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Institutional Report

Geological Survey of India

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Introduction

Founded in 1851, the Geological Survey of India (GSI) has, made significant progress in exploration and assessmentof mineral resources (including coal) of the country through regional exploration and has provided wide ranging contributions to all aspect of geosciences. The principal function of GSI has been, i) to create and update national geoscientific data base for mineral resource assessment through air-borne and marine surveys, ii) conduct geo-technical, geo-environmental and natural hazards studies, iii) glaciology, to assess the health of Indian glaciers, iv) seismotectonics with an objective to provide geosciences based services to the society. GSI conducts its programmes through Mission- Region hybrid matrix mode with its five Mission offices and three support systems with continued calibration of its vision by adopting the best geoscientific practices, anywhere. For operational ease GSI has six Regions

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based on their geographic distribution. The Missions are responsible for envisioning activities, giving guidelines and targets to the Regions and State Units, monitoring performance and guiding sectoral, scientific and technical reports. The support systems are responsible for the internal management, infrastructure and resource policy planning.

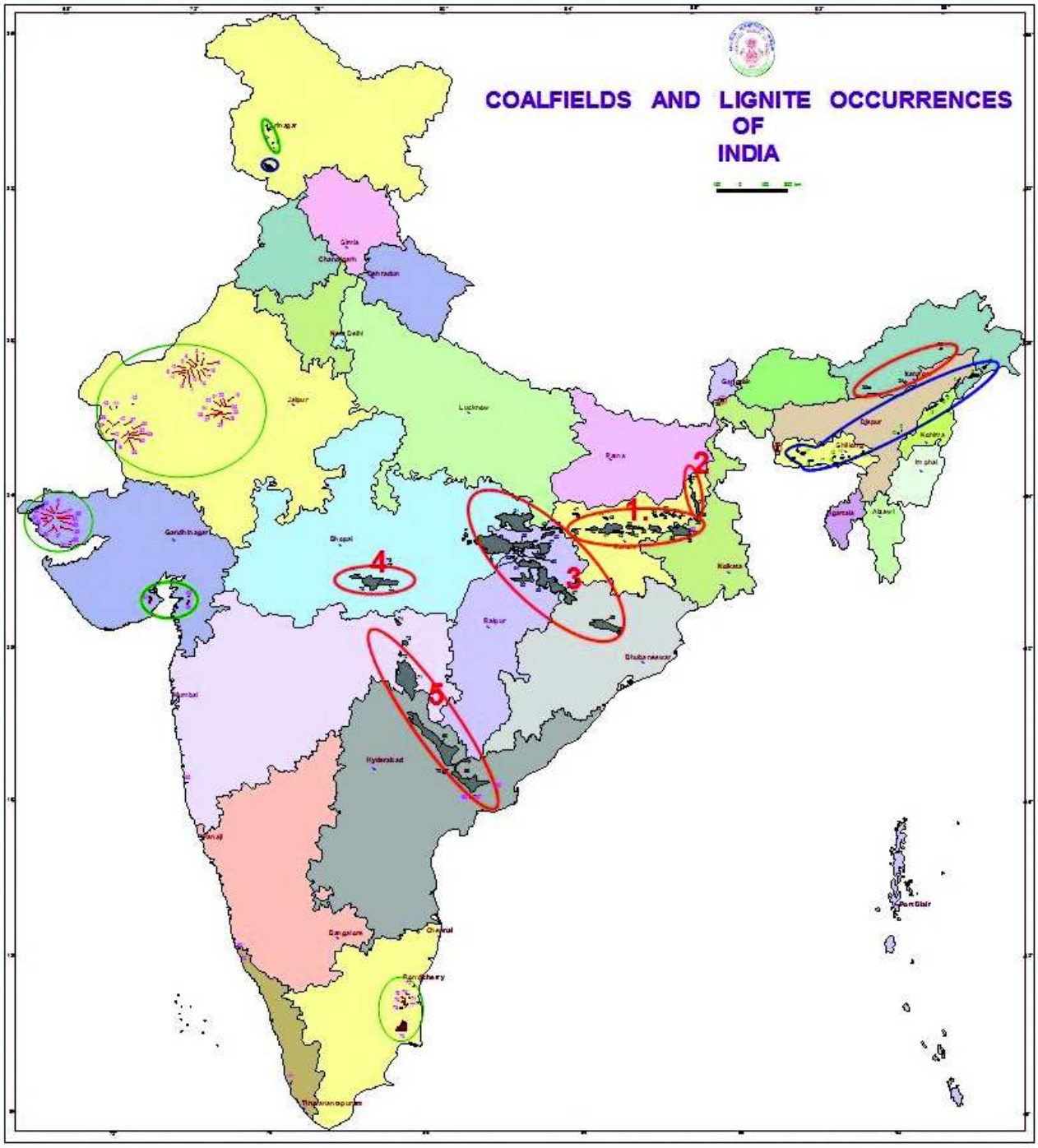
Specialised Thematic Mapping launched in the early nineties has solved many of the outstanding geological problems and have identified new areas for mineral exploration. National Geochemical Mapping and ground Geophysical Mapping Programmes, was initiated in 2001 in the Obvious Geological Potential (OGP) areas for integrating geological, geochemical and geophysical data. Offshore geoscientific studies in the Exclusive Economic Zone (EEZ) and Territorial Waters (TW) along the east and west coasts of India were also taken up.Cruises onboard *RV Samudra Manthan* within EEZ, and *RV Samundra Kaustubh* and *RV Samundra Shaudhikama* within TW. GSI procured *RV Samudra Ratnakar* to replace *RV Samudra Manthan*. A national programme titled "National High Resolution Seabed Mapping and Natural Mineral Resource Evaluation of EEZ of India and beyond" (NHRSM & NREE) was taken up. GSI procured its own "Advanced Light Helicopter – *Garuda Vasudha*" equipped with sensitive state of the art aero geophysical sensors.

