in the sedimentary basin due to site amplification in the thick unconsolidated sedimentary layer. Understanding detailed sedimentary and basement structures is a prime input to synthesize ground motion for possible earthquake scenarios to quantify seismic hazard, and micro-zonation as well as in designing earthquake resistance structures. In this study, we carried out receiver function analysis of teleseismic earthquakes recorded at 17 broadband seismological stations located over the IGP to investigate sedimentary structure. The receiver function inversion reveals sediment layer thickness varying from 0.4-3.8 km at the stations located over sedimentary cover with extremely low shear-wave velocities in the range of 0.5-1.6 km/s in the upper 0.5-1.0 km by gradually increasing to a maximum of 2.6 km/s almost at the base of the sedimentary layer. Observed seismic data interprets a north-easterly dipping Indian basement and a heterogenous topography with varying thicknesses of the sedimentary column having low seismic velocities and large Poisson's ratios. The estimation of the sedimentary thickness and S-wave speed can be fairly correlated with the known borewell logs and previous geophysical studies around the study area. The difference in thickness and shear wave speed may be indicative of variation in lithology and degree of saturation of the sedimentary cover in the western Punjab plains as compared to the eastern Ganga plains across the Delhi-Haridwar Ridge. A contour map has been prepared considering results from the present study as well as from published data. The results obtained from this study can be used as a prime input for site amplification and seismic hazard analysis.

Active fault mapping and preliminary paleo seismic investigations along the Naga thrust fold Belt of North-East India

Anusuya Mohanta[*], R. Jayangondaperumal, Arjun Pandey, Atul Brice
Wadia Institute of Himalayan Geology, Dehradun-248001
[*]Presenting author: anusuya@wihg.res.in

The Indo-Myanmar belt's deformation front is marked by the Naga Thrust (NT), which is the frontmost manifestation of the subduction zone between the Indian and Burmese plates. According to the geodetic survey, the convergence rate of the Indian plate and Tibetan plate in Bhutan and the Arunachal Himalayas is about 20–25% lower than that in the nearby central Himalayas and eastern Himalayan syntaxis. This convergence is accounted for as a distributed deformation between the Naga and Dhauki Faults. According to

the most recent GPS data, the convergence rate along the NT is around 7 mm per year, with a little strike-slip component of approximately 4 mm per year. Despite this, no geological studies have been conducted over this frontal range to determine the active faults that are the cause of the frequent earthquakes that occur in this densely populated area. Using high-resolution satellite images (CARTOSAT-1)., we conducted field investigations in the frontal Indo-Burma range between the Chathe and Dihing River valleys Real-Time Kinematics-Global Positioning System (RTK-GPS) was used to map the probable active faults in order to examine their lateral extension and respective vertical separations.

At Chathe River exit, the T2 terrace is cut by the NT which shows a vertical separation of 9 m. Similarly, at the Dihing River exit, the mapped fault scarp along the NT shows a vertical separation of 6 to 8m and it laterally extends more than 1km. Sediment samples for OSL (Optically Simulated Luminescence) and detrital charcoal samples for radiocarbon dating were collected from the deformed terraces to constrain the long-term deformation history and the recent faulting events along the NT. The presence of the active faults along the NT at major river exits shows the area is subjected to Quaternary deformations and detailed paleoseismic investigations are required to access the earthquake potential and seismic history of the region.

P-T constraints, petrogenesis and age of protolith of HP garnet-amphibolite from the Tethyan Himalayan Sequence of Bhagirathi Valley, Western Garhwal Himalaya

Aranya Sen*, Koushik Sen
Structure and Tectonics Group, Wadia Institute of Himalayan Geology, Dehradun
**Presenting author: aranyasen1992@gmail.com*

The formation of intra-terrane shear zones and regional metamorphic belt along the strike of the Cenozoic Himalayan orogeny is a manifestation of subduction and subsequent collision of the Indian lithosphere with the Asian plate in the Eocene. This metamorphic belt contains High-pressure (HP) metamorphic rocks (garnet-amphibolite, late-stage granulite, and host gneisses) at various structural levels in the Himalaya. Geochemical, chronological, and metamorphic modelling was carried out of an exotic tschermakite bearing garnet-amphibolite unit exposed within the Tethyan Himalayan Sequence of western Garhwal Himalaya of India. Bulk rock geochemistry suggests a tholeiitic fractionation trend and trachy-andesitic nature of the protolith. U-Pb geochronology of zircon reveals an age spectrum with pronounced clusters at ~1550 Ma, ~1350 Ma, 1100-1150 Ma, 900-930 Ma, and ~550 Ma. There is a possibility that the protolith of the HP garnet amphibolite is magmatic. However, near concordant ages at certain intervals might suggest crustal contamination. Integrated geothermobarometry and P-T pseudosection modeling indicate high-P/medium-T conditions (~1.5-1.7 GPa and 600-670°C) of peak metamorphism. Based on these results, we infer that this garnet-amphibolite represents the pre-Himalayan Indian lower crust and during India–Asia collision. The leading edge of the Indian continental lithosphere subducted where mafic and some of the felsic lithologies underwent HP garnet-amphibolite facies metamorphism, and after a possible slab break-up, these rocks exhumed during the Himalayan orogeny.

Possible surface rupture of the 1714 CE earthquake at the backthrust outboard of the Indo-Bhutan range front

Arjun Pandey*, R. Jayangondaperumal
Wadia Institute of Himalayan Geology, Dehradun-248001
**Presenting author: rohitarj42@gmail.com*

The segmentation model is challenged in terms of surface rupture propagation of great earthquakes because of the lack of pre-historic earthquake data on either side of a transverse segment boundary. To check this hypothesis, a pop-up Ultapani anticline (UA) lies between the Kopili and Dhubri Chungthang transverse

faults. was studied at the Ultapani village, outboard of the Bhutanese range front in the State of Assam, India. The UA is bounded by fore and back thrust faults in the south and north in the foreland basin of the Brahmaputra alluvium. Two trenches were excavated on the fore (i.e. southern) and back-thrust fault scarp (northern) of the anticline, suggesting a non-emergent thrust fault to the south and emergent back thrust in the north. The systematic logging and sampling across the uplifted anticlinal structure gave ages ranging from 1436 BCE to 1953 CE. The results derived from study advocate that the fold growth across the Ultapani anticline was initiated probably since ~1436-1131 BCE, with the youngest event dating post ~240-509 CE, possibly related to the 1714 CE Bhutan earthquake. The estimated results show a maximum uplift rate of 8.2±0.1 mm/yr at the vicinity of the Ultapani anticline over the last ~3000 years, in agreement with the previously reported rate at the nearby sites in the Bhutan foothills. Using Kanamori relations and comparing the results of the present study with adjoining regions a minimum seismic quiescence of ~306 years remains, which is capable of generating a magnitude of ~8.0 Mw in the region.

Are the Himalayas segmented? Vantage from a post 4.35 ka great earthquake event in the Darjeeling Himalayas

Atul Brice[1,2*], R Jayangondaperumal[1], Yashpal Sundriyal[2]
[1]Wadia Institute of Himalayan Geology, Dehradun - 248001
[2]HNBGU, Srinagar, Uttarakhand
[*]Presenting author: atulbrice@gmail.com

The ongoing collision between Indian and Eurasian plates results in strain accumulation along the Main Himalayan Thrust (MHT) that is being released in the form of earthquakes. The majority of this accumulated strain is released through great earthquake events (Mw>8). These great earthquake events lead to surface rupture along the frontal most expression of MHT i.e. Himalayan Frontal Thrust (HFT). Recent palaeoseismic studies along the HFT suggest an approximate millennial recurrence of a great earthquake. Our study along the HFT of Darjeeling Sikkim Himalaya provided a unique result where the aforementioned theory doesn't play out. Here no evidence of deformation for ~4350 years occurred based on the calibrated ^{14}C radiocarbon dating and OSL dating from the excavated trench, at Chenga village, Darjeeling, West Bengal. This marks the first surface rupture expression in the Himalaya where accumulated strain is taking a long time to release strain along the frontal thrust. What might be the reason for a such long quiet period of no strain release. In this study, we present some hypotheses that fulfill the conditions wherein accumulated strain is partitioned and dissipated. Combining our results with previous palaeoseismic, geophysical and geodetic studies indicates a distinct region where multiple factors combine to segregate the accumulated strain along the MHT and delay the temporal cyclicity of surface rupture along the HFT.

Prograde growth zoning in metamorphic monazite from metapelites of Higher Himalayan Crystalline Sequences, Dhauliganga Valley, Garhwal Himalaya

C. Chaurasia[1*], S.S. Thakur[1], S.C. Patel[2], A.K. Samal[3], N. Gour[1]
[1]Wadia Institute of Himalayan Geology, Dehradun, 248001
[2]Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai, 4000076
[3]Department of Geology, Banaras Hindu University, Varanasi – 221005
[*]Presenting author: chandnichaurasia33@gmail.com

The petrography combined with REE and trace element study has been carried out to understand the metamorphic zoning of monazite from the metapelites of Higher Himalayan Crystalline Sequence (HHCS), Dhauliganga valley, Garhwal Himalaya. The monazite is a common accessory phase that occurs as solitary

elongated to rounded grains in the metapelites of HHCS rocks of Dhauliganga valley. Petrography shows that the monazite is commonly aligned parallel to the major foliation (S_2) of rocks. Its grain size commonly varies from 50 to 250 μm which increases with increasing structural level with increasing grade of metamorphism in the HHCS. The chemical zoning indicates monazite growth due to prograde metamorphism. Sixteen monazite grains from five pelitic schist samples ranging from kyanite to sill-Kfs grade have been studied. Selected grains were analyzed for core-rim relation, and their chemical composition was compared at different metamorphic grades. The larger grains of monazite, up to 250 μm occurring in sill-Kfs grade rocks at a higher structural level, are either due to monazite growth by slow heating for a relatively longer duration of time or to an increase in the supply of constituent materials from the source to the growing crystal.

The mineral chemical study shows that the LREEs concentration is homogeneous in monazite and does not vary with increasing grade of metamorphism. However, the HREEs content is temperature dependent and varies with the grade of metamorphism. Sm-La plot shows more scattering in kyanite grade rocks (at lower structural level) while relatively uniformly distributed in sill-Kfs grade rocks (at higher structural level); however, no systematic variation among monazite-LREE could be seen due to their mutual substitution. Monazite having compositional heterogeneity in kyanite-grade rocks could be related to the low mobility of REEs. Most of the HREEs are below the detection limit. Gd_2O_3 and Dy_2O_3 are the main HREEs to incorporate in monazite structure, showing considerable enrichment. Y has ionic radii between Dy-Ho, thus showing chemical affinity similar to HREEs. Unlike LREEs, the absolute values of HREE+Y increase from 1.18 to 3.0 wt.% within a temperature range of 659-800°C. Monazite exhibits a low HREE core (av. 0.94 wt.%) and a relatively high HREE rim (av. 1.23 wt.%). Those absolute values continue to increase at the rim (av. 2.42 wt.%) towards the higher grade. Dy content in monazite increases with increasing grade of metamorphism. The large monazite grains from sill-Kfs grade rocks show Dy-rich rim (av. 0.78 wt.%) and Dy-poor core (av. 0.09 wt.%). The Y concentration is relatively low in the core while the rim shows an increase in Y content up to 2.35 wt.%. A strong positive correlation is observed between Y and HREE in the individual grain. It is interpreted that the pronounced rim-ward zoning of Y, Gd & Dy content is the result of prograde metamorphism. Monazite shows no retrograde resetting of REE concentration in the rocks of the middle structural level. However, one sample (HH30) from sill-Kfs grade (at a higher structural level) lacks prograde growth zoning that can be interpreted as retrograde resetting of Y, Dy, and Gd at the margin.

Intra-crustal low-velocity layer beneath the Kishtwar region, North-West Himalaya, India

Chinmay Haldar*, Kalachand Sain
Wadia Institute of Himalayan Geology, Dehradun-248001
**Presenting author: chinmay.haldar@gmail.com*

Converted wave seismological data across the Doda-Kishtwar region in the Kashmir seismic gap of North-West Himalaya is used for the first time to image the crust, including intra-crustal Low-Velocity Layer (LVL) and seismic velocity structure based on receiver functions (RFs) analysis. This study provides the first model as there are no previous results in the Doda-Kishtwar region, and it gives the correlation between the upper crustal LVL and local seismicity. We suggest that the LVL has a significant effect on the geodynamic evolution and seismotectonic process of this region. The inversion of the stack RFs shows an increase in crustal thickness from ~47 km to ~58 km from south to north. The depth to the Main Himalayan Thrust varies from ~21 to 26 km. LVL varies from ~11 km to 13 km with a high value of Vp/Vs of 1.9. Such a high value of Vp/Vs in the LVL of the upper crust may be associated with the temperature rise due to viscous dissipation within the ductile mechanism and/or loosen-up and cooling related to the exposure indicating the presence of fluid/fractional melt at depths in-between ~10 to 15 km. The depth extent of the LVL in this region varies from 11 to 29 km. Interestingly, the LVL coincides with most of the local crustal seismic activity occurrences. We

suggest, that the upper crustal LVL, associated with the weak zone (intra-crustal fluids) could be one of the possible reasons for the generation of most of the upper-to-mid-crustal earthquakes in this region.

Generation of forearc polygenetic melt during slab roll-back: evidence from the mafic volcanics of Nagaland Ophiolite Complex, Northeast India

S. Imtisunep*, A. Krishnakanta Singh
Wadia Institute of Himalayan Geology, Dehradun, 248001, Uttarakhand
**Presenting author: imtiwal@yahoo.in*

Ophiolites are fossilized remains of oceanic crust which are obducted onto a continental crust. On the eastern margin of the Indian plate, this ancient oceanic crust is represented by the Neo-Tethyan ophiolite of Nagaland-Manipur Ophiolites (NMO). Although, the development of ophiolite could be initiated at various tectonic setting like mid-oceanic ridge, supra-subduction zone, and within-plate environment; a large portion of this, have been generated in the supra-subduction zone. Conversely, in the northern part i.e. Nagaland ophiolite complex (NOC) of NMO, the MORB-like and Arc-like characteristic of mafic volcanic rocks, which are neither MOR nor SSZ in origin, possesses an issue with its petrogenesis and magma source. In order to constrain the nature of magmatism, and its tectonic significance, associated with mafic magmatic rocks of NOC, comprehensive petrological, mineral, and geochemistry characteristics have been discussed. The mafic basalt of NOC shows a sub-alkaline character with Nb/Y < 0.50, low Nb/Th (2.36 to 7.94), and low to moderate La/Sm (1.00 to 4.12) indicating derivation from a slightly enriched mantle source (Mid-Oceanic Ridge Basalt). This is supported by their enriched LREE pattern with flat HREE $(La/Yb)_N$ = 1.01-1.8, Zr-Ti ratio, and higher TiO_2 abundances (average TiO_2=1.53). However, they are depleted in HFSEs (Nb) and enriched in U and Pb, which is indicative of a typical subduction origin. This polygenetic magma source typified in the basalts of NOC is supported by the Ti-V ratio and Th/Yb vs Nb/Yb and Al_2O_3-(TiO_2+Cr_2O_3) ratio of whole-rock geochemistry and clinopyroxene compositions of basalt respectively. The magma source of the basalt shows its derivation from a depleted mantle source of spinel-peridotite facies. This MORB-like basalt produced in a subduction zone may be a magmatic expression of subduction initiation and a result of the upwelling asthenosphere, in interaction with MOR mantle lithosphere, and melt+fluids from a forearc SSZ setting. It is possible that the upwelling of the asthenosphere was a result of a sharp change in subduction angle or a rollback of the subduction slab. Upwelling in the mantle continues even after subduction and produces N-MORB and E-MORB compositions of basalt commonly with subduction components. As subduction continues, decompression melting of upwelling asthenosphere produces MORB-like melt. However, with continued asthenosphere upwelling and slab subduction, the depleted mantle source gets hydrated and metasomatized with fluids released from the subducting MOR slab, it produces MORB-Arc basalt as observed in NOC.

Evolution of lake and Quaternary landforms in the Champawat area of the Almora Klippe, Kumaun outer Lesser Himalaya: An insight from geomorphological and tectonic perspective

Khayingshing Luirei
Wadia Institute of Himalayan Geology, Dehradun-248001
Presenting author: ashing_luirei@wihg.res.in

Geomorphology of the landforms evolved around the Champawat area in the outer Kumaun Lesser Himalaya suggests a relatively mature topography than its adjacent area, as evident from various morphological features. Conjugates set of normal faults are observed in the bedrocks and Quaternary deposits at Banlek in

the hanging block of the South Almora Thrust (SAT). The most prominent normal faults are those striking NE-SW and NW-SE and most of them are high dipping faults while some are vertical faults. Sediments akin to lacustrine deposits are observed at four sites; while the contact between the bedrock and the lake sediments is observed at only one site, that too on the peripheral sides. The exposed sediment thicknesses vary from 4.8 m to 9.0 m and consist of an alternation of black carbonaceous mud, oxidized mud, and sandy horizons indicating different depositional regimes. The difference in height between the topmost and bottom horizons of sites 1 and 4 is assumed to be the total thickness of the lacustrine deposits that amount to more than 75 m. Paleostrand as deduced from the topmost layer suggests the paleolake was spread in a much larger expansion. From Site 1 two OSL samples were analyzed and collected from 2.5 m and 8 m from the surface and give OSL ages of 16 ka and 17 ka, respectively; while a sample collected from Site 4 gives an OSL age of 13 ka. The chronological dates obtained suggest the lake originated before 17 ka and the water was drained out after 13 ka. A total of 3653 lineaments were mapped within the study area encompassing 2,277.8 sq km from the eastern Kumaun Himalaya and the maximum of the lineaments trend ENE-WSW or almost E-W (~ 46.5%), the major principal stress is assumed to be in NE-SW direction. Lake, gentle topography and gentle stream gradient in the Champawat area is the result of normal faults and highly weathered bedrock.

Latest marine horizon from the Surma Group, Indo-Myanmar Range: implications for closure of Neo-Tethys

Kapesa Lokho[1*], Ankit Kumar[2], Muthusamy Prakasam[1]
[1]Wadia Institute of Himalayan Geology, Dehradun-248001
[2]Geology Department, DBS College, Dehradun-248001
[*]Presenting author: kapesa@wihg.res.in

The Indo-Myanmar (formerly Burma) Range is located in SE Asia at the southern end of the Tibetan-Himalayan orogen extending southwards from the Namche Barwa Syntaxis (NBS)/Eastern Himalayan Syntaxis (EHS). The Naga Hills lie between the foreland spur of Shillong and Mikir massifs to the west and central Myanmar Basin to the east and have four geotectonic domains from west to east: Assam Shelf, Schuppen Belt, Inner Paleogene Fold Belt (comprising a thick folded sequence of Eocene and Oligocene rocks) and an ophiolitic complex associated with Mesozoic-Cenozoic sediments (Evans, 1964). Miocene planktonic foraminifers occur in shale intercalated with thinly bedded siltstone and sandstone of the Surma Group in the foothills of the Naga Schuppen Belt of the Indo-Myanmar Range. These are the first clearly imaged middle Miocene foraminifera from the Surma Group of the Naga Hills. This new M5-M6 assemblage from the Bhuban Formation correlates with the uppermost Burdigalian to Langhian age (16-14 Ma). The biostratigraphy, paleoenvironment, and paleogeography of the assemblage are significant. It provides a basis for widespread regional and global correlation constraining the timing of Neo-Tethys seaway closure.

Stable Hydrogen and Oxygen isotope investigation of the saline and hyperalkaline springs in parts of the Inner Fold Belt and Ophiolite Complex of Manipur and Nagaland, India

Kapesa Lokho[1], Horthing V. Zimik[2], Sameer K. Tiwari[1], Khayingshing Luirei[1*]
[1]Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand
[2]Discipline of Earth Sciences, IIT-Gandhinagar, Gandhinagar
[*]Presenting author: kapesa@wihg.res.in

Several saline and hyperalkaline springs occur in Manipur and Nagaland. In most parts of Manipur, the

springs occur mainly in the Disang country rocks, with a few in the ophiolite belt. In northern Manipur and Nagaland, they are reported from rocks of the Disang and Barail groups. There is a lack of stable isotope studies of the springs, hence, an attempt is made for the first time to determine the source of the springs utilizing stable water isotopes of hydrogen and oxygen. The springs have TDS contents varying significantly from 532 to 32,700 mg/l. The stable isotopes of hydrogen and oxygen indicate the meteoric and metamorphic origin of the waters. The Indo-Myanmar Range, whose origin is linked to underthrusting of the Indian Plate into the Burma microplate, hosts several saline and hyperalkaline springs. Based on TDS content, the springs are classified into three groups: Group 1 (<1000 mg/l), Group 2 (1000 to 10000 mg/l), and Group 3 (>10000 mg/l). Group 1: Spring waters of this group have $\delta^{18}O$ values ranging from -8.04 to -6.97‰ and $\delta^{2}H$ from -51.91 to -45.81‰. Group 2: The spring waters of this group have $\delta^{18}O$ ranging from -6.33 to -2.59‰ and $\delta^{2}H$ ranging from -44.79 to -35.00‰. Group 3: The spring water of this group has $\delta^{18}O$ values ranging from -5.60 to 6.21‰ and $\delta^{2}H$ values ranging from -35.59 to -21.56‰. Conforming to pH values, Khangkhui Phungthar 1 and 2 springs are classified as hyperalkaline springs. The stable isotopes of hydrogen and oxygen of the spring waters suggest that they are of two different sources - meteoric and metamorphic; the possibility of seawater origin of the springs is ruled out. Structural and lithological controls on the springs shows that the saline springs of Manipur and Nagaland occur mainly in the Disang Group of rocks. The springs of the Khuzama-Viswema-Jakhama-Kidima-Kaibi-Makhel-Shajouba areas occurs near the contact of the Barail and Disang rocks. Two of the samples were collected from the springs in the ophiolite suite comprising the hanging wall of the Phangrei Fault, in Khangkhui Phungthar village of Ukhrul. Salt springs are also reported from the Imphal Basin along the NE-SW trending Thoubal Fault; while some have stopped oozing out.

Tectonothermal evolution of the Lohit Valley, Eastern Himalaya: New Low-Temperature Thermochronological Constraints

Kunal Mukherjee[1*], Vikas Adlakha[1]*, Sayandeep Banerjee[2], Koushik Sen[1]
[1]Wadia Institute of Himalayan Geology, Dehradun-248001
[2]Centre of Advanced Studies, Department of Geology, Banaras Hindu University, Varanasi-221005
[*]Presenting author: kunalmukherjee30@gmail.com

We have broadly illustrated the first low-temperature thermochronological information in Lohit valley, Easternmost Himalaya. Across major lithologic units of Lohit Valley, we have produced 13 ZHe and 7 AHe ages to constrain recent exhumation behaviour which will help to understand the tectonic scenario of the valley. In the southern part of the valley within Mishmi Crystallines ZHe ages range from 7.1±0.33Ma to 12.51± 2.84Ma, while ZHe ages vary from 6.63±0.38 to 9.09±0.52 Ma within the Lohit Plutonic complex. This suggests that the Mishmi Crystallines exposed at the southwestern mountain front are the slowest exhuming domain since ~12 Ma. Throughout the valley, we have established the lowest ZHe ages from the Demwe thrust zone which is contact between the frontal low-grade metamorphic rocks of Mishmi Crystalline and high-grade gneissic rocks of the Mayodia Group. The exhumation rate obtained from the AGE2EDOT software program suggests that the rapid exhumation in the Demwe Thrust zone as obtained from the ZHe cooling ages suggests an out-of-sequence thrusting at ~7 Ma. Helium analysis from the Apatite grains gives us more opportunity to explore recent exhumation activity which helps us to find a correlation between exhumation rate and geomorphic components. The ages of the Lohit Plutonic complex vary from 1.55±0.17 Ma to 3.56±0.42 Ma. The QTQt thermal history modeling of the co-genetic pairs of ZHe and AHe cooling ages of the northeasternmost Lohit Plutonic Complex suggests that the exhumation rates in this region were as high as ~3.7 mm/yr during the Pliocene-Quaternary. These high rates of exhumation are in good correlation with the local topographic relief, hill slopes, and channel steepness which suggests the establishment of the present-day topography of the Lohit Valley region latest by Pliocene-Quaternary. Variation in exhumation rates does not correlate with the present-day precipitation pattern. Tectonics appears to be the prime driver of

the exhumation rates of the Lohit Valley region of the easternmost Himalaya. We have incorporated a thermo-kinematic 3D forward modeling 'PECUBE' to explore a suitable geometric model of the Lohit valley by which our thermochronological ages are reviewed and accord MHT geometry below the crustal surface.