S.No.	Mineral commodity	Area of new find	UNFC	Resources
1	Coal & lignite	Talcher and IB river coal field in OdishaMahanadi-Son, Pench valley, Mand Raigarh coal fields, Chattisgarh and Madhya Pradesh; Wardha Valley coal field, Maharashtra; Raniganj coal field West Bengal; Sohagpur coal field, Madhya Pradesh; Godavari Valley coal field Telangana, Singrimari coal field Assam. Lignite- Nagaur, Rajasthan, Ramad, Tamil Nadu and Rajmahal coal field West Bengal		Coal- 13098 MtLignite-2151 Mt
2	Iron ore	Kalamang, Sagasahi, Ghora Burhani, Bonai- kendujhar, Mendharmaruni, Bhalapuri,Eklama & Chelikama Odisha	333	228.91 Mt Fe Ore/ 51- 68% Fe
3	Base Metal	Khera, Mundiyawas-Khera area, Jagpura , Nangwas, Dariba, Palaswala ki Dhani, Rampuriya-Gadariyakhera, Rajasthan	333	81.713 Mt Cu ore/ 0.22- 1.78% Cu1.84 Mt Pb+Zn/ 0.24- 1.88% Pb+Zn
4	Manganese	Damuda, Bolani- Odisha; Nagpur- Maharashtra	333	1.7 Mt/ 7.65- 29.35 % Mn
5	Gypsum	Saharwa- Daryapur- Haryana	333	2.18 Mt/ 57.86 % Caso4.2H2O
6	Phosphorite	Bhorasar, Banswara – Rajasthan, Modri, Jhabua- Madhya Pradesh	333	3.56 Mt / 7.85- 15% P2O5
7	Bauxite	Tantar- Madhya Pradesh	334	173.96 Mt/ 47.7 % Al2O3
8	Graphite	Tikara, Chiklar & Gowthana- Madhya Pradesh	334	4.73 Mt/ 9- 11.68% FC
9	Gold	Ajjanahalli, Tumkur, Karnataka.Gundelapara, Banswara, RajasthanKhera, Alwar, RajasthanSindauri Ghansyampur, Ranchi, JharkhandJagpura area, banswara district, Rajasthan	333	14.12 Mt Gold ore (with avg. Gr.0.90g/t to 1.8 g/t Au)
10	Limestone	Umphyrluh, Larket- Meghalaya, Daba Gamlin - Arunachal Pradesh,Mittagudipadu-Goli and Jettipalem, Andhra Pradesh, Bagalkot-Karnataka, Sabuka Toba, Minyun Ki Dhani-Rajasthan	333	4219 Mt
11	Graphite	Tiara,Chiklar & Gowthana areas, Betul, Madhya Pradesh	333	4.73MT (with 9%-11.68% FC)
12	Glauconite (Potash)	Newari-Barwadih –Uttar Pradesh	334	635.30MT(4.8% K_2O)
13	Andalusite	Salaidih-Harwariya- Uttar Pradesh	334	24.2 MT (14 % Andalucite)
14	Molybdenite	Vellakkal, Tamil Nadu		47986 t (0.518%)
15	Baryte	Gadisunkapur- Karnataka	333	64210 t / 47.95 – 58.78% BaSo4
16	REE & REM	Dhani- Rajasthan	333	39332.880 t/ 0.146% total REE