Lower Cretaceous Kerguelen Mantle Plume and its role in the breakup of eastern Gondwana: Evidence from the magmatism in Sylhet and Abor magmatism North-East India

Manoj Kumar* **A. Krishnakanta Singh**
Wadia Institute of Himalayan Geology, Uttarakhand 248001
**Presenting author: manoj@wihg.res.in*

Mantle plumes related to Large Igneous Provinces (LIPs) have been linked to the continental breakup and validated by the outpouring of mafic-ultramafic magmas that range from continental flood basalt magmatism to submarine plateau volcanism. In this study, we present a new set of geochemical and mineralogical data on magmatic rocks from the Sylhet Trap of the Shillong plateau and Siang windows of Eastern Himalaya and discuss the nature of magmatism and its tectonic linkage with the Kerguelen Mantle Plume activities. The investigated mafic rocks (basalt and dolerite) of Sylhet Trap and Siang window are predominantly sub-alkaline-tholeiitic in nature. Petrographically, mafic volcanic rocks are composed of plagioclase and clinopyroxene, giving rise to sub-ophitic texture, the dark interstitial region of much finer grains consisting of opaque minerals and devitrified glass. In dolerite dykes plagioclase laths are partially or fully enclosed in clinopyroxene, giving rise to sub-ophitic and ophitic textures. Mafic rocks of Sylhet traps show mild light rare earth elements (LREEs) enrichment with $(La/Yb)_N$ ratio (1.92-2.86) and $(La/Sm)_N$ ratio (1.11-1.40), an almost flat pattern of heavy rare earth elements (HREEs) along with mild Europium (Eu) anomalies Eu/Eu* values of (0.94 to 1.05). Trace element characteristics suggest their affinity with Enriched mid-oceanic ridge basalt (E-MORB) and are generated from an enriched mantle source composed of garnet and spinel with a low degree of partial melting and crustal contamination. Conversely, the magmatic rocks in the Siang window of eastern Himalayan Syntaxis are also tholeiitic in nature and enriched in LREE and slightly depleted in HREEs and fractionated nature of REEs $(La/Yb)_N$ ratio (3.01-7.47) with insignificant Eu anomalies. The similarity in geochemical characteristics of magmatism occurred in Sylhet Trap, Siang window Eastern Himalaya, Rajmahal Trap along with Bunbury Basalt in western Australia and Cona Mafic in eastern Tethyan Himalaya suggest their genetic linkage with Kerguelen mantle plume due to which the breakup of eastern Gondwana into Greater India, Antarctica, and northwest Australia occurred in the late Mesozoic period.

Chromian compositional variability and elemental distribution of Platinum Group Elements in upper-mantle rocks of the Indo-Myanmar Orogenic Belt ophiolites, Northeast India

Monika Chaubey*, A. Krishnakanta Singh
Wadia Institute of Himalayan Geology, Dehradun, 248001, Uttarakhand
**Presenting author: monika.chaubey6422@gmail.com*

It is widely accepted that primary Chromian-spinel is resistant to alteration and metamorphism and is thus a useful indicator for determining the tectonic setting of mafic-ultramafic rocks. Moreover, the Cr# of Cr-spinel in mantle-derived peridotites can be used as an indicator of the degree of magma extraction. Conversely,

Platinum group elements (PGE: Os, Ir, Ru, Rh, Pt, Pd) in the ophiolite suite of rocks provide essential insights into mantle evolution and crust-mantle interaction. PGE geochemistry can be used to obtain information on the origin of a specific ophiolite complex and its geotectonic context, and the chemical-physical conditions that existed in the mantle during ophiolite formation. PGE in magmatic rocks may be controlled by three processes: partial melting, crystal fractionation, and alteration. In this study, we report Chromian spinel composition and PGE data of peridotites from the Indo-Myanmar Orogenic Belt, northeast India to understand the tectonic significance of peridotites and PGE fractionation during magma evolution. The research region is dominated by mantle-derived rocks such as harzburgite, lherzolite, wehrlite, and dunite, as well as basic rocks and a minor amount of chromitites. A wide range of chemical compositions is observed in the mantle sequence of the IMOB ophiolites. Lherzolites display low Cr# (0.12-0.26) and TiO_2 (<0.11) associated with high Mg# [Mg/(Mg+Fet] (0.69-0.76) in the Cr-spinels present in them. They represent the residual product of a fertile mantle that underwent low-degree partial melting (2-10%) in a divergent mid-ocean ridge (MOR) tectonic setting. Conversely, the harzburgites and dunites have high Cr# (0.84–0.90) and low TiO_2(< 0.06 wt%) Cr-spinels and exhibit slightly U-shaped REE distributions indicating their derivation from a highly depleted mantle source in a supra-subduction zone (SSZ) setting. The dunite is composed of a very refractory olivine-spinel assemblage (Fo: 92.1-93.6; Cr#: 71-83), corroborating a boninitic parentage, with influence from melt-rock interactions. The observed IPGE depletion relative to PPGE is compatible with the development of inter-element fractionation in response to preferential preservation of the IPGE in magma source areas or co-precipitation with early fractionation ferromagnesian silicates. The consistency of the Ir/Os, Ru/Os, and Ru/Ir ratios indicates that these elements were in thermodynamic equilibrium during crystallization. Their varied mantle-normalized PGE patterns, together with the Pd/Ir and Pt/Pt* values, are associated with residual mantle material. The published isotopic ages suggest two phases of the development of IMOB ophiolites at 148 Ma (K-Ar ages) and 118-117 Ma (U–Pb age). The presence of both MOR and SSZ melting regimes in the IMOB ophiolites shows that the upper mantle rocks originated in two distinct tectonic environments of the pre-subduction and subduction, respectively. Thus, we argue that the upper mantle rocks of IMOB ophiolites were represented by fertile lherzolite to Cpx-harzburgite and harzburgite, and subsequently to extremely refractory dunite, indicating their generation due to multistage melting and melt-rock reaction processes.

The northern Indian upper crustal margin recycling in Indus Suture zone: The genesis and tectono-magmatic evolution of Peraluminous Ladakh granite in the southern margin of Ladakh batholith, Himalaya, India

C. Perumalsamy[1*], Rajamanickam Murugan[2]

[1]Wadia Institute of Himalayan Geology, 33, GMS Road, Dehradun – 248001, India

[2]Environmental Radionuclide Research Group, National Institutes for Quantum Sciences and Technology (QST), 4-9-1 Anagawa, Inage-Ku, Chiba, 263-8555, Japan

[*]Presending author: peruc@wihg.res.in

The studies on peraluminous Ladakh granite in the southern margin of Ladakh batholith provide important information about the nature of source rocks involved in the generation and marginal evolution of Ladakh peraluminous granite in the southern margin of Ladakh Batholith, Indus Suture zone during the early Cenozoic continental collision and crustal thickening between India and Eurasian plates. This study focused on the combined petrographic, whole-rock major, trace elemental geochemistry, and ID-TIMS Sr, Nd isotopic studies from Ladakh granite in the southern margin of Ladakh batholiths, Indus Suture zone. Petrographically, the Ladakh granite records partial melting, emplacement-related fractional evolution, and sub-solidus microstructure. Based on the chondrite normalized REE pattern the samples are classified into two types, such as i) plagioclase controlled Fractionated granite and ii) residual zircon controlled Intra-fractionated granite. Both granites are high K calc alkaline, S-type peraluminous in nature (A/CNK = 1.00-

1.18), with high normative corundum (1.04 to 3.04 %) indicating sediments dominant crustal melts during the syn-collisional tectonic setting. They show relatively high SiO_2, K_2O, Na_2O, Al_2O_3 and low MgO, CaO, Fe_2O_3 and Mg# (26-46). The enrichment in LILEs with sharp Pb positive spike and depleted in rare earth elements with tough in HFSEs, which is similar to northern Indian upper crustal margin melting with residual mineral assemblage. The crustal signature of high ($^{87}Sr/^{86}Sr$) I = 0.698-0.719 and large negative εNd values (-12.3 to -4.2), Al_2O_3/TiO_2 (241.3-32.6), CaO/Na_2O (0.17-0.61), Rb/Ba (0.08-1.87), Rb/Sr (0.22-6.91), $CaO/FeO^*+MgO+TiO_2$ (0.6-1.73) ratios with two-stage T_{DM} ages (1160-1858 Ma) for Ladakh granite represent the mixed source of igneous and ancient (Archaean-Precambrian) supra-crustal northern Indian margin melting. Therefore, we suggest that Ladakh peraluminous granite from the Indus Suture zone records not only the melting of Juvenile Neo-Tethyan oceanic crust but also records the melting and reworking of the under-thrusted northern Indian upper crustal margin beneath the Eurasian plate during the early Cenozoic India-Eurasia collision and crustal thickening.

First radiometric dating of buried brick temple structures from the Lower Mahanadi valley, Odisha: Clue to a 16th century C.E. catastrophe?

Rajeeb Lochan Mishra[1#*], Anup Mishra[2], P. Morthekai[3], M.G. Yadava[4]

[1]School of Earth, Ocean & Climate Sciences, Indian Institute of Technology Bhubaneswar, Khordha 752050

[2]Department of Ancient History, M. J. P. Rohilkhand University, Bareilly-243006

[3]Birbal Sahni Institute of Palaeosciences, 53, University Road, Lucknow-226007

[4]Geosciences Division, Physical Research Laboratory, Navrangpura, Ahmedabad-380009

[#]Presently at: Structure & Tectonics Group, Wadia Institute of Himalayan Geology, Dehradun-248001

[*]Presenting author: rajeeblochanmishra@hotmail.com

The paper presents the results of the first multi-proxy radiometric dating of a submerged brick temple in the Lower Mahanadi valley at Padmabati village in the Nayagarh district of Odisha, India. Temples in India are dated based on their architectural characteristics attributed to a particular region or dynasty. The temple under study is built according to the 'Kalinga style' of temple architecture, comprising a *Rekha deula* (*sanctum*) and a *jagamohana* (entrance porch or *mandapa*). The luminescence chronology of brick samples obtained from the exposed crowns of the temple places limits on the period of its construction to the 15th-16th century C.E. (*c*. 1405-1550 C.E.), i.e., the period pertaining to the imperial rule under the later Eastern Gangas or the early Gajapati rulers of medieval Odisha. The submerged temple complex at Padmabati is probably the youngest brick temple in the Indian subcontinent reported till date. Radiocarbon ages of soil sequence from the adjoining geomorphic surface suggest the occurrence of a catastrophic flood. We interpret that the flood might have caused due to localized seismic disturbances triggered by the reactivation of the Mahanadi Fault (MF). These series of events subsequently led to the submergence of the temple complex during *c.* 1550-1599 C.E. The present work is probably the first in India, which involves the dating of a temple using radiometric methods.

Geochemistry of continental rift related magmatism from Bhiuli-Nagarota-Kathindi section, Northwestern Himalaya: implication for plume-lithosphere interaction

M. Rajanikanta Singh[*], Paramjeet Singh, Pratap Shethy

Wadia Institute of Himalayan Geology, Dehradun 248001, Uttarakhand

[*]Presenting author: rajanimutum@gmail.com

The Northwest Himalayan region has a record of several phases of mafic magmatic activity spanning from Precambrian to recent in a dynamic tectonic setting. Here, we studied detailed petrography and new whole-

rock geochemistry of mafic volcanic and dykes from the Bhiuli-Nagarota-Kathindi (BNK) section of Himachal Pradesh, NW Himalaya to understand the petrogenesis and possible tectonic setting. Both rock types have comparable mineralogical compositions (clinopyroxene + plagioclase + actinolite-tremolite + chlorite + iron oxides ± hornblende ± epidote ± quartz ± carbonates) overprinted by greenschist to lower amphibolite facies metamorphism. BNK mafic volcanic and dykes exhibit sub-alkaline basalts to basaltic andesites and a typical tholeiite compositional character. The chondrite-normalized rare earth element pattern exhibit similar LREE enrichment and HREE fractionation, whereas Primitive mantle normalized multi-element patterns show pronounced LILE enrichment of Rb, Ba, Th, LREE and HFSE depletion of Nb, K, P and Ti. The Zr–Y–Nb–Th relationships indicates that both the rock type were derived from plume source, whereas low Nb/La (<1), similar high large ion lithophile element concentrations and pronounced negative Nb, Zr, P and Ti anomalies suggests that components other than mantle plume must have been involved in the generation and evolution of both the rock types, i.e., most likely plume and sub-continental lithosphere mantle (SCLM) interaction. The parental magmas of the BNK volcanic and dykes were produced by 4-6% and 10-20% partial melting of spinel+garnet lherzolite and erupted/intruded in an intracontinental rift setting. Overall, the important petro-tectonic processes invoked for the genesis of BNK mafic rocks include (i) adiabatic decompression melting due to ascending plume, the release of heat supplying the thermal condition for melting of SCLM and interaction between upwelling mantle plume and subduction metasomatized SCLM, (ii) this plume-SCLM source's partial melting in the melting regime produced tholeiitic basaltic magma and (iii) crustal contamination during melt migration.

Fluid P-T evolution of migmatites from the Leo Pargil gneissic dome, India: Implication for partial melting processes and exhumation of the gneissic dome

Shashi Ranjan Rai*, Himanshu K. Sachan, Aditya Kharya
Wadia Institute of Himalayan Geology, Dehra Dun-248001
**Presenting author: shashi@wihg.res.in*

Migmatites exposed within the North Himalayan Domes are the result of a prolonged geologic evolution and reveal the anatectic and tectono-thermal processes related to the Himalayan orogeny, petrologic studies of migmatites from North Himalayan Domes are virtually lacking.

These rocks record reworking and partial melting of different levels of the Indian continental crust during a major Himalayan Tectonic event. To understand the partial melting processes, the thermodynamic approach of isochemical phase diagrams as well as fluid inclusion data has been applied. Phase equilibria calculated in the $MnO–Na_2O–CaO–K_2O–FeO–MgO–MnO–Al_2O_3–SiO_2–H_2O–TiO_2$ (MnNCKFMASHT) system suggest peak P–T conditions of 780–820°C, 9.3–9.8 kbar for the sillimanite-bearing migmatite whereas minimum P-T condition of migmatitization constrained at 690°C, 7.2-7.4kbar. The formation of migmatites in the LPD was related to muscovite dehydration melting.

Primary CO_2 and CO_2-H_2O fluid inclusions are hosted by quartz grain. The re-equilibrated fluid inclusions are characterized by the presence of necking, hook-like, and annular shape morphology. These microtextures also advocate that the studied area goes under the isothermal decompression. The primary CO_2 fluid inclusions were entrapped at 6.4 – 3.6 kbar: 720 – 410 °C in sillimanite-bearing migmatite, due to the density reversal. Whereas secondary carbonic fluids were trapped at 4.8 – 2.5 kbar: 610 – 360 °C.

Neoproterozoic magmatic record from south-east Karakoram: Implications on petrogenesis and paleogeographic reconstruction

Shailendra Pundir[1*], Vikas Adlakha[1], Santosh Kumar[2], Saurabh Singhal[1], Satyabrata Das[1]
[1]Wadia Institute of Himalayan Geology, Dehradun, 248001, Uttarakhand
[2]Centre of Advanced Study, Department of Geology, Kumaun University, Nainital, 263001, Uttarakhand
[*]Presenting author: shailendra0089@gmail.com

The Karakoram Terrane (KT) represents the southern margin of the Asian Plate, and mainly comprises of Late Jurassic-Early Cretaceous calc-alkaline I-type subduction-related granites and post-collisional late Eocene-Miocene leucogranites. In this study, we report for the first time the existence of Neoproterozoic (ca. 806 Ma) KT basement in the form of tonalite from the southeastern Karakoram terrane, NW India. The studied tonalite is slightly peraluminous in nature (Molar $Al_2O_3/CaO+Na_2O+K_2O=1.1$), and has calc-alkaline volcanic-arc affinity, strongly fractionated having high LREE/HREE ($La_N/Yb_N=33.99$), and high Sr/Y =19.75 ratio. These geochemical features of the tonalite represent its affinity towards the Tonalite–trondhjemite–granodiorite (TTG) or adakite suite. The geochemical data suggest that the tonalite is more likely sourced from the mafic lower crust where garnet remained in the residue. REE petrogenetic modeling suggests that the melt similar to studied tonalite can be formed through the high degree partial melting (~50%) of the mafic lower crust and the produced melt served as the parent for the development of TTGs in the southern Pamir and more evolved granitoid in the central Tibetan microcontinents. We compile the present and published Precambrian magmatic records from southern Pamir, SE Karakoram, and central Tibet and propose that the investigated tonalite from the southeast Karakoram is a product of a Neoproterozoic Andean-type orogeny that developed on the Rodinia supercontinent's northwestern margin. We also favor the position of Karakoram within the Cimmerian belt along with other East Asian continental blocks.

Carbonatitic magmas can be way more hydrous than ever estimated: Evidence from a rare occurrence of manasseite, ferrohogbomite, and amesite within magnetite from Sung Valley carbonatites

Shubham choudhary[*], Shruti Rana, Koushik Sen
Wadia Institute of Himalayan Geology, Dehradun-248001
[*]Presenting author: shubham.geologist55@gmail.com

Carbonatites are rare igneous rocks that are formed predominantly of carbonates. The mineral, as well as fluid inclusions, play a vital role in understanding the nature and evolution of carbonatitic magma. The present work focuses on the study of aqueous-carbonic bi-phase, aqueous saline bi-phase, and poly-phase fluid inclusions hosted by calcite and mineral inclusions in accessory magnetite in carbonatites from the Sung Valley NE India. These carbonatites are hosted by the Kerguelen mantle plume-related Ultramafic-Alkaline-Carbonatite Complex (UACC). Raman spectroscopy and microthermometry of the primary fluid inclusions in calcite reveal that the bi-phase and poly-phase fluid inclusions are chiefly composed of water. The mineral inclusions in magnetite were identified to be manasseite, ferrohogbomite, and amesite. These extremely rare hydrous mineral inclusions in the magnetite are not a result of hydrothermal alteration but primary magmatic characteristics of the crystallizing carbonatitic magma. This work suggests that the studied carbonatites are formed from ultra-hydrous carbonatitic magma, indicating that the water content in carbonatitic magma could be way higher than ever estimated.

Microtectonic evolution of the non-foliated Karakoram batholith, India: insights into syn-tectonic cooling and exhumation

Subham Bose[1*], Vikas Adlakha[1], Shailendra Pundir[1]
Wadia Institute of Himalayan Geology, Dehradun
[*]Presenting author: subham@wihg.res.in

Granitic magmatism is considered an essential mechanism for crustal recycling in the rapidly accreted crust. Especially along plate margins, the emplacement and ascent of granitic magma, together with the exhumation of granites hold a vital clue to the Earth's thermomechanical workings. The present study investigates the progressive evolution of the microtectonic regimes for the granitic rocks that constitute the Karakoram batholith (KB), north of the Shyok Suture Zone (SSZ), north-western Trans-Himalaya.

Textural and thermobarometric studies suggest that crystallization of the KB initiated at ~ 700–800 °C and ~ 4.2–7.5 kb. Microstructures of feldspar and quartz pertaining to temperatures > 700 °C together with the late crystallization of muscovite evince submagmatic flow. Muscovite-rich domains typically exhibit microstructures indicating temperatures < 650 °C and ~ 4.2–4.6 kb. Aligned mica, along with penetrative grain boundary migration (GBM) and moderately strong crystallographic preferred orientation in quartz, represents the highest deformation intensity that probably prevailed during the initial stages of collision along the SSZ. On the other hand, randomly oriented muscovites that crystallized following peak deformation intensity occur exclusively in micro-domains with polygonal quartz grains. Phase transformation of micas to chlorite occurred at ~ 280–400 °C, during which deformation progressed by minor GBM at relatively slower rates. Submagmatic flow followed by subsolidus solid-state ductile deformation at varying thermal regimes implies the exhumation of the granites from a depth of ~ 19–28 to ~ 5.5–9.5 km. Temperature estimates, coupled with geochronological data, yield average cooling rates of ~ 11–18 °C/Ma from ~ 110–85 Ma that gradually decreased to ~ 1.8 °C/Ma after ~ 85 Ma. Based on the exhumation history inferred from this study, it is also suggested that during the later stage of penetrative ductile shearing along the nearby Karakoram Fault Zone, the presently exposed part of the KB was situated above the brittle-ductile transition zone.

Understanding the Himalayan sediment flux into the Bengal Basin through Subsidence Analysis on 3D seismic data of WB-ONN-2005/4 Block, West Bengal

Sunil Kumar Behera[1,2*], Kalachand Sain[1,2]
[1]Wadia Institute of Himalayan Geology, 33 GMS Road, Dehradun – 248001
[2]Academy of Scientific and Innovation Research (AcSIR), Ghaziabad – 201002
[*]Presenting author: sunilbehera@wihg.ac.in

Bengal as a polycyclic basin is constrained by tectonic boundaries, which has changed its basin configuration from Rift-controlled to Deltaic to present Passive margin setting from Upper Cretaceous to Upper Neogene time. It has also been reported that the shifting of depocentre and heterogeneity in sediment flux has also reshaped the basin configuration through time. Here we demonstrated the subsidence analysis of the Bengal basin by the computation of sediment accumulation and decompaction from 3D seismic data of WB-ONN-2005/4 Block, West Bengal. It is explained that the post-collisional sediment thickness variability in this basin is due to the differential rate of erosion in the Himalayas. It is also explained that the sediment flux is controlled by the Himalayan exhumation and climatic conditions. It is elucidated that the differential sediment compaction rate has resulted in a decrease in layer thickness which is reflected in the non-linear sediment compaction trend. Moreover, the subsurface lithofacies (sandstone & carbonate) respond differently to the thick overburden in the block-WB-ONN-2005/4.

Petrogenesis of abyssal peridotites from the Central Indian Ridge: Insights on mantle refertilization in response to a geodynamic transition

A. Hazra[1,2*], A. Saha[1], K. Mahender[2]
[1]CSIR-National Institute of Oceanography, Dona Paula-403004, Goa
[2]School of Earth, Ocean and Atmospheric Sciences, Goa University, Taleigão Plateau-403206, Goa
[*]Presenting author: arghya.hazra2016@gmail.com

The collective phenomena of enriched asthenospheric melt percolation and pervasive melt-rock interaction at mid-oceanic ridge-rift systems are the principal components of mantle refertilization and compositional heterogeneity. This study presents petrology, mineral chemistry, bulk rock major, trace, and PGE data for the abyssal mantle peridotites exposed along the Vema and Vityaz fracture zones of the northern portion (between 5 and 10°S) of the Central Indian Ridge (CIR) located in the Indian Ocean to address their petrogenetic evolution, geodynamic implications, and factors contributing to the refertilization of the Indian Ocean ridge mantle. Primary mineralogy being olivine, pyroxene and opaques, is, however, overprinted by the hydrothermal alterations and extensive serpentinization of these rocks. Single pyroxene thermometry indicates an equilibration temperature of ~1000-1400°C, thereby indicating crystallization of the studied rocks at a high-temperature regime, probably at the crust-mantle transition zone. Cr-spinel (Cr#: 0.37-0.59) chemistry classifies these rocks as Alpine-type peridotites and corroborates a transitional depleted MORB type to enriched, SSZ-related arc-type magma composition. REE patterns exhibit a U-shaped profile marked by pronounced LREE and HREE enrichment over MREE and overall HFSE geochemistry further attests to an enriched intra-oceanic fore-arc mantle affinity. Higher values of Zr/Hf (avg: 45.16) and Zr/Sm (avg: 73.78) in addition to lower Nb/Ta (avg: 4.75) with respect to primitive mantle compositions (Zr/Hf: 36.25, Zr/Sm: 25.23, and Nb/Ta: 17.39) conform to a metasomatized, enriched mantle signature. Lower Nb/U (avg: 0.19) values with higher Ba/Th (avg: 213.16) and Ba/Nb (avg: 316.27), compared to OIB (Nb/U: 47.06, Ba/Th: 87.5, and Ba/Nb: 7.29) and N-MORB (Nb/U: 49.57, Ba/Th: 52.5, and Ba/Nb: 2.7), attest to contributions from subduction-derived fluids. The distinct boninitic signature of these rocks reflected by LREE>MREE<HREE and PGE compositions substantiates refertilization of the CIR mantle harzburgites by boninitic melt percolation concomitant to initiation of oceanic subduction. The mineral chemistry, trace and PGE signatures of the CIR peridotites envisage (i) replenishment of depleted sub-ridge upper mantle by impregnation of subduction-derived bonintic melts, (ii) tectonic transition from mid-oceanic ridge rift to embryonic supra-subduction zone, and (iii) initiation of spontaneous intra-oceanic subduction along sub-marine transform faults and fractures zones of slow spreading CIR owing to their weakness and mechanical instability.