MAJOR MINERALS ESTIMATED BY GEOLOGICAL SURVEY OF INDIA
[Data as on 01.04.2014 for non-energy minerals&as on 01.04.2015 for Coal/Lignite]
(Resource in million tonnes unless otherwise stated)

Sl No.	Ore/Minerals	TOTAL RESOURCE ESTIMATED, upto 01.04.2014/01.04.2015 (Coal/Lignite)											
		1980	1990	2000	2005	2007	2008	2009	2010	2011	2012	2013	2014
01.	Coal	111000	186044	210448	247846	257380	264535	267211	276810	293497	293497.15	298914.06	306595.56#
02.	Lignite	2855.00	6587.00	29390.00	34864.00	38756.00	38930	39074	39897	41963	41963	43215.86	44114.24#
03.	Tin (metal in tones)	1752	65699	65699	65699	65699	65699	65699	65699	65699	65699	65699	65699 *
04.	Tungsten Ore	38.90	53.68	53.68	53.68	53.68	53.68	53.68	53.68	53.68	53.68	53.68	53.68*
05.	Copper Ore	455.00	509.54	512.24	520.44	572.18	606.18	608.31	608.31	613.426	639.076	670.91	691.933*
06.	Lead-Zinc	241.00	466.00	531.25	532.05	532.57	532.57	532.57	532.57	532.57	533.22	534.41	534.41*
07.	Iron ore	11470.00	13651.00	13651.00	13783.42	13805.45	13811.69	13834.72	13843.94	13891.05	13920.29	13964.62	14119.96*
08.	Manganese Ore	95.00	150.00	155.77	170.15	177.35	179.75	180.70	180.77	180.922	182.206	182.55	182.55*
09.	Bauxite	2489.00	2631.00	2631.00	2636.70	2638.67	2638.67	2638.67	2638.67	2638.67	2812.63	2812.63	2812.63*
10.	Limestone	72229.00	74443.00	81712.00	84035.55	84363.73	84365.22	84365.22	84936.57	85893.12	89279.56	89605.24	89856.01*
11.	Dolomite	3738.00	3958.00	4086.00	4086.00	4086.00	4086	4086	4086	4086	4086	4086.00	4086*
12.	Gold Ore	9.84	22.01	54.38	97.08	106.77	112.22	137.52	144.38	163.26	167.273	170.69	176.585*
13.	Chromite	17	135	146	146	146	146	146	146	146	146	146.00	146*
14.	PGE	–	–	14.2	14.2	15.04	15.04	15.04	15.04	15.292	15.292	15.29	15.29*
15.	Cesium bearing Pegmatite	–	–	0.079	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.11	0.11*
16.	Molybdenm	–	–	5.62	5.62	5.62	5.62	5.62	15.42	15.42	15.46	15.46	15.46*
17.	Rock Phosphate	139	196	199	199	199	199	199	199	199.065	199.965	202.62	202.62*
18.	Potash	–	78	404	404	404	404	404	404	404	404	404.00	1039.30*
19.	China clay	–	–	–	–	–	–	–	–	–	–	2231	2231*
20.	Baryte	–	–	–	–	–	–	–	–	–	–	0.189	0.189*
21.	Silver Ore	–	–	–	–	–	–	–	–	–	–	2.32	2.32*
22.	Graphite	–	–	–	–	–	–	–	–	–	–	–	4.73*
23.	Andalusite	–	–	–	–	–	–	–	–	–	–	–	24.20*