Planetary investigations using VNIR and MIR spectroscopy: Applications to the understanding of evolution of rocky planetary bodies

Himela Moitra
Department of Geology & Geophysics, Indian Institute of Technology-Kharagpur, Kharagpur
Presenting author: himelamoitra@gmail.com

Crater-forming impacts on the Moon excavated materials from great crustal depths to the surface. Therefore, a detailed study of the mineralogical distribution in a spatial context would help us understand the composition of the lunar crust and mantle. The detection of chrome-spinel on the lunar surface provided evidence for multiple magmatic events in the lunar interior, as magma mixing is required for the precipitation of chromitite layers from basaltic magmas. The excavation of these chromitite layers through crater-forming impacts enabled their detection by remote-sensing instruments. For such detections, spectral characterization

of the target minerals is essential. Hence, such characterization was carried out for the chromitite layers of the Nidar ophiolite complex in Ladakh, India, in the VNIR (visible to near-infrared) and MIR (Mid-Infrared) ranges. This characterization reestablished the various trends derived by previous workers between the composition and absorption positions of different spinels. Class-1 type lunar Floor Fractured Craters (FFCs) provide excellent opportunities to study the mineralogical heterogeneity of the lunar crust as they exhibit diverse mafic mineralogies. In our study of crater Atlas, a class-1 FFC, we employed spectral characterization of VNIR data from the Moon Mineralogy Mapper instrument onboard the Chandrayaan-1 mission. Using this high-resolution hyperspectral data, we identified and delineated the distribution of mafic minerals such as olivine, low-Ca pyroxene, High-Ca pyroxene, and spinel on this crater. The presence of these mafic minerals along with plagioclase in the central peak complex of this FFC indicates that there was an Mg-rich pluton emplaced at mid-to-lower crustal depths beneath this region, which was excavated by the Atlas crater forming impact. Following the impact, another magmatic intrusion warped the floor of this crater and generated the fractures, thus making it an FFC. The presence of pyroclastic deposits and Ti-rich mare patches on the floor suggests that volcanism from a Ti-rich magma source was also active in this region. Interestingly, the occurrence of substantial endogenic water associated with mafic nominally anhydrous minerals (NAMs) indicates a hydrous nature of the pluton magma. Hence, it can be implied that the mantle from which the pluton originated was also hydrated. The occurrence of water in the interiors of rocky planetary bodies is also implied by the hydrous alteration found on the carbonaceous chondrites rich in forsteritic olivine, which are considered to bear primordial compositions. Spectral characterization of such a CM2 carbonaceous chondrite, the Mukundpura meteorite, was done in both the VNIR and MIR ranges. The MIR spectra revealed high phyllosilicate content and widespread alteration of olivine to serpentine. However, the aqueous alteration is not pervasive and it is also suggested that most of the alteration took place in the asteroidal parent body. The presence of water in the interior of the Moon and asteroid bodies, as suggested by VNIR and MIR spectroscopy, implies that the interior of the rocky planets in this vicinity would be hydrated to some extent and that the deep interior of the Earth should not be very different.

Glacial Dynamics and Hazards

Mapping of Supraglacial Lakes using Object Based Image Analysis to assess the occurrence of Glacial Lake Outburst Flood over Shishper Glacier

Ayantika Biswas*, Subhranil Mustafi, Ayoti Banerjee, Sarbani Palit
Indian Statistical Institute, Kolkata
**Presenting author: ayantika99biswas@gmail.com*

Due to temperature changes, most Himalayan glaciers have shown resulting an increasing number of glaciers and also an increase in the size of the lakes, so the glacier lake outburst flood occurs (GLOF) occurs. These lakes typically grow from small supraglacial lakes (SGLs). The objective results in mapping the supraglacial lakes (SGLs) using a new approach named Object-Based Image Analysis (OBIA). OBIA is an approach that groups small pixels to form an object. The extraction is majorly based on simple to apply pixel-based classification methods, which results in high misclassification thereby increasing the task of manual post-processing. A new index has also been proposed for the classification of SGLs. As a case study, the SGLs of Shishper glacier of Gilgit-Baltistan have been mapped from the high spatial resolution satellite data using the proposed OBIA approach. The result as proposed from the use of OBIA has been compared to the traditional pixel-based approach with Normalized Difference Water Index, wherein the accuracy of the OBIA approach for mapping SGLs has been found to be increasing than the traditional pixel-based approach. The vulnerability map of the area based on the topographic factors of slope, aspect, and elevation is instigating in the resultant disaster from Glacial Lake Outburst Flood. The elevation is playing a major role in the adversity of the meteorological parameters such as rainfall over the lakes present in the respective area. As the disaster dates have been back-tracked, the effect of such meteorological and topographic factors has resulted in a superimposed effect affecting the occurrence of such disasters. Hence, mapping of such lakes using the proposed object-based image analysis approach and the add-on factors such as prolonged rainfall based on the particular elevation over the particular area, found from the digital elevation model has resulted to be promising towards the occurrence of such events periodically every year, mostly during the pre-monsoon times from March to June.

Assessing the temporal effect of Black Carbon Surface Mass Concentration over Shishper Glacier through Semi-Variance Analysis

Ayoti Banerjee*, Subhranil Mustafi, Sarbani Palit
Indian Statistical Institute, Kolkata
**Presenting author: ayoti.banerjee@gmail.com*

Light-Absorbing Impurities such as Mineral Dust or Black Carbon (BC) trigger a positive gradient in the regime of snow melt mainly due to the incomplete combustion of fossil fuels, forest fires, or other anthropogenic factors. It causes the decrease of snow surface albedo and hence in poorer reflectance of light, eventually resulting in increased melting of snow. The average black carbon concentration over the respective region of interest, i.e., Shishper Glacier (36° 15' N to 36° 30' N and 74° 28'E to 74° 39'E) in the Hassanabad Village of Hunza Valley is 5.79E-09 Kg/m^3. Hassanabad basin is famous for its surge and GLOF history. Many buildings and houses of nearby villages, key infrastructures such as 1200 KW hydro-electric powerhouse, and the China Pakistan Economic Corridor (CPEC) route are highly susceptible to these floods. The region has freezing winters and hot summers and the last five years' data shows annual occurrences of at least one GLOF event in and around Shishper glacier, during April to June tenure. It has been observed that the snow coverage, snow albedo and B.C variation over the AOI is cyclic in nature, reaching a high from November to March. But in 2018 we noticed a fall in the snow albedo values w.r.t 2017 and 2019, even though the snow coverage values remained similar to these previous years. On the contrary, there was a sudden high in Black Carbon Surface mass concentration values at the same juncture, which is an indirect reason for the lowering of snow albedo values. Upon spatial variogram modeling, it has been observed that the semi-

variance of B.C. Surface mass concentration values keeps increasing over large lag distances (although in-situ values of B.C over Shishper are low), indicating the strong influence of highly concentrated black carbon areas adjacent to the Shishper Glacier. Upon temporal variogram modeling, it has been observed that till the 4th month, the semi-variance increases, post which it reaches a sill and starts decreasing from the 7th month. It thus indicates that a high-value cycle starting during November 2018 and ending during March 2019 will have an influence on in-situ B.C values till March 2019 to July 2019 respectively. Thus, there is both a spatial and a temporal dependency of B.C values in and around Shishper and it does affect other snow properties and can have a latent impact of enhanced snow melting reported during the respective GLOF events.

Differential surface melting of a debris-covered glacier and its geomorphological control - a case study from Batal Glacier, western Himalaya

Bhanu Pratap[1*], Parmanand Sharma[1], Lavkush K. Patel[1], Ajit T. Singh[1,2], Sunil Oulkar[1,2], Meloth Thamban[1]

[1]National Centre for Polar and Ocean Research (NCPOR), Ministry of Earth Sciences (MoES), Vasco-Da-Gama- 403804, Goa

[2]School of Earth, Ocean and Atmosphere Sciences, Goa University, Taleigao Plateau

[*]Presenting author: bhanu@ncpor.res.in

The variable response of Himalayan glaciers is often linked with the varied rate of melting under the supraglacial debris cover of the glacier. We conducted debris thickness estimation at 110 locations and in-situ mass balance measurements over Batal Glacier from the semi-arid region of western Himalaya during 2013-2019 to establish a relationship between the ice ablation rates and debris thicknesses. Overall, the annual ablation for the debris-covered area varied between 1.3 and 1.8 m w.e. a-1, with a mean annual ablation of 1.6 m w.e. a^{-1} during 2013-2019. While the point ablation rate does not exceed 3 m w.e. a-1 at any specific area of the glacier throughout the observation period. The melt rate was attenuated up to 80% under the debris thickness ranging from 2 to 72 cm. The formation and thickness of the debris increased linearly down the glacier, sparse in the centreline and higher at the margins due to the contribution from avalanches. Supraglacial water channels and ice cliffs along the centreline were observed as persistent contributors to the ablation rate. However, a higher mean surface slope (12°) of the ablation zone constraints the formation of supraglacial ponds. The area with patchy debris cover has an increased melt rate compared to the completely debris-covered area. Spatially distributed, but reduced ice ablation under varying debris thickness underlines the influence of debris thickness on the underneath ice melt rate for Himalayan glaciers.

The Assessment of Glacial Lake Outburst Flood Hazard and Risk Over the Hindu Kush Himalayan Zone

Richa Singh[*], Rajeev Bhatla

Geophysics Department, Institute of Science, Banaras Hindu University

[*]Presenting author: richa.envt@bhu.ac.in

Increased human interferences on high mountain ranges adversely impacted the glacial dynamics which accelerate changes in climate patterns and induces hazards. Glacier Hazards is basically categorized into glacier surges, glacier lake outburst floods (GLOF), and glacier flood. Major hydroelectric power generation in India is dependent on GLOF. However, sometimes due to a knowledge gap about glacial dynamics and less availability disaster prediction in those pristine condition causes huge damage. The Indian Himalayas has numerous glacier lakes which witnessed many catastrophic disasters which lead to socioeconomic crises along with damage to lives and the environment. These disasters can be triggered by the sudden discharge of a large amount of inflow or heavy mass entering into the lake during avalanches, rockfall, etc, In this study,

remote sensing techniques is used in glacier lake disaster evaluation using channel indexing and mass change detection of the Hindu Kush Himalaya. This study will be helpful in analyzing the potential hazard zone of the Hindu Kush Himalayan zone and getting an idea about disaster severity.

District-level vulnerability assessment of Indian Himalayan Region for Compound Wet Hazards

Kavya M, Akshay Singhal, Muhammed Jaseem, Sanjeev Kumar Jha*
Indian Institute of Science Education and Research Bhopal, MP
**Presenting author: sanjeevj@iiseeb.ac.in*

The occurrence of extreme rainfall events has increased over the Indian Himalayan Region (IHR) over the past few decades. The Himalayan region is more vulnerable to the catastrophic effects of the hazards because of its complex geology, topography, unpredictable weather patterns, and rising anthropogenic activities. The combined effect of more than one hazard in a common space and time increases the severity of the devastating impact on population. The decision-making time for damage recovery and mitigation is very less for these hazards. It is important to determine the most vulnerable region and adopt different adaptive measures for timely disaster mitigation. In this study, we adopted an indicator-based vulnerability assessment method for 87 districts of the Indian Himalayan Region across 11 states. We consider three types of hazards such as avalanches, landslides, and floods which are induced by a common predecessor i.e, Extreme rainfall and together considered Compound Wet Hazards (CWH). The vulnerability of each district is determined based on available weather, local socio-economic data as well as natural/topographical characteristics of the region. This vulnerability assessment approach has three components, i.e., Exposure, Sensitivity, and Adaptive capacity. The indicators of these three components are allotted and assigned appropriate weights. A Compound Hazard Vulnerability Index (CHVI) for different possible combinations of hazards is calculated for each district. The districts are classified into low, moderate, and high vulnerability classes based on the CHVI and a Compound Hazard Adaptation Model (CHAM)is proposed for each class. The classification based on vulnerability to various combinations of hazards can help in reducing the potential risks. The CHAM can give direction to develop more promising strategies for disaster management in the area.

Extraction of Supraglacial Lakes using Object Based Image Analysis to assess the occurrence of Glacial Lake Outburst Flood: A Case Study over Chho Lhamo

Ayantika Biswas*, Subhranil Mustafi, Ayoti Banerjee, Sarbani Palit
Indian Statistical Institute, Kolkata
**Presenting author: ayantika99biswas@gmail.com*

As the global mean temperature increased over the past few years, the Himalayan glaciers have started retreating and the release of such melting feed the moraine-dammed lakes present on their way downwards. Several lakes have formed and the ones that are already present have increased in its size due to excessive accumulation of meltwater. As for the case of Lake Chho Lhamo, a glacial lake located on the border of the Sikkim and Tibetan Autonomous region, the size gets increased by a proportion of about 1.5 times since 1965. The increasing vulnerability of such a lake has been calculated based on the entropy method using the topographic factors of Slope, Elevation, and Aspect wherein, elevation received the highest weightage. The lakes have been extracted based on the features using NDWI from the high-resolution satellite data. Since the data of the lakes are being misclassified with shadow of the region, they had to be segregated out manually to get the proper demarcation of the glacial lakes within the region of interest. A new method, termed as Normalized Difference Supra Glacial Lake Index from the literature, "Extraction of Glacial Lakes in Gangotri Glacier Using Object-Based Image Analysis" by Kavita Mitkari has been used and showed an

accuracy greater than 90% in our region of interest. The glacial lakes that typically grow from small patches of water over the icecaps in glacial mountains are known as supraglacial lakes. Since this is the seeding point for the growth of the glacial lakes and eventually the vulnerability, it is important to map the supraglacial lake (SGLs). The traditional pixel-based method is used for segmenting and classifying the SGLS but to overcome the misclassification result that occurs during classification, OBIA is put into action for such a task. It is an approach that groups small pixels to form an object. The results of the proposed OBIA approach have been compared to the traditional pixel-based approach with Normalized Difference Water Index (NDWI), where the accuracy of the proposed OBIA approach has been found to be increasing than the traditional pixel-based approach. The elevation, after receiving the highest weightage has been found to be playing a major role in the adversity of the meteorological parameters such as rainfall over the lakes present in the respective area. As the disaster dates have been back-tracked, the effect of such meteorological and topographic factors has resulted in a superimposed effect affecting the occurrence of such disasters. Hence, mapping of such lakes using the proposed object-based image analysis approach and the add-on factors such as prolonged rainfall based on the particular elevation over the particular area has resulted in the occurrence of such events periodically every year, mostly during the pre-monsoon times from March to June. The work showed the influence of such meteorological and topographic factors leading to the increase in the vulnerability of the region due to the overaccumulation of meltwater in the defined capacity of the glacial lakes.

Past Glacial movements and its relation to surface and subsurface geology case study from Schirmacher Oasis, East Antarctica

Yogesh Ray[1*], Koushick Sen[1], Subhajit Sen[2], Mirza Javed Beg[1]
[1]National Centre for Polar and Ocean Research,
(Ministry of Earth Sciences, Govt. of India), Headland Sada, Vasco Da Gama-403804, Goa
[2]School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar,
Argul-752050, Odisha
[*]Presenting Author: yogesh@ncpor.res.in, yogeshray@gmail.com

Schirmacher oasis is an ice-free area situated inland approx. 100 km from the coast of Lazarev sea in the central Dronning Maud Land (cDML) East Antarctica. Throughout the oasis glacial landforms and deposits are present. Broadly the oasis is traversed by six major glacial valleys, the valley floor is occupied with meltwater lakes. The bedrock of the adjacent valley walls has well-preserved striations, groves, and glacial polish which are testimony of the flow of the glaciers in this region. The striations and associated structures are ubiquitous throughout the oasis, and systematic collection and analysis of the data can narrate the past glacial movements experienced by the region. The orientation of 276 glacial striations from 20 locations was analyzed, and it was deduced that the resultant direction for the flow of glaciers in past was N15°E. The paleo direction of flow is in agreement with the present movement of the continental ice sheet as ascertained from the Global Positioning System. Interestingly the orientation data is also congruent with the earlier reported subsurface geo-electrical structural trend inferred from the magnetotelluric (MT) study.

Spatial-temporal changes of glaciers in the past three decades, Doda River basin, Zanskar Himalaya, India

Ajay Singh Rana[1,2*], Pankaj Kunmar[1,3], Manish Mehta[1], Vinit Kumar[1]
[1]Wadia Institute of Himalayan Geology, Dehradun-248001
[2]Academy of Scientific and Innovative Research, Ghaziabad-201002
[3]Hemvati Nandan Bahuguna Garhwal University Srinagar-246174, Uttarakhand
[*]Presenting author: ajayrana@wihg.res.in

This study describes surface morphological and dynamical changes of the glaciers in the Doda River basin,

Ladakh Himalaya, India, during the last three decades (1993 to 2021). We used moderate to high-resolution multi-satellite earth observation data (Landsat-TM/ETM+/OLI, Sentinel -2), Google Earth images, SRTM, and Terra-ASTER DEMs to estimate the changes in the glacier area, surface ice velocity (SIV), and geodetic mass balance. This study suggests non-uniform behaviors of the glaciers in the basin. Overall glaciers lost 5.23% of the area between 1993 and 2021. Further, the SIV was estimated using a feature tracking algorithm in Cosi-Corr on the Landsat time-series data. The velocity depends on multiple factors e.g., the slope of the glacier, debris cover, glacier area, steep gradient, crevasses, and morphology of the glacier. The SIV was estimated to be 22.73 ±2.3 m/yr in 1999-2000 and 17.13 ± 1.6 m/yr in 2020-21 which is 24.63% lower than earlier. Moreover, the results for the geodetic mass balance show a negative trend of -0.46 m w.e a^{-1} for the glaciers between 2000 and 2017. The progressive area change and continuous negative mass balance reveal that the glaciers in the Doda Basin are receiving less solid precipitation to compensate for the ongoing glacier shrinkage (area and ice volume).

Forecasting of Suspended Sediment Concentration in the Pindari - Kafni glacier valley in Central Himalayan region considering the impact of precipitation: Using Soft Computing Approach

Pankaj Chauhan[1*], M. E. Akıner[2], Kalachand Sain[1], Amit Kumar[1]
[1]*Wadia Institute of Himalayan Geology, Dehradun, 248001, India*
[2]*Akdeniz University, Vocational School of Technical Sciences, Department of Environmental Protection Technology, Antalya, Turkey*
[*]*Presenting author: pchauhan1008@gmail.com*

In-situ glacier discharge and sediment observations are uncommon in the Himalayan region because of the complex terrain and bad weather conditions. This research is the first study of the glaciers investigated to collect and forecast *in-situ* glacier melt SSC (suspended sediment concentration) data from streams associated with the Pindari and Kafni glaciers in the central Himalayan region valley (Pindar basin) during three consecutive years (2017-2019). Stream discharge and sedimentation play a crucial role in hydroelectric power projects located in the Himalayan Mountain regions. The problem is severe in the flood season due to excessive sediment concentration. In the Pindari and Kafni glacier stream dynamics, discharge, precipitation, and temperature were identified as major regulating components of variations in sediment concentration. Multiple linear regression (MLR) and artificial neural network (ANN) models were used. A bivariate correlation test was carried out, with a significant p-value of less than 0.05. The analytical measurement used daily values calculated between 2017 and 2018. MLR analysis revealed that the precipitation and SSC are not proportional since precipitation has a negative Beta coefficient. The normalized importance of precipitation concerning discharge was determined to range between 11.54 and 76.1 percent. Statistical indices evaluated the performance of the used models, specifically residual sum of squares error (RSS), relative error (RE), and mean squared error (MSE). When predicting future SSCs for Pindari and Kafni streams, the ANN model outperforms the MLR model. The results clearly show that extreme events such as floodings and landslides cannot be predictable considering the research area based on the collected *in-situ* hydro-meteorological data. In light of the results, it is thought that there are other factors, such as solar radiation, that affect discharge values and thus sediment transport. Sustained multi-year observations using machine learning applications could improve regional water resources assessment and management and regulate the policy to develop multi-purpose hydroelectric projects in the region.

Surface meteorological characteristics and climatology in Chandra basin, western Himalaya

Sunil N. Oulkar[1,2*], Parmanand Sharma[1], Bhanu Pratap[1], Lavkush Patel[1], Meloth Thamban[1]
[1]*National Centre for Polar and Ocean Research, Ministry of Earth Sciences-403804, Goa*
[2]*School of Earth, Ocean and Atmosphere Sciences, Goa University, Taleigao Plateau-403206, Goa*
[*]*Presenting author: sunil@ncpor.res.in*

A knowledge of meteorological variables over the glacierized region of the Himalaya is essential to understand the variety of glaciological processes and their response toward climatic variation. Himalayan regions, where substantial and long-term meteorological data sets are sparse, an attempt has been made by establishing a network of automatic weather stations (6) at the basin level. The meteorological data collected are air temperature, surface temperature, relative humidity, wind speed and direction, and incoming and outgoing shortwave and longwave radiation at six meteorological stations. These meteorological variables are stored in the Campbell CR1000 datalogger at 10-minute, 30-minute, and daily intervals. The observed air temperature showed during the winter is below 0°C at all AWS, whereas, in the summer, it is always above the melting point, with the maximum occurring in late August and the minimum occurring in late January. During winter, while snow is present on the surface, the temperature variations between the air and surface are more significant, with the surface temperature consistently being lower. Relative humidity varies from 4% to 92%, with mean values of 66% (± 6%). The daily mean wind speed ranges between 0.7 and 10.2 m s^{-1} with a mean speed of 3.1 m s^{-1} (± 0.95 m s^{-1}). The shortwave radiation is higher during summer, whereas winters are associated with cold, dry, and windy conditions due to low sun elevation and strong westerlies. Longwave radiation is primarily affected by changes in air temperature and relative humidity as a function of elevation. The observations confirm the region is under semi-arid climatic condition with a minor amount of annual precipitation occurring during the Indian Summer Monsoon.

Variation of meltwater discharge between 2017 and 2022 of Parkachik Glacier in Suru River Valley, Western Himalaya, Ladakh, India

Pankaj Kunmar[1,2*], Ajay Rana[1], Vinit Kumar[1], Manish Mehta[1]
[1]*Wadia Institute of Himalayan Geology, Dehradun-248001*
[2]*Hemvati Nandan Bahuguna Garhwal University, Srinagar-246174, Uttarakhand*
[*]*Presenting author: Pankajyadav@wihg.res.in*

A gauging site has been established in September 2017 near the snout of Parkachik Glacier in the Suru River Basin, western Himalaya, Ladakh for observation of meltwater discharge. The conventional velocity-area method and Float method were used to calculate the meltwater discharge of the Parkachik glacier during the hydrological years between 2017 and 2022. The results show that the variations in average daily discharge values from 2.73 m^3/s (2022, May-sept), 2.77 m^3/s (2021, June-oct), 5.66 m^3/s (2019, May-Sept), 4.79 m^3/s (2018, Sept-Nov) & 4.73 m^3/s (2017, Sept-Oct). This data indicates that higher discharge was recorded in 2019 as compared to 2021 & 2022 in the ablation period (June-August). The lower discharge in 2021 are in response to lower temperature & high snowfall during the winter reduced glacier melt discharge. Overall, the Parkachik glacier released 1.42×10^7 m^3 (for 35 days), 1.08×10^9 m^3 (for 65 days), 5.17×10^9 m^3 (for 100 days), 2.3×10^9 m^3 (for 110 days) and 3.7×10^9 m^3 (114 days) volume of water in 2017, 2018, 2019, 2021 & 2022 respectively.

Landslides and their Risk Reduction

Landslides analysis of lower Himalayas

Kushal M
IIEST Shibpur

The Himalayan region is the source of many snow fed rivers which flow at the surface as well as sub-surface level, but when this flow is disturbed due to catchment fragmentation by anthropogenic reasons like the construction of houses, roads, and other structures, leads to localized blockage to the flows and loss in slope stability; most often the sub-surface flow at this hilly terrain is neglected. So, proper monitoring of the underground stream network is very important before any construction planning and execution. This paper introduces an index- Catchment fragmentation index adopting which can help reduce the intensity of floods and landslides (mainly rainfall-induced).

Slope instabilities due to construction of new roads around sangaldan area, Ramban District, Jammu & Kashmir

Pratap Chandra Dhang
Deputy General Manager, Ircon International Limited, Siliguri
Presenting author: pratap09.isi@gmail.com

Nowadays Ramban district, Jammu and Kashmir is worst affected by slope instabilities. Since 2012 infrastructural development in Ramban, J&K is in full swing, especially the construction of roadways to remote areas. A major rail link project is undergoing in the same region, and for this project, many approach roads have been built, which are also connecting the remote villages. People got benefitted from these no doubt, but the main problem faced during and after construction (in the initial few years) of these roads was the issue of landslides. The areas in Sangaldan (Dist. Ramban), like Harog-Kohli, Narmullah-Barala, Dharam, and Mehgdhar-Sumbar, have been selected for the study of the slope instabilities. The tenure of this present study of slope instabilities in this particular region is from 2012 to 2017 with the objective of the study mainly to demonstrate the cause of such instabilities. The slope instabilities arose due to an imbalance between the (1) tangential force causing shear stress parallel to the slope and (2) force resisting gravity action or shear strength of the material on the slope, which includes the frictional resistance and cohesion. The imbalance usually occurs due to factors involving geological, geomorphological, hydrometeorology, seismic and anthropogenic. Under such circumstances, Ramban region is situated in the mighty Pir Panjal Range where the topography of the region is mainly controlled by geological structures formed due to the tectonic stresses. The study area lies on the valley created by the Chenab River, Chinji Nala, and Sumbar Nala which run through the weak lineaments created by Murree Thrust/Fault and Panjal Thrust (or MCT). Sandstone and mudstone of the Murree Group (Pliocene-Miocene) occur on the footwall of the Murree Thrust. Whereas the low to medium-grade metasedimentary succession of the Autochthonous Fold Belt (AFB) (Proeterozoic-Permian) occurs on the hanging wall of the Murree Thrust. The unconsolidated overburden material belongs to recent talus and scree deposits (thickness ranges from 4 to >50 m). Recent seismicity in the Himalaya is restricted to two distinct zones, one is between MBT/MFT and MCT. The region received 120 mm of average precipitation (rainfall and snowfall) from 2012 till the end of 2017, in two parts yearly. And the major anthropogenic activity in the region was the cutting of slopes for the construction of the road. On account of the above-mentioned conditions slope instabilities have been classified into two groups: (i) Instability due to natural factors (NF), and (ii) Instability due to anthropogenic influence on natural factors (ANF). It has been observed that instability NF is still undergoing and have a larger extent with a longer pause period, whereas instability ANF stabilizes after a few frequent landslides and some slope protection measures with modified drainage systems in that particular area. Therefore, the slope instability in the region has been considered as a cause of natural landform evolution which is exaggerated due to some anthropogenic activities.

Hardiya Nala Landslide: A Case Study of Structural Controlled Landslide, Inner Kumaun Lesser Himalaya, Uttarakhand, India

Priya Joshi[1*], Mohit Kumar Puniya[2], Pitamber Dutt Pant[3], Rajeev Upadhyay[1]
[1]Department of Geology, Kumaun University Nainital-263002, Uttarakhand
[2]National Geotechnical Facility, Survey of India, Dehradun-248001, Uttarakhand
[3]Uttarakhand Open University Haldwani-263139, Uttarakhand
[*]Presenting author: joshi.2priya@gmail.com

Landslide is a common phenomenon in mountainous regions, exclusively in engineering slopes along highways and roadcuts. The study area falls in Kumaun Lesser Himalaya near Thal township. Structural mapping along with rock mass classification systems are used to delineate the weak and vulnerable zones for rock failure, known as structural damage zone. In this study, the Hardiya Nala landslide has been mapped, and outcrop scale structural damage zones are marked. Different classification systems, Rock Mass Rating (RMR), Slope Mass Rating (SMR), Q-System, and Factor of Safety (FOS), have been applied to classify rocks. Ductile and Brittle-Ductile damage zones are marked during the field mapping. The rocks in these Geological Structural Damage Zone (GSDZ) fall in class III to class V in RMR and SMR classification systems; also, kinematics analysis correlates with the FOS. The Q value ranges from 0.04 to 3.27. This study presents that the various classification system gives similar results; also, it can be correlated with damage zones which is the main factor for sliding activity. Thus, geological and geotechnical investigations can be used for better evaluation of landslides and for providing stability measures.

Combined Seismic Early Warning System (CSEWS) for Geo-Hazards in Himalaya

N. Purnachandra Rao[*], R. Rajesh, Himangshu Paul
CSIR- National Geophysical Research Institute, Uppal Road, Hyderabad – 500007
[*]Presenting Author: pcrao.ngri@gmail.com

The Himalayan region is host to a wide range of geohazards like rockslides, landslides, glacial avalanches, and associated floods in addition to earthquakes. Although very challenging, it is the need of the hour to develop reliable early warning systems using state-of-the-art technological developments. Recent advances demonstrate the utility of seismic monitoring in the detection of all kinds of geohazards and the possibility of a Combined Seismic Early Warning System (CSEWS) for geo-hazard monitoring using the dense deployment of seismic stations. Concerning the 7 February 2021 catastrophic flood in the Uttarakhand region of Himalaya, it was recently demonstrated that from the Rontigad region where a cascade of rockslide, debris, and flood events initiated, a lead time of nearly 30 min was possible for warning in the downstream area whereas about it was about 10 minutes for the Tapovan hydropower plant where a large number of people were killed. However, it is important to note that the network density, data communication speed, computation, and dissemination time are crucial parameters for a successful real-time warning system. While the current seismic network in Uttarakhand was very useful to study the feasibility of early warning, a denser dedicated network with nearly 5 to 10 km interstation separation is under deployment towards the development of a combined early warning system that would address all the geohazards. Considering the fact that the Himalayan region has a high level of hazard from various events, including the possibility of a great earthquake of 8 magnitudes, it is even more pertinent to establish such multi-purpose networks to minimize the loss of lives and property over the years to come.

Landslide Location Analysis using Seismic Multi-station polarization back-projection

R. Rajesh, N. Purnachandra Rao, Himangshu Paul, V. Venkatesh, A.N.S. Sarma, R. Vijaya Raghavan, G. Suresh, Satish Saha
CSIR-National Geophysical Research Institute, Hyderabad
Presenting author: rekapalli@gmail.com

We present here a new approach for locating the landslides using multi-station seismic data. Although the seismic waveforms of landslides and debris flow events exist, the conventional seismic methods based on phase picking have always failed due to the lack of clarity in the onset times. The methods like seismic spatial migration and amplitude source location have been used for the successful detection of landslides and tracking of associated mass flow events. However, the accuracy of these methods relies on the apriori knowledge about the average seismic wave velocity and attenuation factors of the study region. In this scenario, we propose the polarization back-azimuth projection method, which is found to be very useful for quick computation of the precise location of the seismic source from back azimuths computed at multiple stations in a local seismic network. This method has the great advantage that it is independent of regional information on the crustal velocity, attenuation factor, etc. In this study, we compute the location of the devasting Uttarakhand rockslide that occurred on 07 February 2021 in the Rontigad region near the Rishiganga-Dhauliganga river valley in the Chamoli district of Uttarakhand state in the Himalayan region of India using the proposed Polarisation back azimuth method. We compare the results of the proposed method with the results of amplitude source location and spatial migration techniques using seismic data from 14 broadband stations of the CSIR-NGRI, Uttarakhand seismic network. The results suggest that the location estimated using the proposed method is very accurate and matches closely with the location identified in the satellite imagery. The time required for the Polarisation back azimuth method is constant whereas it varies with the grid distance of event location from the starting grid node in the spatial migration and amplitude source location methods. We suggest that the proposed method is the robust choice for locating/tracking landslides, rockslides and mass flow events in real-time and optimal to be used in real-time monitoring and early warning systems.

Identification of Landslide-Generated Seismic Signals Recorded at Seismological Stations in Arunachal Pradesh

Sahil kumar*, Simran, Sweety Sharma
Department of Geophysics, Kurukshetra University, Kurukshetra
**Presenting author: geophy2023sahil@kuk.ac.in*

Landslides are classified as one of the world's most dangerous natural hazards due to the potential threat to infrastructure, society and property. Present-day studies in Arunachal Pradesh show that landslides can be detected at distances up to tens of km by seismometers originally installed for earthquake monitoring. It has also been shown that various types of landslides leave a specific seismic signature and that seismic data therefore can be used to detect and characterize landslides.
This project investigates if the occurrence of past landslide (mass movements) events on Papum Pare and Itanagar district in Arunachal Pradesh have been registered at permanent seismic stations, and then tries to identify and characterize the signals left by a specific mass movement type.

This project is performed using the earthquake analysis software SAC (Seismic Analysis Code) is a general-purpose interactive program designed for the study of sequential signals, especially time series data. Emphasis has been placed on analysis tools used by research seismologists in the detailed study of seismic events. This seismological approach can help to test theoretical concepts of landscape dynamics and yield an

understanding of the nature and efficiency of links between individual geomorphic processes, which is required to accurately model landscape dynamics under changing tectonic or climatic conditions and to anticipate the natural hazard risk associated with specific meteorological events.

Mapping of structurally controlled underground channels/ caves using Ground Penetrating Radar technique (GPR) in parts of Cuddapah Basin, South Indian Shield

Sakram Gugulothu*, K. Satish Kumar, K. Swapna Sri, P. Siva Sankar and Anand K. Pandey
CSIR-National Geophysical Research Institute, Hyderabad
**Presenting author: sakram@ngri.res.in*

The karst topography with a series of caves is observed in carbonate rocks around Bellum, Bugga, Bhandhrapalle, Panchalingeshware swami, Karva Balli, Yaganti, Bila, Kothalla, and Errabadi regions in Cuaddapah basin, which lies adjacent to the mining areas. The structurally complex region has frequent occurrences of faults with block movement, which is speculated to have control on the Karst topography. The subsurface geometry and extent of these caves are poorly understood and have implications for natural or industrial hazards. We carried out shallow subsurface imaging using geophysical techniques to get clues about the geological structures and caves for the groundwater potential and natural hazard assessment. We carried out shallow subsurface imaging over a depth of >30 m using a 40 MHz antenna of the Ground Penetrating Radar (GPR) in time mode along 13 profiles near cave-infested Belum village. We identified structural features like faults, and fractures along with the caves in flaggy-massive limestone and quartzite. The air/water-filled cavern and minor weak zones are also observed within the limestone. The results are constrained by structural and other geophysical methods. The observed anastomotic box-type cave patterns in the limestone appear to be the structural controlled and phreatic origin. The characteristic signature of shallow saturation indicates the limestone aquifer, has good groundwater storage potential but may cause a severe hazard to the mining zone if finds a connecting passage.

Understanding of the 8th August, 2009 Landslide at Quity village, Pithoragarh district, Uttarakhand through MASW Studies

K. Swapna Sri*, K. Satish Kumar, P. Siva Sankar, M. Shri Hari Rao, G. suresh
CSIR-National Geophysical Research Institute, Hyderabad
**Presenting author: swapna979@ngri.res.in*

The 8th August 2009 event is one of the notable landslide events in Uttarakhand located 7 km away from Quity village, Pithoragarh district. Its impact is the wiping of two villages i.e Jhakhla, Lah, and the loss of 43 lives of people. Geomorphological studies shows, it is due to cloud burst and neo-tectonic activity of Munisyari/Main Central Thrust. Apart from this event, many landslides are also observed in the surrounding region implies, this area is vulnerable to landslide occurrence. In this regard, Multichannel Analysis of Surface Waves (MASW) studies are executed in the surrounding regions to understand the subsurface characteristics up to the depth of 100 m in terms of shear wave velocity. It can be useful to plan and reinforcement of existing structures for future earthquake and mitigation studies. MASW study was conducted at three locations at Munisyari, Nachani and Berinag villages which are 9 Km, 14 Km, and 28 Km respectively away from the landslide location. It is observed from the 2D shear wave velocity images, three different layers are present from the surface to a depth of 100 m. Layer 1 is associated with very low shear wave velocity (<400 m/s) up to the depth of 25 m followed by a moderate shear wave velocity (700 m/s to 1200 m/s) layer up to the depth of 50 m. The massive rock is present from 50 m with a shear wave velocity of >1500 m/s. Further, a very weak zone is observed within the 10 m consisting of saturated soils. The geotechnical parameters like Vs-5 to Vs-

30, N-value, Stiffness, Predominant frequency, Amplification and liquefaction potential are estimated and discussed with respect to landslide events.

An Artificial Intelligence approach for Landslide Susceptibility Assessment in the Beas Valley, Himachal Pradesh

Ramandeep Kaur*, Vikram Gupta
Wadia Institute of Himalayan Geology, Dehradun-248001, Uttarakhand
**Presenting author: ramandeep@wihg.res.in*

Landslide is one of the most destructive geo-hazards in the Himalayan terrain causing loss of lives and damage to the environment. Therefore, the identification of landslide-prone areas through susceptibility mapping becomes an essential step towards mitigating the landslide hazard and for the sustainable development of the area. Many state-of-the-art artificial intelligence algorithms have made the task convenient and efficient giving optimized spatial prediction. One of them is Random Forest (RF) which is a decision, tree-based ensembled model. Over the years, the utility of RF has greatly increased in susceptibility studies as it has produced the highest predictive capability among other models.

In the present study, RF has been used for landslide susceptibility mapping in the upper Beas Valley in the state of Himachal Pradesh, India. A high-resolution dataset comprising spatial inventory of landslides and thematic maps of thirteen conditioning factors of landslide including elevation, the inclination of the slope, slope aspect, plan-curvature, profile-curvature, topographic wetness index (TWI), geomorphology, lithology, land use and land cover (LULC), rainfall, and proximity to drainage, road and thrusts were prepared. The prepared dataset was randomly divided into 70:30 as a training dataset and validation dataset, respectively. The susceptibility maps prepared using the trained model exhibit that ~ 40% of the total area falls under high and very high landslide-susceptible zones whereas ~28% and ~32% of the total area in low and very low hazard zones respectively. Sensitivity analysis performed, to check the robustness of the model with respect to each conditioning factor, reveals that the inclination of the slope, elevation, distance to thrust, road, TWI and slope aspect are the most influential conditioning factors for the occurrences of landslides in the area of study. The area under the curve (AUC) for the RF model obtained is 0.92 which represents a 'very good fit of the model. The prepared landslide susceptibility maps of the area would help the planners and local authorities in mitigating landslide hazards, landscape protection, and land use planning as the area is undergoing a lot of infrastructural development in terms of road construction and hydroelectric projects.

Implications of morphotectonic parameters on the spatial distribution of landslides in the Darma valley, Kumaun Himalaya

Mohd Shawez*, Vikram Gupta
Wadia Institute of Himalayan Geology, Dehradun-248001, Uttarakhand
**Presenting author: shawez@wihg.res.in*

A landslide is the downward and outward movement of slope-forming materials due to gravitational force that is occurring in most of the tectonically active mountains around the world. Numerous geological, geomorphological, hydrological, and anthropogenic factors cause landslides in an area. Amongst these active tectonics play a major role in causing landslides in active mountain chains like Himalaya. In this study, we aim to quantify the relationship between the spatial distribution of landslide occurrences and the tectonic regime of the Darma valley of Kumaun Himalaya. The study area is located between longitudes 80°18′31″–80°36′00″E and latitudes 30°31′15″–29°57′20″N and covers a stretch of ~ 90 km along the Darma River between the Nasha Bugyal and Tawaghat. The area comprises various lithounits like phyllite, quartzite,

schist, and gneiss and grouped into Tethyan Sequence (TS), Higher Himalaya Crystalline (HHC), and Lesser Himalaya Crystalline (LHC) and separated from one another by South Tibetan Detachment system (STDS) and Vaikrita Thrust (VT), respectively. An inventory of 256 landslides has been mapped using high-resolution satellite images. In order to understand the active tectonics in the area the morphometric indices have been measured at an interval of 300m along the Darma river, thus a total of 300 measurements were made. These morphometric indices are the stream length gradient index (SL index), longitudinal profile, steepness index (K_{sn}), and the ratio of valley floor width to valley height ratio (V_f).

The high values of Ksn (~2000) and SL index (~12000) and low values of Vf (~0.015) occur along the Vaikrita Thrust indicating that the area around this thrust is relatively tectonically active. The spatial distribution of landslides is also clustered around Vaikrita Thrust indicating the role of the tectonic regime on the spatial distribution of landslides in the area.

Natural Water and Thermal Springs

Delineation and Conceptualization of freshwater and saline water hydrogeology from high-resolution electrical tomography and lithological models in the Rajasthan area

Dewashish Kumar*, Gaurav Kumar, Rishu Pandey
CSIR-National Geophysical Research Institute, Hyderabad – 500007
**Presenting author: dewashishkumar@ngri.res.in*

High-resolution electrical resistivity tomography, along with hydrogeological study at nine different sites in all the nine blocks of Sri Ganganagar district, Rajasthan has been carried out to understand the alluvium aquifer strata and their hydrogeological variability. Detailed interpretation of high-resolution electrical resistivity tomography results revealed significant subsurface geological characteristics and hydrogeology in the Sri Ganganagar district of Rajasthan. The resistivity tomography models inferred a dry hard sand layer in the near-surface layers, clay-dominated saturated sand, and distorted sand structure with a thin underlying pocket of fresh groundwater zones (shallow and limited) between these layers with distinct resistivity contrast. The resistivity tomography models clearly revealed that below the dry sand layer and thin fresh groundwater zone, there lies the clay-dominated saturated sand with a resistivity value <5 Ohm.m, and this clay enriched in these saturated sand layers is chiefly responsible for the saline groundwater characteristics, particularly at the deeper depths >60 m. The presence of a thin fresh groundwater zone at shallow depths between 25 to 40 m between the dry sand and the clay-dominated saturated sand is the only zone(s) for fresh groundwater exploitation; hence, groundwater quality is good at shallow depths. These inferences have been clearly seen in the results of resistivity tomography models where resistivity lies between 10 to 35 Ohm.m in these alluvium formations. In addition, 3D conceptual models have been prepared in terms of a 3D-solid lithological model and fence diagram to showcase the detailed lithological scenario mainly focused on fresh groundwater variability in the study area. Resistivity and regional hydrogeology were carefully observed through the mid-section of the 2D-ERT models. Four varied lithological scenarios were interpreted from the 2D-ERT models in terms of sand, saturated clay-dominated sand, saturated clay-dominated sand with saline water and saturated sand with fresh water. These units have been further geo-scientifically interpolated to the extent of the study area and helped categorize the various sub-surface lithological sections. Three-dimensional solid lithology and fence diagrams were further smoothened to remove visual discrepancies in the final models. In the 3D lithological model, the top section consists of sand interposed with saturated sand with freshwater towards the south-eastern zone, intermediate depths comprise of the saturated sand with fresh water with patches of saturated clay-dominated sand towards the southern side, and the deeper depth consists of saturated clay dominated sand with saline water throughout the model area. This work and results helped for developing the exploration and exploitation strategy of groundwater resources in these very challenging geological formations and can act beneficial for humankind in the Rajasthan state.

Mapping Saline Water Ingress in Bhachau Taluka, Kachchh basin, Gujarat Using Geophysical and Hadrochemical Analysis

Rakesh Nikam*, Sumer Chopra
Institute of Seismological Research (ISR), Gandhinagar – 382009
**Presenting author: rakeshnikam@isr.res.in*

In the Kachchh district, groundwater is the major source for agriculture and domestic uses. The repetitive draught cycles and seawater intrusion is the major cause of concern in this region. The Bhachau taluka is categorized as overexploited. The present study addressed this issue and attempt to delineate the saline water and freshwater interference in coastal parts of the Bhachau taluka by integrating geophysical investigations and hydrochemical data. The two-dimensional (2D) electrical resistivity tomography (ERT) survey is

conducted in the Bhachau taluka. Five ERT profiles are acquired and its pseudo sections are correlated with the available lithology data. The electrical resistivity results correlated with the hydrochemical analysis of 18 groundwater samples revealed that the seawater intrusion occurred in the alluvial sediment aquifer at a depth of 10-20m. A low resistivity layer value is <1ohm.m for clay layer with saline water, while a range between 5 and10 ohm.m represents brackish water. The hydrochemical parameters like TDS, pH, and EC are measured in the field and other parameters are tested in the lab. The hydrochemical characteristics divided the groundwater into two groups according to the level of impact of seawater intrusion. The major source of chemical evolution in the groundwater is the saline water intrusion and it is mostly observed the in Samkhiyali alluvium plain area. The Mesozoic and Tertiary formations have freshwater aquifers.

Hydro-Geophysical Investigation to Demarcate Groundwater Potential Zone and Assessment of Aquifer Protective Capacity in Hard Rock Terrain using Dar-Zarrouk Parameters, Tapi River Basin, India

Sohel Pathan[1*], Khan Tahama[2], T. Vijay Kumar[1], Gautam Gupta[3] , Tanvi Arora[4#]
[1]School of Earth Sciences, SRTM University, Maharashtra-431606
[2]Indian Institute of Geomagnetism, New Panvel (W), Navi Mumbai-410218
[3]Dr. KSK Geomagnetic Research Laboratory, IIG, Prayagraj-221505
[4]CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad-500007
[#]Presenting author: sohelpathan.sk167@gmail.com ; tanvi@ngri.res.in*

Indian civilization emerged in river basins, where the locations of the earliest settlements were in close proximity to bodies of surface water, such as springs, flowing rivers, and streams, as well as sources of groundwater. Due to the massive increase in the usage of groundwater for domestic, agricultural, and industrial purposes over the past few decades, the water table has decreased considerably and groundwater is depleting faster than nature replenishes it. The long-term water needs of people and natural systems may be negatively impacted by the overexploitation of groundwater. The requirement to prospect for more groundwater sources and to monitor their quantity and quality became necessary to deal with the ever-growing population, and rapid growth to exploit the water resources for their rising needs.

The present study region includes Burhanpur (MP) and Jalgaon (MH), which are part of the Tapi river basin. A significant portion of the Tapi River Basin is in a semi-critical to overexploited zone, making it imperative to investigate the basin's groundwater sources. Located in the northern part of the Deccan Plateau, the Tapi River Basin is home to a number of river tributaries. In the basin, there are two separate physical areas: the plain, which contains the Khandesh regions; and the steep Satpura, Satmalas, Mahadeo, Ajanta, and Gawilgarh hills, which are heavily forested. The study area has an undulating topography comprising of low-lying plains, linear ridges, remnant hills, and a heavily fractured plateau. The Deccan trap formation and the Tapi alluvium are two types of geological formations found in the study area.

For this work, published resistivity data from 36 sites were analyzed. It includes 17 VES soundings which were carried out, employing a Wenner electrode configuration with equally spaced electrodes and 19 VES soundings were extracted from 2D ERT Data. The data were gathered in the Tapi river basin between latitudes 20.99º and 21.38º and longitudes 75.80º and 76.40º. Two parameters from the geo-electric inversion data, layer thickness, and resistivity were used to derive the Dar-Zarrouk parameter. The inversion results showed that the resistivity value ranges from 0.12 Ω-m to 250 Ω-m and the thickness varies between 0.50 and 119.20 m. Longitudinal conductance values vary from 0.39 to 42.73 Siemens. The transverse resistance value ranges from 36.50 to 28973.41 Ωm2, while the anisotropic coefficient value ranges from 0.71 to 2.16. The coefficient of anisotropy suggests some structural control with a clear demarcation boundary. High transverse resistance values, observed at the south-eastern part of the study area, are likely to be a potential zone for groundwater. The protective capacity of the aquifer was further evaluated using longitudinal conductance, and the results

obtained indicate that the study area is dominated by aquifers with moderate to excellent protective capacities.