as on 01.04.2015
* as on 01.04.2014



GSI conducted investigations for ferrous and non-ferrous minerals (base metals and strategic minerals), precious minerals and industrial and fertilizer minerals. Numerous new locales of copper, lead-zinc, gold, limestone, bauxite, coal and lignite, diamond, PGE and REE were discovered. Numerous projects covering fundamental and multidisciplinary geosciences were taken up. GSI continued to

participate in the 30th Indian-Antarctica Expeditions. Delineation of land-ice-sea (LIS) interface (grounding-line) around Schirmacher Oasis in Central Dronning Maud Land, East Antarctica; monitoring of the Dakshin Gangotri glacier snout, snow accumulation / ablation on the shelf area and on the Polar Ice Sheet in the Schirmacher oasis, etc. were completed. GSI also participated in the Indian scientific expedition to Arctic and South Pole. GSI Training Institute (GSITI) provides high- quality cutting-edge training in the areas of Geological Mapping, Mineral Exploration and Geo Informatics with state-of-the-art facilities for field and laboratory studies.

GSI has given special thrust to augment the mineral resource potential of the country as per the growing need of the hour. Its activities in mineral exploration as well as baseline surveys increased manifold to sustain the momentum of national economic development and to meet the increasing demands of various stakeholders. It carried out mineral investigations in different part of the country for energy minerals like coal and lignite, non-ferrous minerals like base metal and bauxite, strategic minerals like molybdenum, tungsten, Rare earth metals, precious mineral like gold, PGE, diamond, ferrous minerals like iron, manganese & chromite, fertilizer minerals like apatite and phosphorite, and industrial minerals like limestone, gypsum, graphite, glass sand, talc & steatite. These investigations generated additional resources of coal & lignite, iron ore, manganese, gold, base metals (zinc & copper), molybdenum, limestone, glauconite, andalusite and graphite. Significant achievements were made for deficient and scarce commodities like gold ore in Jagpura, Rajasthan, Ajjanahalli, Karnataka, deficient multi-metal copper-gold resources in Banswara, Rajasthan, copper ore in Alwar and Sikar, Rajasthan, graphite in Betul, Madhya Pradesh and andalusite along with potash from Sonbhadra, Uttar Pradesh. Augmentation of Iron ore, which is the prime raw material in the steel industry was also accomplished in Sundergarh, Odisha and Kabirdham, Chhattisgarh. To tap the placer mineral resources from Sea, special cruises were taken up in the Territorial Water (TW) for identifying promising areas for placer minerals, lime mud and phosphorite etc. and in EEZ for locating favourable zones for polymetalic nodules by the newly acquired research vessel R.V.Samudra Ratnakar.

Baseline Geoscience Data Generation

One of the fundamental activities of GSI is the generation of geoscientific maps on different scales, as per the requirement or theme/problem, using state-of-the-art mapping cum survey techniques. GSI is also engaged in preparation of geochemical and geophysical maps of the mineral potential areas along with the thematic geologic maps on progressively higher resolution (1:25000 or better). Aerial Survey using Remote Sensing techniques and Marine Survey are taken up in order to produce maps of the landmass, coastal areas and extended economic zone (EEZ) of the country.