Hydrochemical analysis of the groundwater drained through handpumps and natural springs in the Garhwal region of Uttarakhand

Abhishek Mehra[1*], B. S. Kotlia[1], G.K. Sharma[1]
Department of Geology, Kumaun University, Nainital
[*]Presenting author: mehrageo1555@gmail.com

Groundwater especially spring water is one of the major sources of drinking water in hilly areas. In Uttarakhand State, most of the population depends on natural spring water for their daily water demand. The monitoring of groundwater used for drinking purposes assumes great importance for human health because some heavy metals are considered harmful to human health when their concentration exceeds the permissible limits. Identification of heavy metal contamination is very useful for the utilization of groundwater resources that may also help in future water resource planning for the area. As per our knowledge, no detailed study in terms of heavy metal analysis of groundwater has been carried out in Garhwal Himalayan Region (GHR). Therefore, three districts (Rudraprayag, Uttarkashi and Chamoli) from the Garhwal region of Uttarakhand were selected to perform hydrogeochemical studies (potential of hydrogen (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), concentration of heavy metals such as Chromium (Cr), Manganese (Mn), Iron (Fe), Copper (Cu), Lead (Pb) and Nickel (Ni) and Zinc (Zn)) of groundwater and springs to determine their suitability for drinking purposes. A total of 24 samples were collected during the post-monsoon season of the year 2022. pH ranges between (7.02-8.9), TDS ranges from 0.031 to 0.042. Electrical Conductivity ranges from 0.012 to 1.64. The values of heavy metals Zn (0.05-4.34), Cr (0.01-0.012 ppm), Mn (0.085-0.09ppm), Cu (0.009-0.019ppm), are within the permissible limit of the government of India. However, the Pb (0.52-0.115), Ni (0.085-0.091 ppm) and Fe (0.23 to 0.90 ppm) concentrations are higher than the permissible limit. The higher concentration of Pb in the groundwater is observed in the areas near the auto garage and automobile shops so we can conclude that discarded batteries and mobile oils might be causing the lead to percolate down to groundwater.

MT and AMT studies across thermal springs in SW part of Maharashtra

Vasu Deshmukh[*], P.V. Vijaya Kumar, P.B.V. Subba Rao, A.K. Singh
Indian Institute of Geomagnetism, Panvel, Navi Mumbai-410218
[*]Presenting author: vasu.deshmukh@iigm.res.in

Both Magnetotelluric (MT) & Audio magnetotelluric (AMT) surveys were carried out across the Aravali and Tural hot springs in the southwestern part of Maharashtra. Integrated AMT and MT studies bring out (a) shallow conductivity anomaly related to the upward propagation of meteoric water through faults/fracture zones. (b) Major fracture/fault zones extending up to mid-crustal depths through which Deccan volcanism may have erupted and (c) the presence of mid-crust (12-15 km) conductivity anomaly related to trapped carbonate fluids that are linked to basaltic magmatic intrusions at the base of the crust (Moho). It has been observed that the surface water temperature at Tural and Rajawadi is higher than at Aravali. This has been attributed to the deep circulation of meteoric water through the basement and igneous intrusion (volcanic plug) beneath Tural and Rajawadi geothermal springs that act as a source rock which is absent beneath Aravali geothermal zone.

Precious Minerals and Hydrocarbons

Evaluation of Topological and Morphological properties of Shale using Lattice Boltzmann Method and Pore Network Modeling

Abhay Shukla*, Swarandeep Sahoo
Indian Institute of Technology (Indian School of Mines), Dhanbad
**Presenting author: abhayjc1712@gmail.com*

As the energy demand is increasing day by day, it leads to a shortage of non-renewable energy resources like petroleum, natural gas, and coal which contributes more than 70% of the energy consumption of any country. Characterization of Unconventional reservoirs at the pore scale level is crucial to access the potential of such resources. Digital rock analysis has emerged as a promising approach in this regard as an alternative to laboratory measurements. Digital pore networks have been reconstructed using micro-computer tomography (μCT) to analyze rock morphology as well as fluid flow properties. In this study 2D, grayscale images obtained from X-ray micro-CT have been segmented into grain and pore using the binarization method. Simulation of fluid flow using the Lattice Boltzmann method on D3Q19 lattice and Pore Network Modeling (PNM) using maximal ball algorithm is performed for the shale sample to quantify its topological and morphological properties. Pore network modeling of the sample has been used for the analysis of geometrical properties like Pore Radius, Throat length, Throat radius and coordination number distribution. Porosity has been estimated using Pore Network Modeling which is in good agreement with the experimental value obtained in the laboratory. Fractal Dimension for both 2D and 3D structures has been calculated using the Box counting method. It is found that the value of permeability is 26 mD. The fractal Dimension for 2D image is found to be 1.84, whereas for a 3D structure it is 2.89, showing high heterogeneity in shale. Heterogeneity characterization at the multi-scale pore level is examined by studying fluid flow behavior. The effective Porosity and Permeability of shale are very low and lack any direct relationship. The prerequisite of 3D fluid flow study through unconventional heterogeneous rock like shale is of great importance in reservoir modeling. Thus, Permeability has been estimated from the simulation of fluid flow using the Lattice Boltzmann Method and hence hydraulic conductivity in this study.

Hydrocarbon reservoir and source rock characteristics of Yinkiong group of eastern Himalayas, Arunachal Pradesh

Anannya Bordoloi
Cotton University
Presenting author: anannyabordoloi3@gmail.com

In the present study, petrography has been employed in interpreting the sandstone reservoir characteristics in addition to the evaluation of source rock potential of shale abetted by rock eval pyrolysis data. A petrographic study indicates the sandstones constituting main quartz, feldspar, sedimentary lithic fragments, and calcite and argillaceous cement with concavo-convex and sutured grain contacts. Few feldspars have undergone alteration and quartz grains are seen corroded by argillaceous cement and matrix. The sandstones are moderate to poorly sorted with sub-angular to angular to sub-rounded grains. The presence of calcite cement has led to the low porosity of the sandstones which is also indicated by sorting and irregular grain shapes. Additionally, the presence of clay cement has eliminated the potential of a good reservoir by obstructing the pore spaces where fluids can accumulate. Sandstones are texturally immature owing to the uneven grain size, moderate to poor sorting, and calcite and clay cement which suggest low porosity and permeability and, as a result, poor reservoir quality. Evaluation of source rock characteristics has been done using rock eval pyrolysis data which suggests that the Yinkiong shales have poor source rock potentiality with kerogen types II-III. The source rock maturity of the studied shales is low and accumulations are small. This finding is aided by the low TOC content which reveals the Yinkiong shales to be mainly gas-prone source rock.

Seismic Noise Reduction using Convolutional Neural Network: A case study from KG basin

D. Haritha*, N. Satyavani
Deep Seismic Group, CSIR - National Geophysical Research Institute, Hyderabad-500007.
**Presenting author: haritha-bh@ngri.res.in*

Noise reduction is one of the main steps in seismic processing because noisy seismic data disturb data processing and interpretation. Deep learning has gained incredible attention in solving geophysical problems. We propose an unsupervised learning-based convolutional neural network to reduce the noise in seismic data. Max-pooling and up-sampling are used for dimension reduction and increase in the encoder and decoder, respectively. Convolutional Neural Network keeps the spatial formation of the input and extracts the important information without any loss of the data. The adaptive moment estimation acts as a backpropagation algorithm to optimize the loss function. The key parameters of the network, like, Convolutional layers, filter size, and learning rate have been selected after performing a series of tests with different values for each of the parameters to reduce the noise in the data. The results show that the present network applied to the seismic data shows improvement in the reflections.

Modeling of Reservoir Geomechanical Parameters in the Gas Hydrate Reservoirs in the Eastern Continental Margin of India

Dip Kumar Singha[1*], Pradeep Kumar Yadav[2], Pradeep Kumar Shukla[2], Kalachand Sain[3]
[1]*Department of Geology and Geophysics, IIT Kharagpur-721302*
[2]*Department of Geophysics, BHU-Varanasi-221005*
[3]*Wadia Institute of Himalayan Geology, Dehradun-248001*
**Presenting author: dipks21@iitkgp.ac.in*

The study of reservoir geomechanics is significantly important for the future production of gas hydrate and technology development, as well as for borehole stability and drilling optimization in the continental margin. The main parameters of reservoir geomechanics are pore pressure, rock mechanical parameters, vertical stress, minimum and maximum horizontal stresses, and stress orientation respectively. These parameters are extremely crucial for the success of depressurization for gas hydrate in coarser sediments. It also depends on the permeability of the sealing layer, those parameters affect the permeability, stiffness, and rock strength of the sealing rock layer underlying the gas hydrate. The presence of gas hydrate in a sedimentary formation increases its elastic strength and decreases its permeability. Being an energy-deficient country, India has conducted two oceanic drilling programs namely national gas hydrate programs 01 and 02 (NGHP-01 and NGHP-02 respectively) so far in search of gas hydrate reserves and development. We estimated various in-situ parameters at NGHP-01 sites of the Mahanadi basin in detail as follows; The average azimuth of maximum stress orientation is N18.84°W (NNW to SSE), the average stress gradients of minimum and maximum stress are 10.48MP/km and 10.58 MP/km, the value of UCS which is varying from 2.25 to 3.29 MPa with the Poisson's ratio ranging 0.42 to 0.48 with an average value of 0.45. The gradient of vertical and pore pressure is 10.67 MPa/km and 10.11 MPa/km respectively. The Moho-Coloumb study reveals the stable conditions of the wellbore in these well sites. At the two sites of NGHP-02 sites of the Krishna-Godavari basin, recently we have modeled and compared geomechanical parameters with the validation of the pressure core data suggesting effective stress, shear modulus, shear strength, and permeability to be 1.67 to 1.73 MPa, 425-643 MPa, 0.73-0.6 MPa, and 0.001-0.0036 mD respectively for 48% and 52% of gas hydrate saturation. These parameters are required for numerical modeling for the future production of methane gas.

Insights in hydrocarbon prospectivity of Spiti-Zanskar Basin, Tethys Himalaya

Harilal
Oil and Natural Gas Corporation (Retired) KDMIPE Dehradun
Presenting author: hariaru@gmail.com

We integrated past research with current field works and analyzed for finding data/information gaps in order to envisage the hydrocarbon prospectivity of the Spiti-Zanskar Basin of the Tethyan Himalaya. To fill the data gap and ensure prospectivity, new technologies of exploration can be implemented. The Spiti-Zanskar Basin is one of the 26 sedimentary basins of India with Category III characterization where only "prospective resources" are envisaged without any exploration and discovery. The current un-risked undiscovered resource is about 11 MMTOE.

The basin has been a natural laboratory of active multidisciplinary research for centuries and its evolution, stratigraphy, and surface geology are known with the convergence of results. The multistage evolution of the basin is documented as Late Precambrian rifting, Late Cambrian-Early Ordovician orogeny, Early Permian rifting, and other associated tectonic activities. The basin was obliterated as a consequence of the collision of the Indian Plate with the Asian Plate and the formation of the Great Himalaya with fold-thrust belts (FTB). The deep seismic reflection conducted across Tethys Himalaya and southern Tibet has shown underthrusting of the Indian lithosphere beneath Tibet. The earlier studies suggest the existence of source and reservoir rocks but the subsurface imaging and drilled data which is necessary for reconstructing the complete subsurface petroleum system model is lacking.

The source rock is relatively better known. Rock-Eval Pyrolysis on surface samples of Jurassic Spiti shales indicates potential source rock with kerogen Type-III organic matter and TOC greater than 1% (3.19% in some cases). Statistically Jurassic and Cretaceous source rocks account for more than 55% of current Oil and Gas accumulations in the world. Unaltered dark grey-black carbonaceous shale buried at depth may be a potential source rock. The analyzed limestone and sandstone from the surface profile show poor porosity but buried samples may have good porosity. Being tectonically active, with numerous thrusts and folds, suitable traps and migration paths ways (conduits) may be common in the subsurface. The alternating shale formations may be good seals.

To ascertain a complete petroleum system (an assemblage of source, reservoir, trap seal rocks, and migration from source to trap), recent technological developments in exploration are considered. Remote sensing spectral analysis may give detailed surface lineaments, drainage patterns, lithological details, seepages and geomorphic features. Recent remote sensing studies supported by field verification and Spectroradiometers have already provided new insights. The Full Tensor Gradiometry (FTG) with multicomponent and multivariable (Gravity, Magnetic and Lidar/Radar) recordings are available to model subsurface structural details. Passive seismic technology is able to give structural and velocity details useful in hydrocarbon exploration. Node-based seismic reflection surveys assisted by Wi-Fi and LTE and the application of helicopters and drones may be useful for details subsurface imaging and finding suitable locations for drilling an exploratory well. All the data acquisition techniques may be planned considering the high altitudes (1500 to 6770 m above MSL) difficult logistics, hostile terrains, very harsh climate, and narrow fair weather operating window.

The discussion shows that the integration of past research and current works and new technology will facilitate discoveries as soon as these are implemented in the basin.

Attribute analysis of a fluid saturated sedimentary layer near Narcondam Island from high-resolution reflection seismic data

Harshad Kumar Srivastav[1*], Dibakar Ghosal[1], A. Sai Kumar[2]
[1]Indian Institute of Technology, Kanpur
[2]Oil and Natural Gas Corporation Limited, GEOPIC, Dehradun
[*]Presenting author: kharshad@iitk.ac.in

The Andaman subduction zone is tectonically active and hosts many seamounts, a chain of volcanoes including the Barren and Narcondam islands, and the Andaman Sea as well as many other small-scale offshore basins. Here, we present the seismic attribute analysis of an offshore basin located southeast of Narcondam Island. We process a 30 km long 2D seismic high-resolution reflection profile and generate a post-stack depth converted migrated section. The water depth ranges from 1390–1560 m, and the sediment thickness in the basin varies along the profile, reaching a maximum of 2.37 km. We observe a seafloor parallel reflector with negative polarity in the sedimentary basin deposits at 2.79-2.81 s (2.19-2.21 km) TWT and with an interval velocity of 1.57 km/s, indicating the presence of a fluid-saturated layer. We then carry out the amplitude variation with offset (AVO) analysis, followed by the amplitude variation with angle (AVA). We use the two-term Aki-Richard's equation, restricting the analysis up to 22^{o} and computing the intercept and gradient for the aforesaid sedimentary reflector. The reflection coefficient versus angle/offset plot shows an increase in amplitude values with offset, whereas the gradient-intercept plot shows the intercept and gradient of the reflector as -0.7630 and -0.5892, respectively, and lie in the third quadrant, indicating the sedimentary layer to be fluid-saturated. The origin of the fluid can be associated with hydrothermal activities as the basin is volcano supported.

Seismic processing and De-multiple Techniques results: A Case study

Kiranmai Samudrala[*], Satyavani Nittala, Prakash Kumar
CSIR-National Geophysical Research Institute, Hyderabad – 500007
[*]Presenting author: kiranmai@ngri.res.in

Multiples are events that have undergone more than one reflection. The amplitudes of the multiple are the product of the reflection coefficient of each reflector involved. There are mainly two classes of multiples i) Long path multiple and ii). Short path multiples. Demultiple techniques work by predicting the multiples from the data and then eliminating it from the data by adaptive subtraction which can be done iteratively. Different techniques were used to identify the de-multiple those are Wave Equation Multiple Rejection (WEMR), Radon Analysis and Filtering, F-K Multiple attenuations, Surface-Related Wave Equation Multiple Rejection, etc. Wave Equation Multiple Rejection (WEMR), Surface-Related Wave Equation Multiple Rejection (MASWEMR), and Radon Analysis and filtering give the best results of all. WEMR is specifically to attenuate water bottom multiples in marine data. MASWEMR removes surface multiples. Surface multiples are events that have undergone at least one downward reflection at the Earth's surface. Radon analysis and filter transform seismic data into a domain where multiple and primaries are readily distinguishable and can be separated. In our study, we found that the WEMR technique is giving better results compared to all other techniques.

Geophysical exploration for gold and associated minerals, case study: Kakol area, Granite-Greenstone Belt

Kolipaka Venu[1*], Ram Raj Mathur[2]
[1]Research Scholar, Osmania University, Hyderabad
[2]Assistant Professor (Retd.), Osmania University, Hyderabad
[*]Presenting author: venugeophysics@gmail.com

The Kakol Gold Block is known for its gold potential. The States of Karnataka & Goa forming a part of the Indian Shield are constituted of rock formations ranging in age from 3300 m.a. to 5 m.a. Barring a narrow coastal strip of about 5000 sq. km. of Tertiary and Quaternary sediments and another 31,250 sq. km. of Deccan basalts, the remaining area is occupied by Archaean Proterozoic rocks. The major part of the state is constituted of the Dharwar Craton comprising greenstone belts, gneisses and granites which, at the southern margin of the craton, give way to granulite suite of rocks. kakol structures, N-S and NE-SW trends have been defined as controlling gold mineralizations in Between Latitudes N14039'41.04" and 14043'27.84" Longitudes E75030'00" and 75034'8.76", whereas some of these structures are not gold-bearing. To determine structures related to gold mineralization, airborne magnetic data collected during the Mining System of India have been processed and interpreted. Identified lineaments have been followed in the ground to establish their link with gold showings in the Kakol area. Geophysical interpretations show trend similarity for different orders of conductivity. They allowed for characterizing resistance and conductive structures with prevalent N-S and NE-SW directionalities. Conductive structures are qualified as good conductors and they coincide with tourmaline sandstones and quartz-albite veins, which are both often artisanally recognized as indicators of gold mineralization in kakol. Field observations show that resistance structures correspond to felsic rocks. These structures can bear gold only when silicified and they have spatial relations within the Kakol area. This study shows the efficiency of IP and magnetic methods to characterize structures in relation to the gold mineralization in Kakol

Petrophysical and Geochemical Characterization of the Eastern Dharwar Craton Kimberlites

Kusham[1]*, Shalivahan[1], Sambuddha Mukherjee[2], Prakash Kumar[3], S. Ravi[4]
[1]Indian Institute of Petroleum and Energy, Visakhapatnam, Andhra Pradesh
[2]Geological Survey of India, Kolkata
[3]CSIR-National Geophysical Research Institute
[4]Geological Survey of India, Bengaluru
[*]Presenting author: kusumsandhu33@gmail.com

Kimberlites are one of the most prominent rock types in the world to host diamonds. Several petrophysical databases are available in the world but it's rarely available in India. There are several known kimberlite fields mapped in the Dharwar Craton, India. In this study, we provide a comprehensive database of petrophysical and geochemical properties of 17 drill core samples mainly from the Wajrakarur Kimberlite Field (WKF) in the Eastern Dharwar Craton (EDC), India. The major physical properties of an ideal petrophysical database are density, magnetic susceptibility, and electrical conductivity. The combination of paramagnetic and ferromagnetic minerals characterizes the rock's magnetic properties. Bulk, grain, and texture control the petrophysical properties of the rocks. The majority of a rock's mineral components characterize the bulk behavior of the rock. Contrary to this, a minority mineral component controls the grain and texture behaviors of a rock. Petrophysically, serpentinization is a very significant form of alteration that occurs in association with several mineral systems. Serpentinization comprises the conversion of olivine and pyroxene to serpentinite-group minerals and magnetite. Serpentinization is a very significant factor because of the decrease in density and increase in magnetism. In the present study, the degree of serpentinization has been calculated using

the chemical composition of Kimberlites and it has been corroborated with petrophysical studies.

For the Eastern Dharwar Craton Kimberlites, we find that 1) Magnetic susceptibility is the most important factor controlling the petrophysical properties of the majority of the kimberlites. 2) Most of the EDC kimberlites have suffered granulite facies metamorphism although from several previous studies we find that the surrounding country rock has suffered greenschist facies metamorphism. 3) Most of the kimberlite samples have a density in the range of 2.7-3.1 g/cm^3 with a majority of the kimberlite pipes having a density of around 2.8 g/cm^3. 4) High magnetic susceptibility values indicate a high concentration of magnetic minerals. 5) The majority of the kimberlites followed the magnetite trend. The petrophysical and geochemical database provides a constraint to the exploration techniques.

Comparison of Post-Stack and Pre-Stack Impedance Inversion for Identification of Gas hydrates and free Gas zones

Latha Sri P[1,2*], Satya Vani N[1]
[1]*CSIR-National Geophysical Research Institute, Marine seismic group, Hyderabad, Telangana*
[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002*
[*]*Presenting author: lathasri@ngri.res.in*

Seismic inversion is one of the best Geophysical methods for the identification of earth's subsurface features. The seismic inversion method can be classified basically into two categories, namely Pre-stack seismic inversion and Post-stack seismic inversion. In this study, we have attempted to carry out the Post-stack impedance inversion and Pre-stack impedance inversion techniques for the identification of Gas hydrates and free gas zones in the KG (Krishna Godavari) basin. For this process, we used 2D seismic data and well-log data from the KG basin, computed the initial models then inverted those initial models with the real data, and finally obtained the Post-stack and Pre-stack inversion final models. We have computed the result and noticed that the Pre-stack impedance inversion gave a better result than the post-stack impedance inversion. In Pre-stack impedance inversion BSR (Bottom Stimulating Reflector) has appeared very clearly compared to post-stack impedance inversion.

Joint inversion of the gravity and magnetic data using the Bayesian approach

Mahak Singh Chauhan
[*]*CSIR-National Geophysical Research Institute (NGRI), Hyderabad-500007*
Presenting author: mahak.singh@ngri.res.in

Inversion of potential field data has been a very important tool for interpreting geological structures. Decades-long efforts by researchers have been made to improve and to develop inversion techniques for modeling gravity and magnetic data. The widely used methods are: (1) based on discretization of model space and iteratively minimizing the objective function; or (2) using the analytical models in the forward operator of fitness function and minimizing the error. Any of such methods give a final model ('*best-fit model*') corresponding to the minimum value of the fitness function. However, such a model may not represent the global minima of the fitness/error function, especially in the case of a multi-dimensional problem that may have several minima of equal importance. This is due to the inherent ambiguities in the potential fields where many models can fit the same data with equal accuracy. However, mapping of the model space using the inversion techniques based on probabilistic approaches quantify the high-probable areas of model space and provides an overall better understanding of model parameters. The source parameters are represented through posterior probability distributions instead of a best-fit model. Therefore, I here use the Bayesian inversion, a Markov chain Monte Carlo (MCMC) method using a Metropolis-Hasting sampler for inverting the gravity and magnetic data. The joint likelihood function is written and data error is incorporated through the

covariance matrix. The inversion has been applied on gravity and magnetic data for interpreting the synthetic and real case examples.

Unsupervised Clustering on Well Log Data for Facies Classification in Raniganj Sub-basin, India

Mannat Khanna[1*], Shaik Nasif Ahmed[2,3], Nimisha Vedanti[2,3]
[1]Department of Geophysics, Kurukshetra University, Kurukshetra
[2]CSIR-National Geophysical Research Institute, Hyderabad-500007
[3]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002
[*]Presenting author: mannat1230@gmail.com

Facies classification is typically carried out using geophysical well logging data. However, the manual interpretation of geophysical logging data is time-consuming and tedious. In this study, unsupervised machine learning techniques are used for the classification of facies across 3 wells in the Raniganj sub-basin, India. Using unsupervised learning, well log measurements are grouped into distinct facies by identifying the underlying patterns in the data, without the need for labels i.e. pre-existing information on facies, for training the model.

The unsupervised learning classification is carried out using clustering methods viz. K-Means clustering and Gaussian Mixture Modelling (GMM) algorithms, which divide data points into groups on the basis of shared characteristics. The algorithms are provided with the optimum number of starting clusters, evaluated from the elbow plot and silhouette method. The facies classified from both the models honours the characteristics of the established lithology, however, GMM shows slightly better results, as it accounts for the variance in data while classifying.

Synergistic CH_4 recovery and CO_2 sequestration in hydrates under maritime conditions

Sai Kiran Burla[1*], Hari Prakash Veluswamy[1], Pinnelli S.R. Prasad[2]
[1]Department of Chemical Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, 24766
[2]Gas Hydrate Division, CSIR–National Geophysical Research Institute (CSIR–NGRI) Hyderabad – 500 007
[*]Presenting author: burlasaikiran@gmail.com

The most versatile fossil fuel with the purest burning characteristics is natural gas. Currently making up around 24% of the world's energy consumption, natural gas is expected to continue to rise consistently at a rate of 1.7% through 2040. In addition to traditional gas reserves, recovering natural gas from unconventional deposits, including shale gas, tight gas, and natural gas hydrates, is receiving attention because of the immense energy potential in these resources to satisfy the expanding demand. The natural gas hydrates resource estimations were 20,000 trillion cubic meters (TCM), but the economically recoverable reserves are estimated to be around 3000 TCM, double the amount of all other conventional fossil fuels. In the Indian territory, these deposits are identified within the Krishna Godavari (K-G), Mahanadi, Kerala-Konkan (K-K), and the Andaman basin (mostly sI hydrates). The molecular replacement is fundamentally attractive because several reasons, like the molecular diameter of both CH4 & CO2, are similar and can be replaced. Once achieved, it serves a dual purpose of sequestering unwanted greenhouse gas 'CO2' and recovering the most wanted fuel gas 'CH4' from the hydrate deposits. Additionally, it can successfully avoid the drawback of traditional exploitation methods. The present study attempts to understand molecular swapping in the methane hydrates formed in the sediments mimicking the natural conditions. The CO2 gas is pumped into the stable methane hydrates, and the recovery/ exchange efficiency is estimated.

Fluid substitution modeling of Hazad Sands due to CO_2 injection in Gandhar oilfield, Cambay Basin: India's first CO_2 EOR project

Saqib Zia[1,2*], Nimisha Vedanti[1,2]
[1]*CSIR – National Geophysical Research Institute, Hyderabad-500007*
[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002*
[*]*Presenting author: saqib.ngri21j@acsir.res.in*

Gandhar oilfield is a pilot field to implement India's first large-scale CO_2 Enhanced Oil Recovery (EOR) project operated by Oil and Natural Gas Corporation Limited (ONGC), Government of India (GoI). It is one of ONGC's major brown-field, which was discovered in 1983. The oilfield produced approximately 30,000 barrels of oil per day in 2018 leading to a decline stage. ONGC has planned to implement the CO_2 EOR technique in this field to recover an extra 15% of residual oil equivalent to 20 million barrels of crude oil for strengthening India's energy security.

One of the objectives of this project is the feasibility of seismic/well-log data to monitor the CO_2 injection into the reservoir. The injected CO_2 will change the bulk property of the reservoir rock and hence the recorded geophysical signal (seismic/well-log). Rock-physics theories act as a link between the bulk properties of the reservoir rock and the recorded geophysical signal. Fluid substitution theories model the effect of different pore fluids on the acoustic properties of the rocks. Hence, we used the Gassmann substitution theory to model the acoustic properties of Hazad sands altered by CO_2 injection.

We perform Gassmann fluid substitution on a well data from Gandhar oilfield, Cambay basin in Hazad sands interval only where CO_2 is supposed to be injected. The matrix properties were modeled using rock physics theories given by Voigt and Reuss. The bulk modulus and density of pore-fluids (brine/water, oil/gas, and CO_2) were modeled using the theory of Batzle and Wang (1992) for the given temperature and pressure of reservoir rock. The dry frame bulk modulus of the reservoir rock initially saturated with oil/gas and brine was calculated. Then the saturated bulk modulus of the reservoir rock (Hazad sands) with assumed 20% of CO_2 saturation and the remaining pore-fluid was calculated. The resultant bulk modulus and composite density were used to compute the P-wave velocity of the Hazad sand. The post-CO_2 injection P-wave velocity shows a little decrease in comparison with the pre-CO_2 injection P-wave velocity. It is also observed that the bulk modulus and density of pore-fluids modeled by Batzle and Wang (1992) produce more realistic velocities when compared with the literature.

Optimization of Density-Velocity relations for Velocity estimation in the Raniganj Sub-basin, India

Shaik Nasif Ahmed[1,2*], Saqib Zia[1,2], Nimisha Vedanti [1,2]
[1]*CSIR-National Geophysical Research Institute, Hyderabad-500007*
[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002*
[*]*Presenting author: nasif.ngri20j@acsir.res.in*

Multiple factors such as Mineral composition, porosity, fluid content, and depth of burial have an influence on the rock velocity and density. Studies show the systematic relationship between velocity and density in sedimentary rocks. Although the existing Gardner's and Lindseth's empirical relations are found to be useful in certain lithologies, their parameters do not give precise predictions in Indian coal basins. Gardner's relation works well with Sand and Shale lithology but departs significantly from expected behavior in coal regions. Lindseth's relation predicts well in coal regions but gives a very poor approximation for Shale regions. As Gondwana basins are dominated by Sand, Shale, and Coal lithology, proper optimization is required.

Geophysical Well-log data covering 4 wells in the Raniganj Sub-basin are used for density-velocity constants evaluation. The Optimization is carried out using an ML-based regression approach, 3 wells are used for training and 1 blind well is reserved for testing the model. The Data is classified into 3 different classes viz. Sand, Shale, and Coal regions using GR and density logs. The Linear Regression approach is used to find the coefficients that best fit the data in the least-square senses. A set of constants are obtained using a local fit for Sand, Shale, and Coal. Results are evaluated in terms of RMSE, and a significant improvement is observed by fitting the data locally instead of using the default parameters. With the optimized parameters, very little difference between selecting Gardner's or Lindseth's approach is observed.

A rock physics model for simulating elastic properties of unconventional shale reservoir

Shib S Ganguli[*], Sadat Rahaman[2]
[1]CSIR-National Geophysical Research Institute, Hyderabad-7
[2]Domkal, Murshidabad, W.B. 742303
[*]Presenting author: shibg@ngri.res.in

Understanding the effects of organic matter content, mineralogy, and pore microstructure on elastic properties remains one of the major challenges of unconventional shale reservoir characterization. A suitable rock physics algorithm establishing relations between rock composition and macroscopic properties can be useful to get insights into rock characteristics. We present a shale rock physics modeling approach that takes care of various rock constituents to simulate the elastic properties of shale rock. Kuster-Toksöz algorithm has been employed to infer the elastic parameters of the kerogen and fluid mixture. The stiffness parameters of mineral constituents are assessed using the Voigt-Reuss averaging approach and a self-consistent approximation (SCA) approach is used to model clay filled with formation water. Subsequently, free pores were incorporated along with clay, minerals, and kerogen employing the differential Kuster-Toksöz algorithm to develop a new framework for simulating the elastic parameters of shale rock. Comparative analysis with a conventional rock physics-based velocity prediction approach applied to different shale data indicates the efficacy of the presented approach is significantly better than other available models.

Synthetic studies using an in-house Acoustic Full Waveform Inversion (AFWI) code

Vikas[1*], D. Ghosal[1], S. Roy[2], A. Sai Kumar[3]
[1]Indian Institute of Technology Kanpur, Earth Sciences, Kanpur
[2]Indian Institute of Technology Kanpur, Computer Science and Engineering, Kanpur
[3]Oil and Natural Gas Corporation Limited, Dehradun-GEOPIC
[*]Presenting Author: vvats@iitk.ac.in

The biggest challenge in the upstream oil and gas industry is to obtain a highly resolved image of the subsurface. With the advancement of computation facilities, travel time tomography has been turned into a routine task in industry, in which long-wavelength velocity-depth models are obtained using the first arrivals of seismic phases. However, obtaining short-wavelength subsurface features is still a difficult task, especially in a complex geologic setup. Acoustic Full waveform inversion (AFWI), which is based on the deterministic inversion theory can help to understand the finer details of the subsurface structure with a maximum resolution of half of the wavelength of propagating wave by exploiting detailed information from the seismogram. We have prepared an algorithm to increase the computational efficiency of (FWI) using high-performance computing (HPC), implemented over the OpenMP API, which reduces the computational cost by many folds. To adjust the input parameters based on the data and to see the output, a graphical user interface for FWI is also built. We successfully tested our code on benchmark models to check the validity of

this strategy We first carry out three 2-D synthetic tests on (1) a model with a gradual increase in velocity with a 100 X 100 m low-velocity structure embedded at a depth of 400 m, (2) a checkerboard patterned anomaly in a uniform velocity model, and (3) a standard Marmousi model. The synthetic experiments show that our inverted models recover the physical properties of the real models in a manageable amount of computational time, and the user interface makes the implementation of FWI easy.

Prediction of missing log using Machine learning

Jitender Kumar[1,2*], Kalachand Sain[1,2]
[1]Wadia Institute of Himalayan Geology, Dehradun
[2]Seismic Interpretation Laboratory-WIHG, Dehradun
[*]Presenting Author: jitender@wihg.res.in

The present study emphasizes the usefulness of machine learning (ML) workflows in the prediction of missing logs. In petroleum exploration, the sonic log (DT) is mainly used for the calculation of reservoir porosity and for pursuing petro-physical studies and geological analysis. However, sometimes these logs do not exist in the well record either due to data loss or not recorded at that time. So, the prediction of these logs is essential for evaluating a better petrophysical analysis and reservoir characterization from existing data.

For the petrophysical well data, we have tested the prediction of the sonic log (target log) from the density, gamma and resistivity logs (input logs) using various ML algorithms that include the random forest and XGBoost. It is observed that these ML algorithms could make a quite accurate and reliable prediction of missing logs using other available logs. The correlation coefficient (0.8 to 0.9) between the ML predicted and available logs show that the ML and associated algorithms play a very important role in the prediction of missing logs, particularly in cases where we have less amount of log data for training unlike the deep learning models, which need a substantial amount of data.

Assessment of Hydrocarbon potential of eastern flank of the Surin-Mastgarh Anticline, North West Himalaya

Madhab Biswas[1,2*], Kalachand Sain[1,2]
[1]Wadia Institute of Himalayan Geology, Dehradun – 248001
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad- 201002
[*]Presenting author: madhab.biswas5@gmail.com

Anticlines are of enormous interest to geoscientists in the search for Hydrocarbon, especially if it is made up of Cenozoic sedimentary rock such as Surin-Mastgarh Anticline (SMA). From the 1970s, various reports (predominantly by ONGC) on hydrocarbon exploration in the SMA region suggest it as a low potential zone. Here we have demonstrated the potential sub-surficial zones of Hydrocarbon from four recently acquired 2D seismic traces from the Eastern flank of the SMA region. The analysis of seismic attributes, computation of Root Mean Square Velocity, and tracing and sketching of the texture of seismic amplitudes have been done to understand the subsurface geometry of the anticline, its stratigraphic divisions, inter-tectonic relations, etc., which indirectly aid us to find out about the source rock and the migration of the hydrocarbon to the reservoirs. It is inferred that most of the potential zones are Natural Gas Reservoir. There is no hydrocarbon reservoir present within the Surin-Mastgarh Anticline. Most of the potential natural gas-bearing reservoirs are present within the Late Proterozoic Duplex Thrust complexes overlying the Main Himalayan thrust. It is also explained that there are Pre-Siwalik Tertiary rocks present below the MHT, which are actually the Source rock of these hydrocarbons. It is elucidated that there are thousands of small-scale faults and fractures inter-connected the Duplex Thrust Complexes to the surface, which are seeping out the Natural Gas from those reservoirs for millions of years.

Tomographic Imaging to identify the Sub-basalt Sediments and Active Tectonics in the Narmada-Tapti Rift Zone, Central India - a Review.

K. Laxminarayana[1,2*], Biswajit Mandal[1,2], M. M. Dixit, Sanjay Kumar, P. Karuppannan, Laxmidhar Behera[1,2] , Prakash Kumar[1,2]

[1]CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500007, India.
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201002, India.
[*]Presenting author: laxmingeo109@gmail.com

Deccan Volcanic Province in Central India is one of the world's most extensive flood basalt volcanic in India. It is always challenging to obtain velocity structures below the Deccan traps region due to the high impedance of the basaltic layer. Here we use P-wave refraction travel time tomography to image the shallow structure along three profiles of long offset seismic refraction data in the region. Our study shows the basement depth varies from 1.5 km to 3 km across the Narmada South Fault. We also identified a sub-basalt graben bounded by the Narmada South Fault in the northeast and the Tapti North Fault in the southwest. It is a horst and graben structure with a width of 70km, and its basement rests at 3km depth. A shadow zone with a velocity <5 km /s underlying the higher velocity of the Deccan Trap basalt (3.5 to 5.0 km/s) is interpreted as the sub-basalt part filled with sediments. These sediments could be the potential zone for hydrocarbon. Our study also reveals that the Barwani Sukta Fault and the number of many faults reaching up to the basements and extending hundreds of km laterally control the region's tectonics. These neo-tectonic faults may be capable of generating large-magnitude earthquakes, including one that occurred on 21 May 1997 mb 6.0 Jabalpur earthquake.

Conservation of Geoheritage sites in Himalaya: Siwalik Fossil Park, a case history

V. P. Mishra
Secretary, Palaeontological Society of India, Lucknow
Presenting author: mishravijayp@gmail.com

Siwalik rocks forming the foothills in the Indian subcontinent are famous worldwide among geoscientists for the large variety and number of vertebrate fossils mainly mammals entombed in these sediments. In addition to mammalian fossils, fossils of fish, a few amphibian, snakes & birds, crocodiles, tortoises, molluscan shells, leaf impressions & fossil wood have also been recovered from Siwalik rocks. Several sections mainly in the Markanda valley, north of Chandigarh, south of Nalagarh, around Nurpur, Uttarbaini, and Ramnagar in H.P., Haryana and J. & K. states are richly fossiliferous.

A geosite in Siwaliks at Saketi in the Sirmaur district of Himachal Pradesh was established as Fossil Park way back in 1974. Siwalik Fossil Park, Saketi has been developed by the Geological Survey of India, in collaboration with the Himachal Pradesh Government, which is a significant step towards the preservation of prehistoric animal sites, restoration of their natural environment, and utilization of the same for scientific, educational and recreational purposes. The museum at the Siwalik Fossil Park, Saketi displays a large number of Siwalik vertebrates. A number of life-size models of Siwalik vertebrates have also been erected at the locations from where their fossils were recovered in the park. The Siwalik Fossil Park has been designated as National Geological Monument in 2001 by the Geological Survey of India.

In addition to fossiliferous sites, Siwaliks exhibit exemplary sedimentary structures, tectonic features, and even neotectonic activity. At least some of these sites also need to be conserved and preserved for future generations. Several more fossiliferous Siwalik geosites are needed to be preserved in the Jammu region, Himachal Pradesh, Haryana, Uttarakhand, West Bengal, and Arunachal Pradesh.

During last several years only one fossil park / geosite in the Siwaliks of northwestern Himalaya could be established. Since the land of the geosites belongs to the States, the state authorities need to be informed/sensitized/provoked/guided in conserving and preserving of certain Siwalik geosites having features of special interest/fossil locations. This may be of help in future to declare more geoheritage sites/monuments in Indian Siwaliks. Since the Siwalik foothills do preserve several cultural, religious, and heritage sites, the geosites may also be included in tourist circuits.

Signatures of a 17th century great earthquake at Hime village, Subansiri river valley, Eastern Himalayan Front, India

Arjun Pandey
Wadia Institute of Himalayan Geology, Dehradun
Presenting author: arjun@wihg.res.in

Ongoing convergence across Himalayan decollement has been responsible for generating megathrust earthquakes since the commencement of collision. These inescapable seismic threats pose a serious risk to the inhabitants as well as to the infrastructure of the region. The infantry paleoseismic record in this highly vulnerable mountain chain often generates conflicting conclusions amongst paleoseismologists regarding the rupture length and the magnitude of these seismic events. Historical archives document dozens of earthquakes all along the Himalayan arc whose geological evidence is lacking, posing the question of whether these claimed large to great events in the chronicles reached the surface or they remained blind like the 2015 Gorkha earthquake.

We excavated a ~15 high fault scarp at Himebasti (27.54˚ N, 94.36˚ E). Twenty-one radiocarbon samples were collected to constrain the faulting event in the trench. The collective information of these results suggests that the area has been devastated by a great earthquake post-1445 CE with a dip-slip displacement of 15.32 ± 4.69 m. We correlate the event with the 1697 Sadiya earthquake which shook the major cities of eastern Himalaya and destructed a town named Sadiya with continued aftershocks for six months. To constrain its magnitude we used empirical scaling relationships from modern instrumental seismology relating magnitude with intensity, source location, and rupture geometry. Our results constrain the 1697 A.D. Sadiya earthquake to have ruptured the HFT at the eastern Himalaya, most likely during an Mw 7.9–8.1 event with a minimum rupture length of ~100 km.

Delineation of Gas Hydrates using advanced seismic tools: Example from Offshore Mahanadi Basin, India

Jitender Kumar[1,2*], Kalachand Sain[1,2], P. Rama Rao[3]
[1]*Wadia Institute of Himalayan Geology, Dehradun*
[2]*Seismic Interpretation Laboratory-WIHG, Dehradun*
[3]*Andhra University, Visakhapatnam*
[*]*Presenting Author: jitender@wihg.res.in*

Gas hydrates (GHs) are ice-like crystalline solids that are found in shallow sediments of outer continental margins and permafrost regions. These are considered major future unconventional energy resources of India. Several parameters like bathymetry, seafloor temperature, sediment thickness, rate of sedimentation, total organic carbon content, and geothermal gradients indicate that submarine sediments are good hosts for gas hydrates. The amount of methane prognosticated in the form of gas hydrates along the Indian margin is more than 1500 times of the country's present natural gas reserve. Only a 10% recovery can meet India's overwhelming energy requirement for about 100 years. Therefore, delineation and assessment of gas

hydrates are essential for evaluating the resource potential of gas hydrates. Since the discovery of major oil/gas fields has not taken place in the last few decades, unconventional energy resources like gas hydrates seem to be the best alternative. The GHs are delineated by identifying an anomalous reflector, known as the bottom simulating reflector (BSR) on the seismic section. The present work presents a study for the delineation of GHs bearing sediments based on the computation of seismic attributes from high-resolution 2D seismic data in the Mahanadi (MN) offshore basin, in the eastern margin of India. Seismic data is preconditioned by preserving dip and azimuth information at every sample location. The post-stack 2D seismic data is then filtered using a structure-oriented filter called the dip-steered median filter (DSMF) along with the steering data. This generates DSMF seismic data which is further used to extract suitable instantaneous seismic attributes e.g., amplitude, phase, frequency, RMS amplitude, and sweetness. The attribute responses are critically analyzed to demarcate the zones of GHs from free gas. Other techniques, such as Short-time Fourier Transform (STFT) and Continuous Wavelet Transform (CWT) based spectral decomposition (SD) techniques are used to illuminate the high energy low-frequency anomaly from the data, which indicates the presence of free gas below the BSR. From the study, it is inferred that the CWT technique promises higher spectral-spatial resolution than the STFT. The empirical mode decomposition (EMD) approach is also used to prominently delineate the gas hydrate-bearing zone from the free gas zone. The EMD is a powerful signal analysis tool that splits the signal into individual decomposition modes, called the intrinsic mode functions (IMFs). Each IMF is associated with symmetric and narrow-band waveform ensuring that the instantaneous frequencies are smooth and positive. However, to avoid mode mixing and splitting, aliasing, and endpoint artifacts, two variants, ensemble EMD (EEMD) and complete ensemble EMD (CEEMD) have been estimated to overcome the negative features. The study demonstrates that the EMD can be employed to demarcate the GHs and free gas zones.

Mechanism of shallow crustal exhumation across the India-Asia convergent margin

Shailendra Pundir[1*], Vikas Adlakha[1], Rahul Devrani[1], Santosh Kumar[2]
[1]Wadia Institute of Himalayan Geology, Dehradun, India,
[2]Department of Geology, Kumaun University, Nainital, India
[*]Presenting author: shailendra@wihg.res.in

The Trans-Himalayan mountains in the north of the Indian subcontinent represent one of the youngest collisional systems, with a maximum elevation up to ~7 km. The timing and mechanisms that led to the formation of the high Trans-Himalayan Mountains remain enigmatic despite decades of research. In this study, we carried out zircon fission track (ZFT) and apatite fission track (AFT) low-temperature thermochronological investigations and present a record of exhumation rates obtained from our results from the collision zone of the Himalayan-Tibetan orogen, which has been carved by the dextral Karakoram fault (KF) along its western margin. According to our thermochronology results across the KF, we suggest that the transpression likely regulated exhumation between 10 and 8 Ma. While, in the north of KF at the south Asian plate margin (Tibetan margin) in the SE Karakoram the exhumation rates are twice as high as the Ladakh range, to the south of the KF, since at least middle Miocene. We propose two different mechanisms that caused the rapid exhumation of the Tibetan Margin. First, we propose that during the Oligocene-Miocene the rapid exhumation was in response to topographic uplift and subsequent erosion due to the convective removal of the lower lithosphere, triggered by the rollback of the subducting Indian lower crust. Second, our thermochronology results document an additional two-fold increase in the exhumation rates of the Tibetan margin since the late Mio-Pliocene for this we propose that the underthrusting of the Indian Plate below Tibet during the late Mio-Pliocene was responsible for this additional increase of exhumation rates of the Tibetan margin. The study on these regions' topographic slope, relief, and channel steepness are in good accord with the exhumation rates. Thus, the coupling of tectonics and topography dictated the exhumation patterns since the late Mio-Pliocene.

Thermal conductivity at elevated temperature and physical properties of the granitoids from the Singhbhum and Bundelkhand Cratons, India: Implications on crustal thermal modeling

Nishu Chopra[1], Labani Ray[1], P. Rama Rao[2], M. Subrahmanyam[2]
[1]CSIR-National Geophysical Research Institute, Hyderabad-500007
[2]Department of Geophysics, Andhra University, Visakhapatnam-530003
[*]Presenting author:nishuchopra31@gmail.com

Cratons are the only continental segments to elucidate the crustal thermal structure, in terms of crustal temperature-depth profile and arriving mantle heat flow, which is a key factor in geodynamics. Essential parameters for the crustal thermal structure are surface heat flow, which is the boundary condition, and plausible crustal models for radiogenic heat production and thermal conductivity variation with depth. In cratons, granite/granitoid constitute a significant component of the upper crust, and therefore their thermal conductivity values and variation with temperature play an important role in understanding the crustal thermal structure.

This study considered two geological provinces of the Indian shield, viz., Singhbhum and Bundelkhand Cratons. Among these, no thermal conductivity data is available for the Singhbhum Craton before this study. The thermal conductivity of the upper crustal rocks also changes with temperature very significantly, and it also plays an important role in thermal modeling, which is not available for these two cratons. The first-time measurement of thermal conductivity at elevated temperatures is carried out in India.

The variation in thermal conductivity at ambient temperature from Singhbhum Craton shows that thermal conductivity for different granitoids increases from north to south region. Whereas, Bundelkhand Craton, it shows a distinct variation within the various granitoids that prevailed there.

Further, expressing the thermal conductivity variation with temperature as $\lambda T = \lambda RT\ (1 + bT)–1$. In Singhbhum Craton, the temperature coefficient (b) value varies between 0.8×10-3 and 1.2 ×10-3 K-1 for different granitoids. In Bundelkhand Craton, two distinct b values have been found, 1.1×10-3 to 2.2×10-3 K-1 for alkali feldspar granite to monzogranite and 0.4×10-3 to 1.2×10-3 K-1 for granodiorite to tonalite to quartz diorite. In thermal modeling, generally, a fixed b value (1.5×10-3 K-1) is considered for the upper crust, but the finding of this study shows that for compositionally different granitoids, b are distinctly different. This study will give an accurate b value which will be used for arriving at the correct thermal model for those regions instead of considering a general value.

Moreover, in many thermal modeling, thermal conductivity is assumed due to the lack of thermal conductivity data or lack of proper samples for measurements. In such a situation, indirect method (e.g., calculated from the mineral composition of the rock) can be used. A study on a subset of different varieties of granitoids shows that the harmonic mean model is a good approximation for low anisotropic and low porous rocks.