Preparation of geoscientific maps on different scales through ground, marine and airborne survey has been a core activity of the Geological Survey of India. Mapping has been carried out to solve problems related to stratigraphy, tectonic set-up, crustal evolutionary trend, metallogeny /ore localisation. Out of the total mappable area of 3.14580 million sq km, of the country, 3.09935 million sq km was completed by 2015, i,e, a coverage to 98.52%. Further GSI plans to cover about 80,000 sq km by thematic mapping programmes by 2017.

Mapping has helped in delineating mineralised zones for gold and associated base metal in Gundelpara, Kundiyan-Parmeshwarpura and Dhamana-Devariya, Rajasthan; Kadiri Schist belt, Andhra Pradesh; Nanhwara-Vilayat Kalan area within Mahakoshal Group of rocks, Madhya Pradesh; REE in Dhani Granite and Gothara Granite, Rajasthan; Sausar Mobile Belt and Tirodi biotite Gneiss, Maharashtra. Chromite & PGE mineralisation in the Chimalpahad ultramafic complex, Andhra Pradesh and ultramafic/mafic rocks of Nilambur valley, Kerala.

National Geochemical Mapping

National Geochemical Mapping is another activity of GSI, the data from the surveys is being used in mineral exploration to target concealed mineralised bodies in soil cover areas, soil fertility assessment, human/ animal health, and in establishing environmental baseline of geochemical parameters. NGCM is to create a seamless geochemical base map on 1:50,000 scale of different elements for the entire country where the main medium of sampling is fluvial/stream sediment or slope wash material in 1km x 1km or

2km x 2km cells depending on the various terrain conditions of the country. Composite samples from these cells are subjected to analyses for 68 elements to identify anomalous zone/s of elemental concentration after due geological interpretation.

The country has an area of 3.28 million sq km, spreading over 5112 toposheets (1:50,000 scale) depicted by hard rock, soft rock and alluvial sediments. Till March 2015, 16.54% of landmass equivalent to 0.54 million sq km spreading over 754 full and 285 part toposheets has been mapped. Out of 0.54 million sq km covered so far 0.24 million sq km falling in the obvious geological potential (OGP) area is covered. A GIS based Geochemical Database Management and Information System (GDMIS) has been developed, to create maps enhanced for mineral exploration. Exploration programmes based on the NGCM data were taken up in many regions.

National Geophysical Mapping Programme

The National Geophysical Mapping Programme (NGPM) of GSI aims to generate baseline Geophysical data to help locate and delineate subsurface geological structures and develop conceptual models of mineralised belts. This is done by a combination of geological and geochemical maps to locate potential/ probable target areas for mineral exploration. Thus the gravity-magnetic anomaly maps helps in planning and formulating strategies for structural and tectonic studies, geo-technical studies, mitigation of natural hazards and management of environment and urban planning. So far NGPM has covered, a total of 0.28 million sq km area and this is about 9% of the land area.

Marine and Coastal Surveys

A detailed offshore programme "National High Resolution Seabed Mapping and Natural Resources Evaluation of the EEZ (NHRSM&NRE) of India and beyond" is underway. So far Marine and coastal surveydivision of GSI has completed seabed mapping of 1,32,585 sq km out of in 5 km × 2 km grid within Territorial Waters (TW) and 18,54,534 sq km in the Exclusive Economic zone (EEZ) beyond Territorial Waters. The total EEZ coverage including TW is 19, 87,119 sq km out of a total EEZ area of 20,14,900 sq km. Vast resources of economic placer minerals and relict sands have been delineated besides identifying encouraging occurrence of lime mud, phosphate bearing sediments and Fe-Mn encrustations within the EEZ of India.

During 2012-2015, the Marine and Coastal Survey Division has estimated total resources of 132,196 mt of placer deposits over an area of 466 sq. km along the east and west coast of India.