Magnetotelluric constraints on the lithospheric architecture of the Dharwar craton, India

Kusham[1], P. Rama Rao[2], Naganjaneyulu K[3]
[1]Indian Institute of Petroleum and Energy, Visakhapatnam
2Andhra University, Visakhapatnam
[3]CSIR-National Geophysical Research Institute, Hyderabad
[*]Presenting author: kusumsandhu33@gmail.com

The magnetotelluric study related to the crustal structure and Lithosphere-Asthenosphere boundary (LAB) is highly impacted by national and international standards. A structural measurement is a basic step to map a mineralization zone and any earthquake-prone area. The Dharwar craton is situated in the Southern Indian Shield Region. The lithospheric mantle beneath the Dharwar craton is imaged by using 74 magnetotelluric stations distributed along three parallel west-east oriented profiles. The measurements are within the period range of approximately 0.01 to 10,000 s. Dimensionality and directionality analyses were done to obtain the nature of the Earth. Modeling/inversion was carried out using the latest 2D and 3D inversion codes. The significant findings of the research work are 1) The first 3-D inversion model using magnetotelluric data for the Dharwar craton 2) The high-resolution 2-D and 3-D images of the Crust and Upper Mantle of the Dharwar craton are useful contributions to the geodynamics of the region 3) Conductive features in the crust of the eastern Dharwar craton are correlated to the presence of fluids present in the region 4) The conductors in the crust of the western Dharwar craton are due to sulphur present in the form of pyrite 5) Upper mantle conductors in the eastern Dharwar craton are due to kimberlite melt 6) Upper mantle conductor in the western Dharwar craton is due to the re-fertilization process 7) Identified eastward subduction polarity in the Dharwar craton 8) The magnetotelluric models obtained show the Chitradurga shear zone (CSZ) is the boundary between the eastern and western Dharwar craton 9) Lithospheric thickness is more than 200 km in the Dharwar craton. These findings have significant societal and economic implications including mapping weak zones/faults/shear zones that are susceptible to the occurrence of earthquakes and the emplacement of diamondiferous kimberlites and other mineralized zones. These studies map the lithospheric mantle beneath the Dharwar Craton that is underlain by a thick root around 200 km - an environment conducive to a diamond stability field (eastern Dharwar craton). Lithospheric structural mapping in terms of the electrical conductivity anomaly is a good alternative to the other geophysical methods and provides a better constraint to the Earth's model.

Gender Equity in Geosciences

Mrinal K Sen
Jackson School of Geosciences, University of Texas at Austin

In any workplace, diversity and inclusion optimize and improve performance. This is because a wide range of approaches and perspectives is the key to drive invention and innovation. There has been an increased awareness on the necessity to work in a more gender-balanced social structure. However, in the STEM (science, technology, engineering and medicine) field, women are the underrepresented minorities. The metaphor 'Leaky pipeline' describes this phenomenon. Although this is prevalent in most STEM fields, studies conducted in different parts of the world show clear underrepresentation of women in Geosciences. Data show that the number of women geoscientists in leading positions is small compared to men. Similarly, the number of women as first authors in the leading Geoscience journals is also disproportionately small. The objective of this talk is to present some data from published literature from different parts of the world and have an open discussion on addressing this issue.

Geomagnetic signatures associated with the Hunga-Tonga Volcanic eruption event on January 15, 2022

N. Phani Chandrasekhar*, Kusumita Arora, Joshi Catherine
CSIR-National Geophysical Research Institute, Hyderabad, India
**Corresponding: phani@ngri.res.in*

On 15 January 2022, at around 04:00 UTC, the submarine volcano Hunga Tonga-Hunga Ha'apai erupted in the Pacific Ocean and injected an enormous amount of mass and energy into the atmosphere. This eruption caused a severe disturbance in the E-region ionosphere or even higher, providing an opportunity to investigate the geomagnetic effects associated with acoustic resonance. We have examined the 1 min vector and scalar data from 20 geomagnetic observatories to evaluate the time-frequency characteristics of the geomagnetic signals associated with the volcanic eruption.

Our analysis indicates that the geomagnetic signatures associated with the volcanic eruption are more prominent in the X-component at equatorial and low-mid latitudes, reflecting the influence of the eruption over a 16000km radius from the Hunga Tonga. The analysis of the observed similarities and differences in the geomagnetic signatures at the observatories associated with the volcanic eruption will be presented and discussed.

Dynamic Rockfall Analysis of NE Region: Prediction and Prevention

T.N. Singh
Director, Indian Institute of Technology Patna, Bihar
Email: tnsiitb@gmail.com

Rockfall problems are increasing day by day due to fast and accelerated infrastructural development. North Eastern part of Himalaya is comparatively weaker than other part of Himalaya. To increase the connectivity, road network is most preferred economically viable solution. Existing road widening due to connect the area with mainland, pose various technical problem in term of stability, safety and sustainability.
Rockall problems are slightly different from normal rockslides, debris flow, sinking ground, etc. The problem of rock fall may trigger initially at small magnitude but damage is more due to high momentum and velocity.

In this paper, an attempt has been made to analysis and review the rock fall potential area of North Eastern Himalayan region and also provide better solution which will be safe, secure and scientific in nature based on field, laboratory and simulation tools.

Machine learning passive Seismic imaging

Sunjay
Geophysicist IGCP UNESCO Projects
Presenting author: sunjaytellus@gmail.com

Seismological data analysis is done by wavelet transform -spectral decomposition, singular spectrum analysis, nonlinear nonstationary signal processing by empirical mode decomposition Hilbert Huang transform, etc. Passive seismic imaging earthquake data-based exploration technique is employed for extractive industry geosciences hydrocarbon, minerals, coal geothermal energy resources exploration, lithosphere subsurface imaging earth crust sounding, faults imaging tectonics sediment thickness measurements, etc. Machine learning picks out hidden vibrations from earthquake data, seismic waves at low frequencies around one hertz are often drowned out by the earth's noisy seismic hum, which is useful to delineate deeper subsurface geological structures. Seismic site effect H/V horizontal to vertical spectral ratio HVSR- Fourier amplitude spectra of the horizontal and vertical component of microtremors, V/H spectral ratio VHSR, etc calculated for passive seismic imaging. Wavelet transform suffers from spectral leakage smearing of the signal. For removing spectral leakage Synchrosqueezed wavelet transform empirical mode decomposition is employed for passive seismic attributes analysis. Passive seismic imaging is efficient for ocean bottom seismometer deepwater hydrocarbon exploration, Fiber optics sensors DAS distributed acoustic sensor for broadband passive seismic data acquisition.

Machine learning ML /deep learning /statistical learning uses computer algorithms for understanding the relationships between large amounts of complex interrelated subsurface geological information data. Artificial intelligence adaptive, cognitive science applications for geosciences subsurface imaging and interpretation, Artificial Neural Network ANN-CNN Convolutional Neural Network, DNN Deep Neural Network, ResNet Residual Neural Network, unsupervised and supervised machine learning, deep learning, reinforcement learning for seismological data analysis, etc. Physics Informed Neural Network PINN, grey box model [whitebox-physics, BlackBox-data, black+white= grey], Graph Neural Network GNN machine learning wavelet transform for machine learning WCNN training CNN with wavelet transform for geological subsurface feature extractions. SeisBench toolbox for machine learning in seismology.

Pre-Congress Workshop on AI/ML for Geoscience
November, 15, 2022, WIHG, Dehradun

Artificial Intelligence (AI) Applications in Geoscience

Human brain is an expert system in analyzing patterns or, putting it in other way human intelligence is quick in demonstrating its proficiency for making qualitative analysis. For example, if you are asked to identify your family members from a crowd, it takes a fraction of second to execute this particular job. However, if you are asked to perform certain quantitative tasks e.g., weights and height of each person in the crowd, how much property (e.g., bank balance, land area, vehicles etc.,) each of them possess, what is the permanent identity number of each within the crowd etc., after certain time such computations becomes difficult and tiresome. The brain becomes exhausted in delivering accurate answers to these questions. If a machine (e.g., calculator or a computer) on the other hand is programed to do such jobs, quantitative solutions could be rapidly and easily achieved. A machine has the ability to work continuously and deliver such solutions with great accuracy. When these machines are trained to work under a guidance of human intelligence, optimum solutions to large and complex problems can be achieved at much ease. This motivates to amalgamate human intelligence with machine intelligence to solve complicated non-linear problems

Content of the Workshop

Session 1
- What is and Why AI

Session 2
- Types and Techniques

Case Studies
- Subsurface Interpretation
- Geohazard Mapping
- Mineral Classification

Course Instructors

Dr. Kalachand Sain, Director, WIHG
Dr. P.C. Kumar, Scientist, WIHG

Wadia Institute of Himalayan Geology
(An Autonomous Institute of DST, Govt. of India)
33, General Mahadeo Singh Road
Dehradun-248001 (INDIA)

3rd Triennial Congress of Federation of Indian Geosciences Associations on Geosciences of Himalaya for Sustainable Development

16-18 November, 2022

EXCURSION GUIDE TO THE HIMALAYAN FRONTAL FOLD-THRUST BELT

Prof. R. Jayangondaperumal

Dr. Rajeeb Lochan Mishra

Wadia Institute of Himalayan Geology, Dehradun 248001

WADIA INSTITUTE OF HIMALAYAN GEOLOGY

(An Autonomous Institute of Department of Science & Technology, Government of India)
33, General Mahadeo Singh Road, Dehradun 248001
EPABX : 0135-2525100, Fax : 0135-2625212
Website: http://www.wihg.res.in

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SUMMARY

The Himalaya is an orogenic belt of the Cenozoic Era, which extends for ~2500 km with syntaxial bends on its western and eastern extremities, respectively. The Himalaya is divided from south to north into four parallel longitudinal mountain belts of varying width, each having its own physiographic features and geological history. They are the Outer (or Sub-) Himalaya, the Lesser (or Lower) Himalaya, the Higher (or Greater) Himalaya, and the Tethys (or Tibetan) Himalaya. Farther north, lies the Trans Himalaya which includes the Ladakh, Karakoram, and Mansarovar ranges. The Himalaya lies between the Indian subcontinent to the south and the high plateau of Tibet with ~4 km average altitude to the north.

Our country has a unique geological history comprising geological and geodynamic processes spanning over a long period representing Precambrian to Quaternary. The Himalaya is one of the most significant creations of collisional tectonics. It remains essential to investigate and understand various geological, geodynamics processes, tectonic control, climate change, natural resources, etc.

Young minds consistently contribute to the growth history of geoscientific research. The field excursion during the 3rd Triennial Congress of the Federation of Indian Geosciences Association (FIGA) will cover the region of Dehradun in the Sub-Himalaya and adjoins. Dehradun is a late-Quaternary intermontane basin, a synformal depression, flanked to the south by the Mohand anticline. The southern, frontal limb of the anticline abuts against the Ganga-Yamuna alluvial plain along a physiographic-tectonic contact, the trace of this contact defines the Himalayan Frontal Thrust (HFT), also known as the Main Frontal Thrust (MFT). The HFT marks Holocene fault scarps produced by paleoearthquakes.

The one day field trip will cover three spots on the active Himalayan frontal thrust near Mohand, where youngest fold-thrust belt meets the modern Indo-Gangetic alluvial plain, the Bhauwala Thrust, an out-of-sequence thrust north of the HFT, forming fault scarps, and lastly the Main Boundary Thrust (MBT) near Rajpur.

Introduction

Field excursion will cover the region of Dehradun in the Sub-Himalaya and adjoins. Dehradun is a late Quaternary intermontane basin, a synformal depression, flanked to the south by the Mohand anticline. The southern, frontal limb of the anticline abuts against the Ganga-Yamuna alluvial plain along a physiographic-tectonic contact, the trace of this contact defines the Himalayan Frontal Thrust (HFT), also known as the Main Frontal Thrust (MFT). The HFT marks the occurrence of Holocene fault scarps produced by paleoearthquakes.

The one day field trip will show, (1) the active Himalayan frontal thrust (or Main Frontal Thrust) accretionary wedge and its relation to the modern foreland basin near Mohand, where youngest fold-thrust belt meets the modern Indo-Gangetic alluvial plain (IGAP), (2) the Bhauwala Thrust, an out-of-sequence thrust north of the HFT, forming fault scarps, (3) the Main Boundary Thrust (MBT) near Rajpur (Fig. 1).

Geological Setting of the Dehradun Valley

Between the HFT and the MBT (Fig. 2) there are numerous structurally controlled valleys in the Sub-Himalaya, referred to as Doon (or Dun) valleys (Nakata, 1972). Dehradun is one of them. Displacement along the north dipping MBT has produced a sharp escarpment and raised the Lesser Himalaya to elevations of 2000 to 3000 meters. The Sub-Himalaya consists of fluvial sediments of Siwalik Group deposited outboard of the rising Himalaya. The age of the Group ranges from 0.5-18 Ma. The sequence coarsens upwards from the

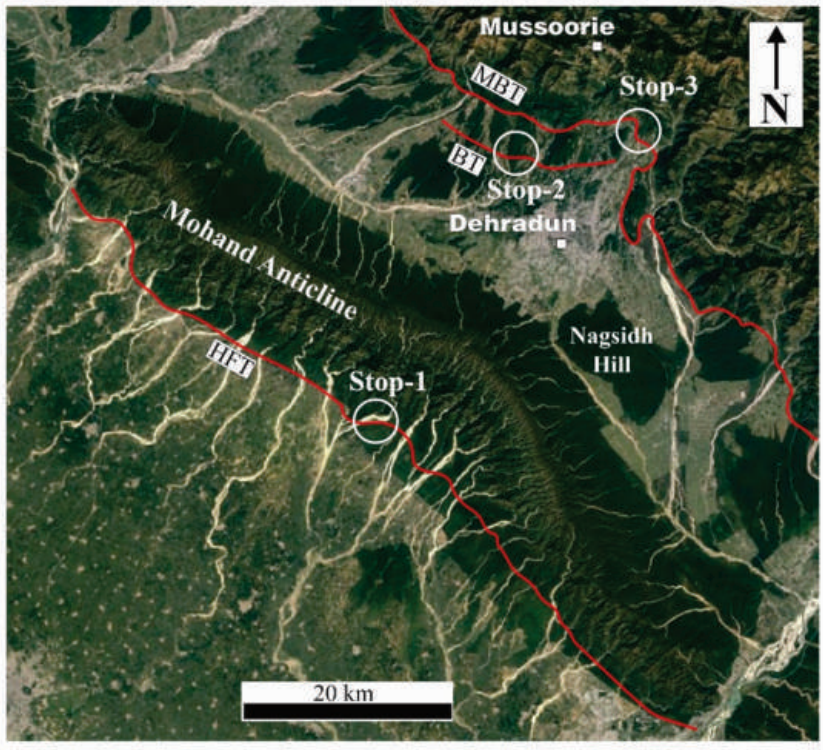

Figure 1. Map showing the three stops (1-3) for field excursion.

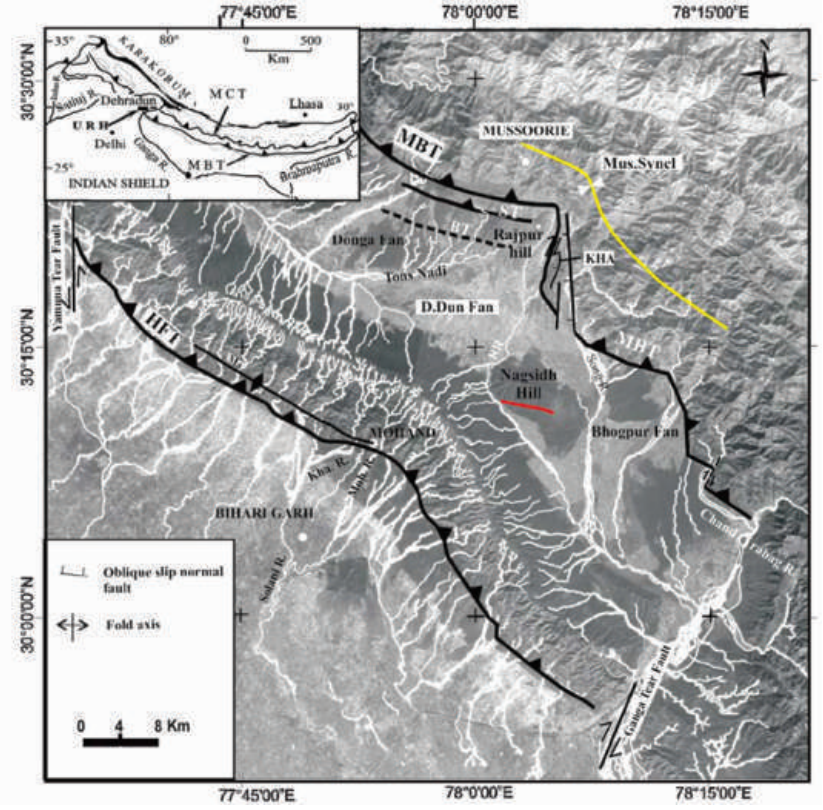

Figure 2. Cartosat-1A imagery showing the Mohand anticline and other structural elements between the HFT and MBT (Jayangondaperumal et al., 2010).

predominantly mudstone and siltstone of the lower facies through the predominantly sandstone and conglomerates of the middle and upper facies, respectively (Kumar et al., 1983).

Displacement along the HFT has raised the hanging wall Siwalik Hills to elevations from 500-1000 m above the adjacent Indo-Gangetic plain, south of Dehradun (Figs. 2, 3). Siwalik Hills to the northeast of the Mohand Thrust, a segment of the HFT, comprise mainly homoclinal strata with northerly dips of 20-30° (Wesnousky et al., 1999). Along a relatively narrow zone at the HFT, a dip reversal defines the Mohand asymmetric anticline (Rao et al., 1974), with dips of 50° and greater on its southern flank (Fig. 4). The anticline is well defined to the west of the Yamuna River but to the east between the Mohand village and the Yamuna River, the anticlinal structure merges closer to the HFT and is characterized by numerous closely spaced and laterally discontinuous folds (Rao et al., 1974; Raiverman et al., 1993).

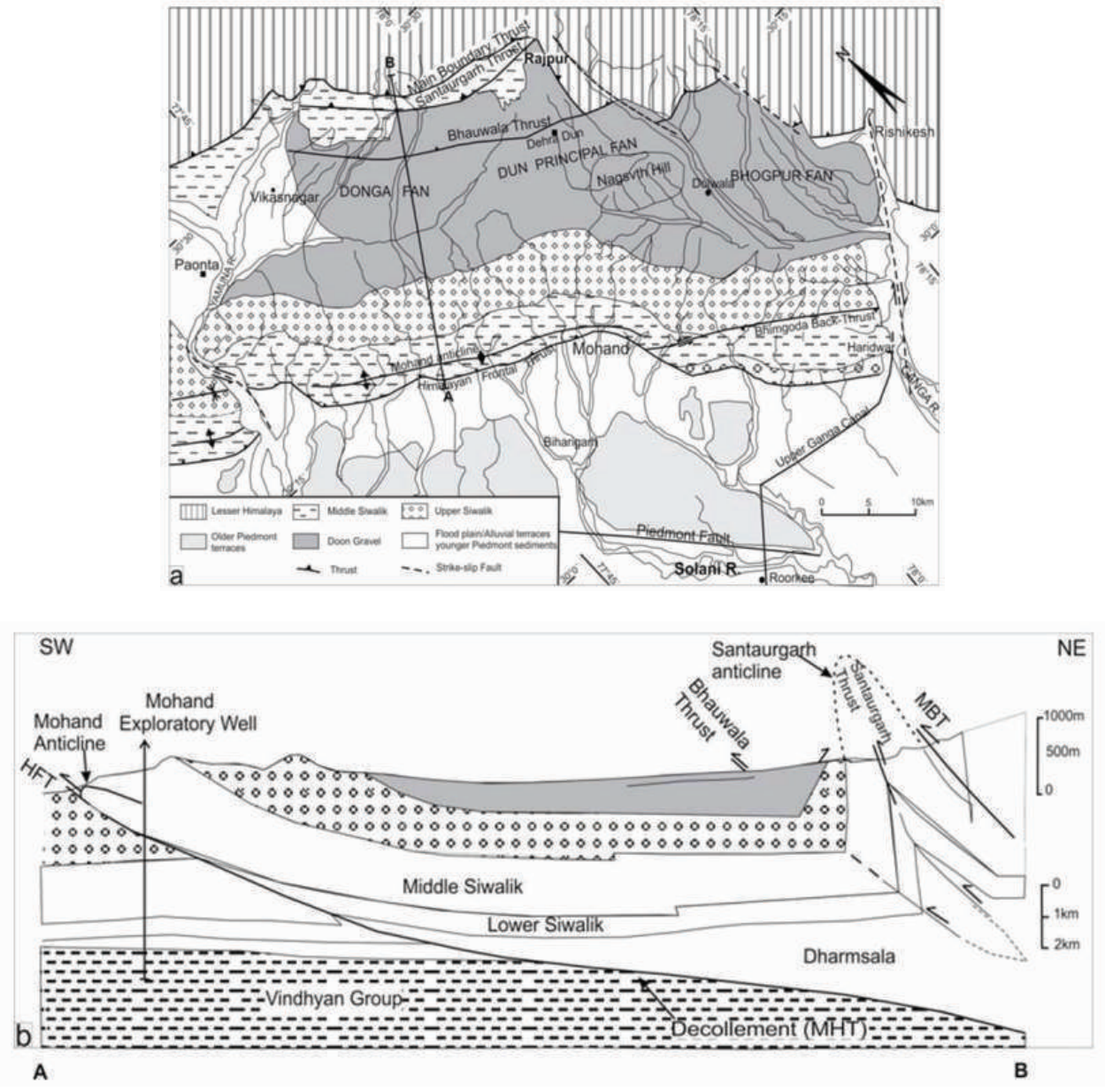

Figure 3. (a) Geological and Geomorphological mapping of Dehradun and adjoining regions. (b) A simplified cross section along A-B marked on top panel) (after Thakur et al., 2007).

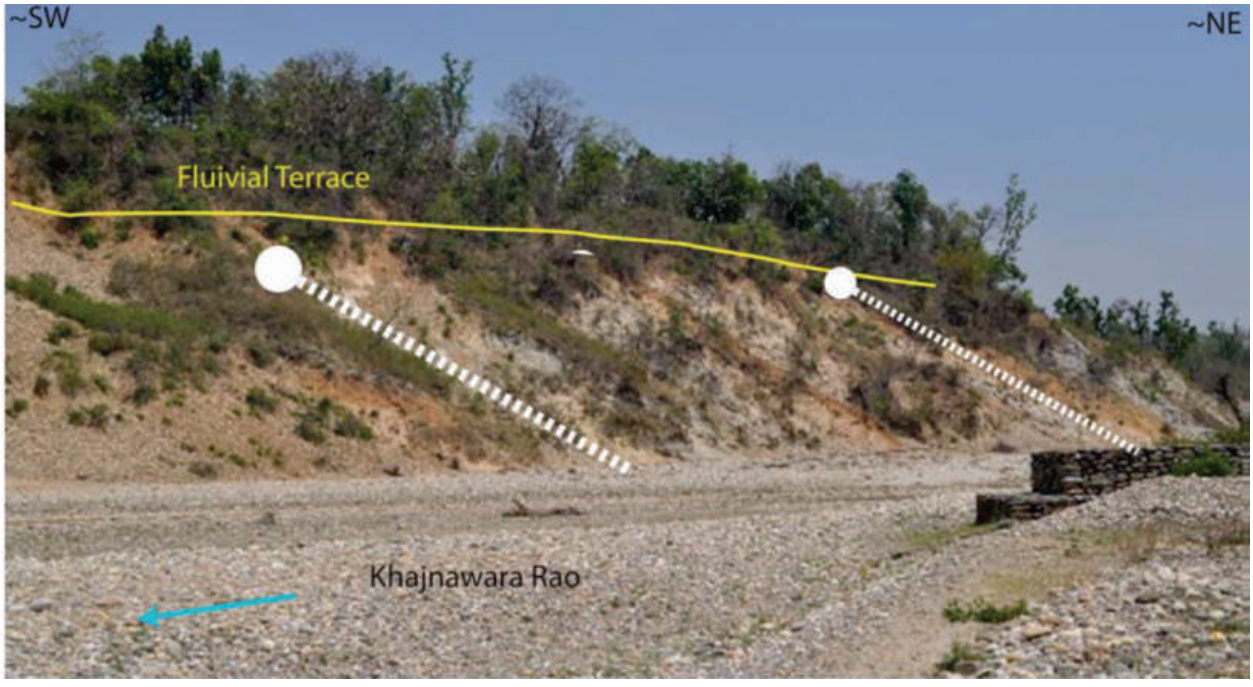

Figure 4. Mohand anticline showing north dipping Middle Siwalik Sandstone overlying with fluvial terrace.

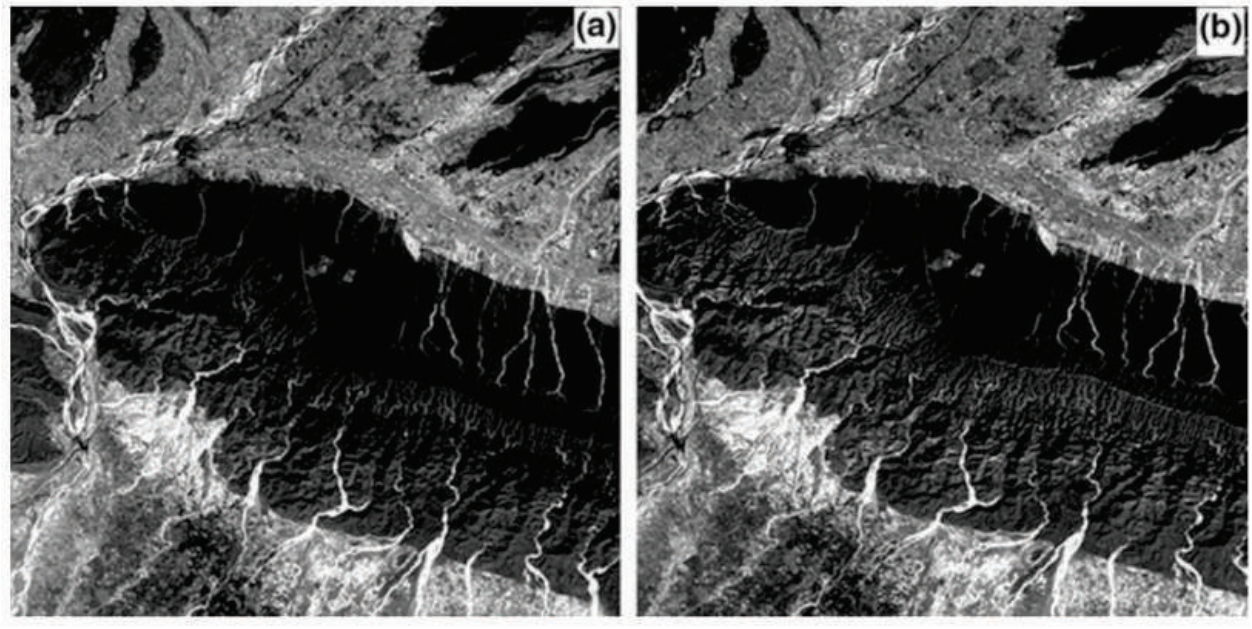

Figure 5. Cartosat-1A stereopair images, (a) Band-F, (b) Band-A showing the Mohand Anticline, NW Himalaya.

Field Stops

The field visit begins from the central part of the Dehradun fan (where the city is located) and pass by road through the Sub-Himalayan range along a south-flowing Mohand Rao (Figs. 1 and 2) to reach Stop-1. Along the road, alluvial fans, hill slope deposits and monotonous outcrops of north dipping sandstone and Boulder Conglomerate of Siwalik Formation are seen.

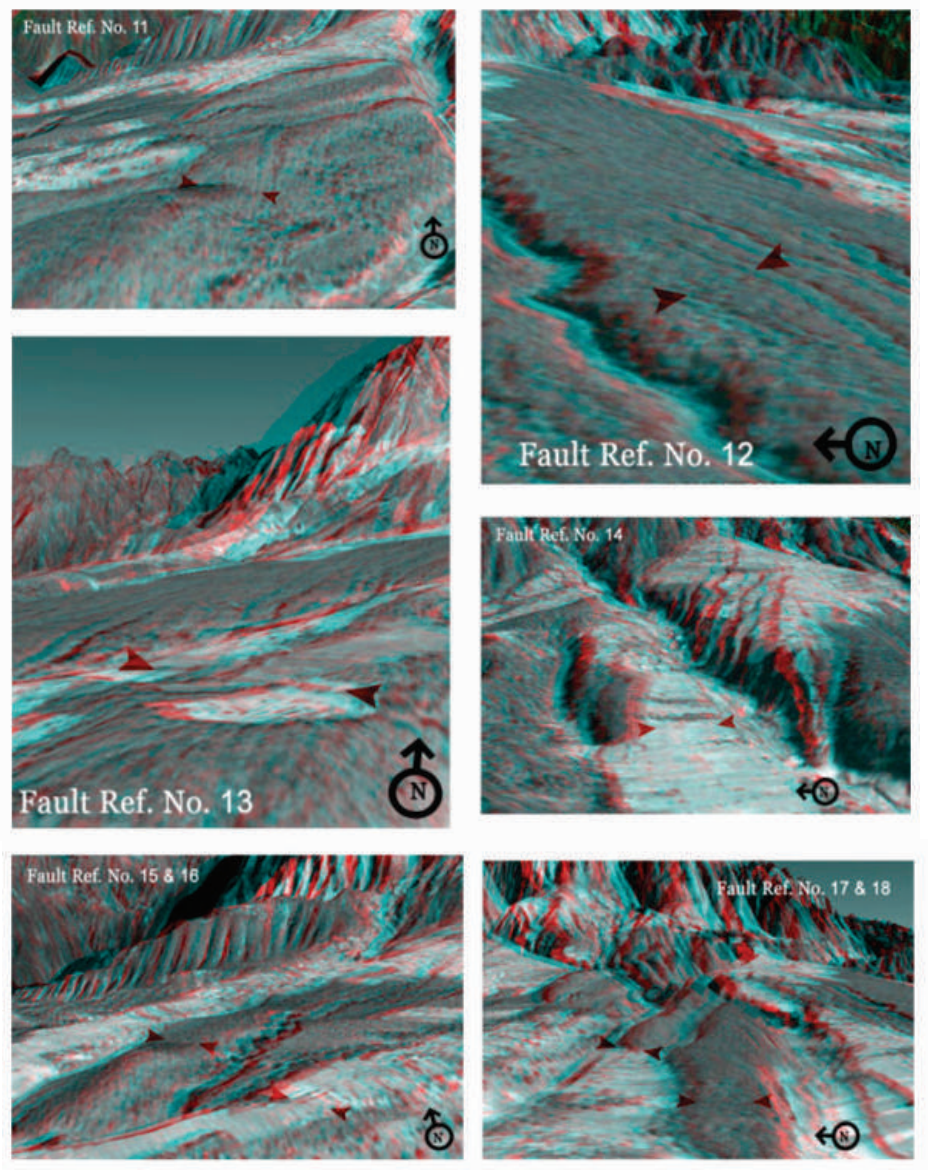

Figure 6. Cartosat-1A based three-dimensional anaglyph images showing fault scarps (red arrows). The active faults were identified and mapped on Cartosat-1A imageries through a flagship project of the Wadia Institute of Himalayan Geology and also available in the online database in the institute website (Jayangondaperumal et al., 2018).

Stop 1: Himalayan Frontal Thrust exposure along the Khajnawara Rao section

At stop-1, south dipping middle Siwalik sandstone abruptly terminates along west bank of Khajnawara River cut cliff section (Fig. 4). Well preserved strath terrace can be seen at a height of ~25 m from the current river grade. Figure 5 shows a Cartosat-1A stereo pair of the Mohand anticline and figure 6 is an anaglyph showing the fault scarps identified and mapped (Jayangondaperumal et al., 2018).

Method for determination of uplift rate

Generally, rock uplift is equal to river incision, as measured from the height of terrace remnants above the

modern river channel. However, a river may also incise due to climatically induced channel geometry and base level changes because of which the local incision may not necessarily be equal to local tectonic uplift.

Age of terrace deposits and estimation of river incision

In north-western India, along the Himalayan Frontal Thrust, terrace deposits are exposed ~25 m above the modern stream level. They are considered to be uplifted by displacement along the underlying HFT. The age of terraces were obtained by excavating pits on the Khajnawara Rao and Shahjahanpur Rao terraces. Radio carbon dating of the terraces constrained the age to ≥1665 ± 215 BC (≤3663 ± 215 radiocarbon years before present) (Wesnousky et al., 1999).

Previous studies have indicated that of the total convergence across the Himalayan orogeny, only a small fraction is being accommodated by shortening at the front of the Himalaya. However, Wesnousky et al. (1999) mapped and surveyed the fluvial terraces along the HFT and have estimated the uplift rate as ≥6.9 ± 1.8 mm/year and horizontal shortening as 11.9 mm/year using a simple trigonometric calculation incorporating height of terrace deposits along in the Khanjawar valley section.

Stop 2: Fault scarps on the Bhauwala Thrust

South of the Santaurgarh Thrust, the N–S trending isolated ridges of thick Dun gravels with pedimented Siwaliks base abruptly terminate with a topographic break. The southern tips of these ridges are aligned along a prominent lineament with uplifted northern block representing the BT (Fig. 7). The BT marks the southern boundary of the steeply dipping pedimented Siwaliks with the Dun gravel cover. This geomorphological and tectonic expression has been observed along all the river sections in the Donga Fan. The BT continues further eastward in the Dun Principal fan, where streams make a sharp knee-bend turn along the lineament. On the basis of the OSL ages of the Dun gravels and their relative positions, the timing of fault activity has been evaluated in Thakur et al. (2007).

Near the Kandhauli village, ~10 m high tectonic scarp of the BT is exposed (Fig. 8). The scarp trends NW–SE and formed within the Dun gravels. Paleoseismic study implies the scarp is a fold scarp formed as a result of fault propagation of a blind fault that may lie at a greater depth than the excavated trench (Jayangondaperumal et al., 2018). OSL dating of the Dun gravels exposed in the trench wall indicates the formation of fold scarp after 15.0 ka (Jayangondaperumal et al., 2018). In the Dun surface, the Santaurgarh and BT are identified in the geomorphic map as well as ortho-rectified Cartosat-1A satellite images (Fig. 7).

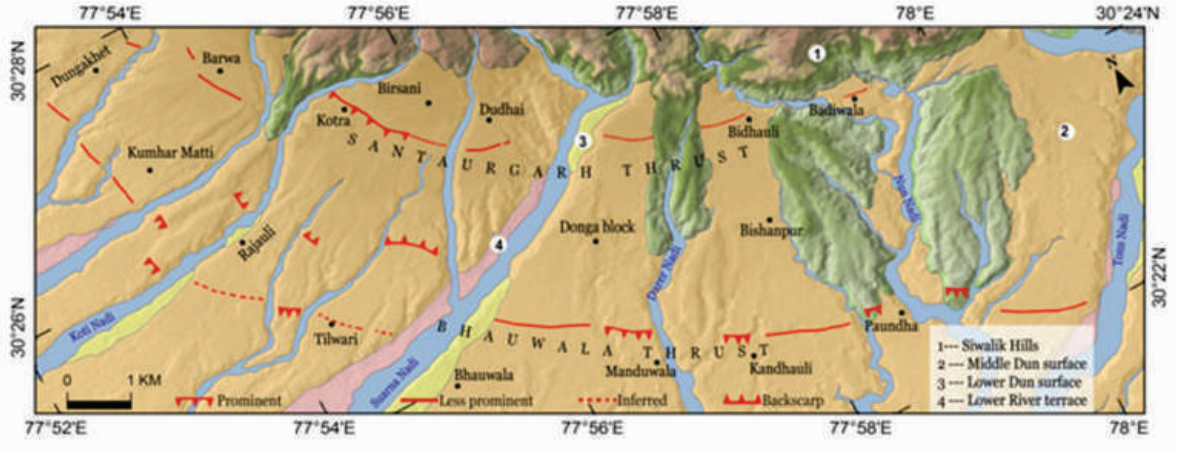

Figure 7. Fault traces of the Santaurgarh and Bhauwala thrusts are characterized with break in slope and formation of scarps within the Dun fan surfaces between the Dungakhet and Tons Nadi (Jayangondaperumal et al., 2018).

Figure 8. Active fault scarp (red dotted line) displacing medial part of Middle dun fan surface near Kandhauli.

Stop 3: Main Boundary Thrust exposure

The northern margin of the Dehradun basin is characterised by an abrupt rise of the Lesser Himalaya Mussoorie range. The base of the range front is marked by the Main Boundary Thrust (MBT). The Mussoorie range is made of Lesser Himalaya sequence of Krol Group, overlain by a small klippe of crystalline thrust

sheet. The Tal Formation of the upper portion of the Krols in the Mussoorie range has important geological history. Earlier, the Krol group was considered as Paleozoic-Mesozoic sequence. The discovery of conodonts fauna in the Tal Formation assigned lower Cambrian age, thereby changing the stratigraphic age of the Lesser Himalaya sequence (Azmi, 1983).

In the Sub-Himalaya zone between the Yamuna and the Ganga rivers, the Siwalik group rocks are folded, from south to north, into Mohand anticline in the frontal Siwalik range, broad Dun syncline occupying the Dun valley, and the overturned Santaurgarh anticline in northern part of the Dun valley (Thakur et al., 2007). The southern margin of the Mohand anticline is marked by a physiographic and tectonic break between the range front and the alluvial plain defining the HFT (Fig. 1). The northern margin of Dun, lying at the base of the Mussoorie range, is demarcated by the MBT, which marks a major tectonic – physiographic boundary between the pre-Tertiary Lesser Himalayan formations of the Krol Group and the Neogene Siwalik sediments of Sub-Himalaya.

At Dehradun-Mussoorie trail toll barrier gulley, a tectonic contact between the Chandpur Formation of the Krol Group and the Dun gravels is observed. The contact zone, a few to ~ 10 m wide zone is characterised by pulverised siltstone, silty shale and quartzite of the Chandpur Formation and fault gauge with incorporation of the Dun gravels. Toward the lower elevation of the gulley near the lower road, the dark grey slaty siltstone and quartzite rest over the Dun gravels along the fault gauge (Fig. 9). A sand lenses in the underlying dun gravels yields OSL (Optically Stimulated Luminescence) age 30 ka. Near the toll barrier on the top side of the gulley, at higher elevation, a younger Dun gravels fan overlaps the tectonic contact between the pulverised Chandpur and the Dun gravels. A sand horizon from this locality OSL dated gave 20 ka age. These two ages, 32 ka and 20 ka bracket, the timing of the reactivated motion on the MBT.

Figure 9. At a locality close to Rajpur, ~10 km north from the Dehradun city, the Chandpur phyllite (dark grey) constituting the basal part of the Krol Group sequence overrides the unconsolidated Dun gravels dated 30 ka. The phyllite near the contact is pulverized and characterised with fault gauge. The fault contact dips 30º northeast (Jayangondaperumal et al 2015).

References

Jayangondaperumal, R., Dubey, A. K., Kumar, S., Wesnousky, S. G., Sangode, S. J. (2010a). Magnetic fabrics indicating Late Quaternary seismicity in the Himalayan foothills. Int. J. Earth Sci 99 (Supl. 1), pp. 265–278. https://doi.org/10.1007/s00531-009-0494-5

Jayangondaperumal, R., Thakur, V. C., Joevivek, V., Priyanka, R. S., Gupta, A. K. (2018). Active tectonics of Kumaun and Garhwal Himalaya. Springer Publications, p. 163.

Jayangondaperumal, R., Thakur, V. C., Tiwari, M. (2015). Excursion guide Himalayan frontal folds-thrusts belts. 30th Himalaya-Karakoram-Tibet Workshop. Wadia Institute of Himalayan Geology, Special Pub. 3, p. 17.

Kumar, G., Raina, B.K., Bhatt, D.K., Jangpangi, B.S. (1983). Lower Cambrian body- and trace-fossils from the Tal Formation, Garhwal Synform, Uttar Pradesh, India. J. Palaeontol. Soc. India, 28, 106-111.

Nakata, T. (1972). Geomorphic history and crustal movements of the foothills of the Himalayas. Science Reports, Tohoku University, 22, pp. 39-177, 7th Ser. Geography.

Raiverman, V., Srivastava, A. K., Prasad, D. N. (1993). Structural style in northwestern Himalayan foothills. Himalayan Geology, 15, pp. 263-280.

Raiverman, V., Srivastava, A. K., Prasad, D. N. (1993). Structural style in northwestern Himalayan foothills. Himalayan Geology, 15, pp. 263-280.

Rao, Y. S. N., Rahman, A. A., Rao, D. P. (1973). Wrench-faulting and its relationship to the structure of the southern margin of the Sub-Himalayan belt around Ramnagar, Uttar Pradesh. J. Geol. Soc. India 14(3), pp. 249–256.

Thakur, V. C. (2013). Active tectonics of Himalayan Frontal Fault system. Int. J. Earth Sci 102(7): pp. 1791–1810.

Thakur, V. C., Pandey, A. K., Suresh, N. (2007). Late quaternary-holocene frontal fault zone of the Garhwal Sub Himalaya, NW India. J. Asian Earth Sci 29(2/3), pp. 305–319.

Wesnousky, S.G., Kumar, S., Mahindra, R., Thakur, V.C. (1999). Uplift and convergence along the Himalayan Frontal Thrust of India. Tectonics, 18, pp. 967-976.

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AHI PSI ISES DST

MoES WIHG NCESS AMD CSIR-NGRI

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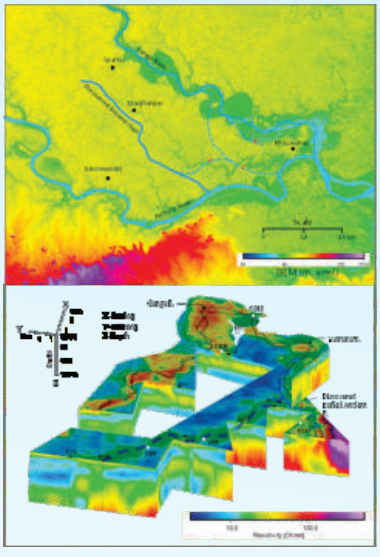

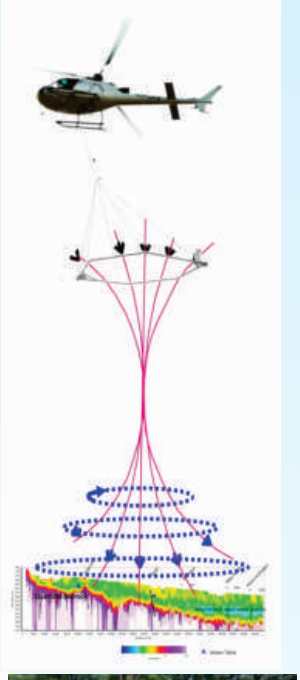

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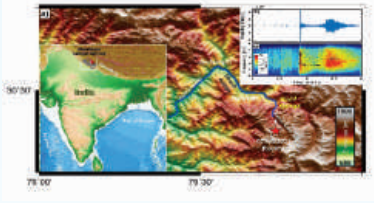

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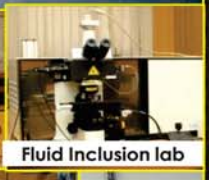
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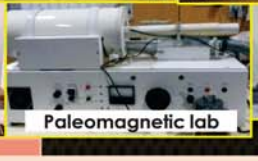
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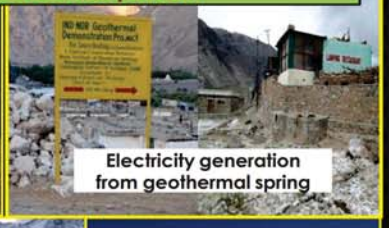
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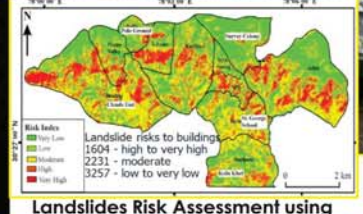

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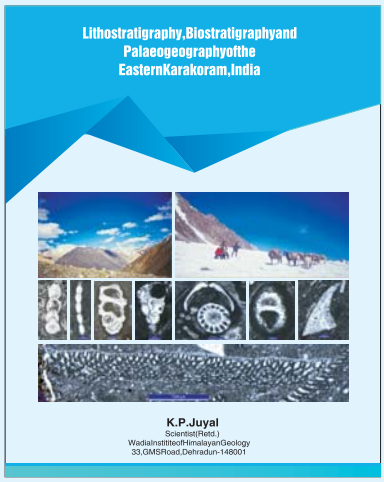

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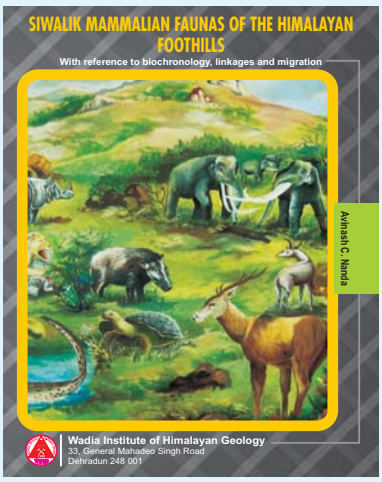

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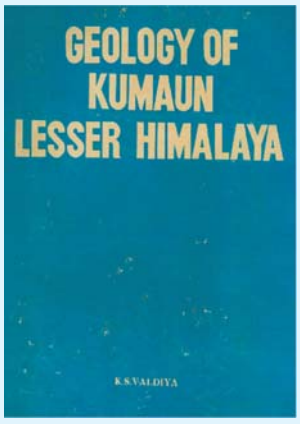

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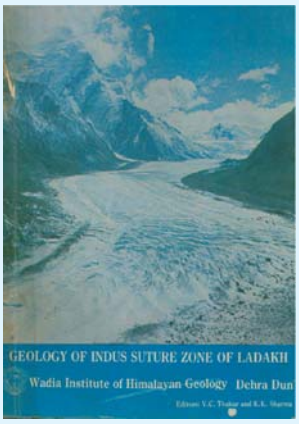

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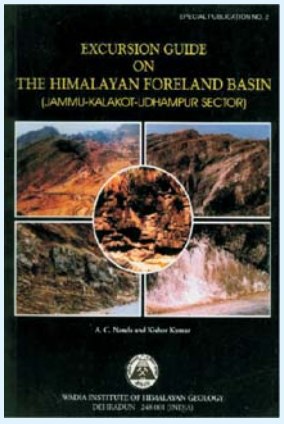

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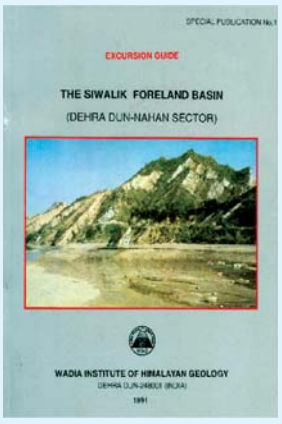

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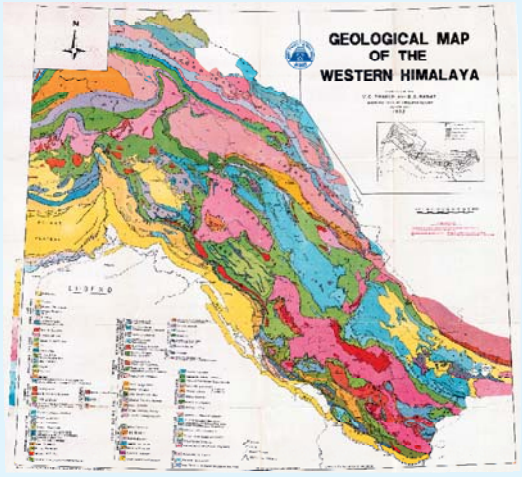

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Publication Section
Wadia Institute of Himalayan Geology,
33, GMS Road, Dehradun 248001, India
Phone: +91-0135-2525430, Fax: 0135-2625212
Email: himgeol@wihg.res.in,
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For Further Information Please Contact:
Prof. Suddhasatwa Basu
Director
CSIR-Central Institute of Mining and Fuel Research
Barwa Road, Dhanbad – 826 015 (Jharkhand)
Phone : 91-326-2296023/ 2296006/ 2381111
Fax : 91-326-2296025/2381113
E-mail : director@cimfr.nic.in
Website:- www.cimfr.nic.in

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