Societal Programmes

Geotechnical Investigations

GSI has successfully completed several of Water Resource Projects including hydroelectric, irrigation and river-linking projects within the country and outside, in a cost-effective manner. GSI also extended its expertise in the construction of communication projects, thermal power projects, and nuclear power plants and in urban development schemes based on techno-economical and eco-friendly considerations. Geotechnical evaluation of tunnels/bridges at sites located at higher altitudes and passing through vulnerable reaches of different geological formations was successfully carried out by GSI. A few projects are listed below

- The Arpa-Bhainsajhar Barrage Project, Chattisgarh envisages construction of a 12.35m high and 147 m long central barrage to irrigate 2500 hectares of land covering 92 villages in the command area. The barrage area in general, is occupied by overburden material comprises alluvial clay, flood plain deposits and river sand. Surface and subsurface investigation revealed that the quartzite of Chandrapur Formations of Chhattisgarh Group will be the foundation medium in major part of the barrage and the depth to bedrock varies from5.0 m to 14.80m.
- Pench Diversion Project, Chhindwara District:A 41m high and 6330m long composite, concrete-cum-earthen dam is under construction at the confluence of Pench River to provide irrigation facilities in parts of Chhindwara and Seoni districts. The foundation medium in the COT comprises moderately weathered to fairly fresh massive type basalt with vesicular-amygdular type basalt in small patches. Excessive water seepage through side walls was also reported. At spillway site, to decipher the nature of foundation medium, fifteen boreholes, with

cumulative depth of 164m were drilled. Study of Geological L–section revealed that the designed foundation grade (+584m) would mainly encounter massive basalt of "Good to Very Good" rock category.

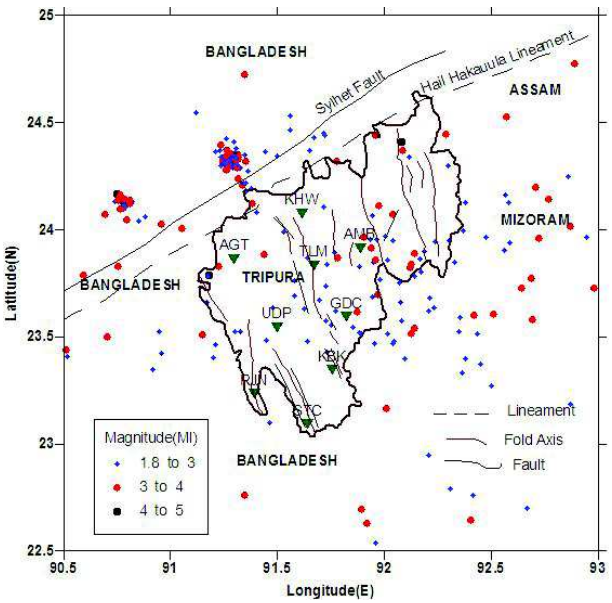
- The Khindsi Feeder Canal Project, Maharashtra envisages construction of a 15.33 km long Water Conductor System to utilize the surplus waters from the Nawegaon Khairi dam (on Pench River) to recharge Khindsi Reservoir, by diverting 63 mm^3 of water annually. 3-D geological mapping on 1:200 scale over a cumulative reach of 320 running meters covering 2240 m2 area and wall mapping of 640 running meters covering 11900 m2 areas was carried out. The foundation strata encountered is found good for construction of the R.C.C. conduit structure.
- Suntaley Hydropower Project:The project envisages construction of 48m high composite dam across river Rangpo, near Suntaley Tar village, East Sikkim. The water will be carried through 4.10 km long Head Race Tunnel (HRT) to a surface powerhouse on the left bank of Rangpo River having installed capacity of 60 MW (2x 30). 3D geological logging of exploratory drift on the left abutment of the Dam (on dam axis) reveals that the drift comprises of phyllitic quartzite and highly puckered phyllite intersected by shallow dipping foliation joint and three other prominent joints and a random joint. No major shear is exposed in the drift.

Seismic/Earthquake Studies

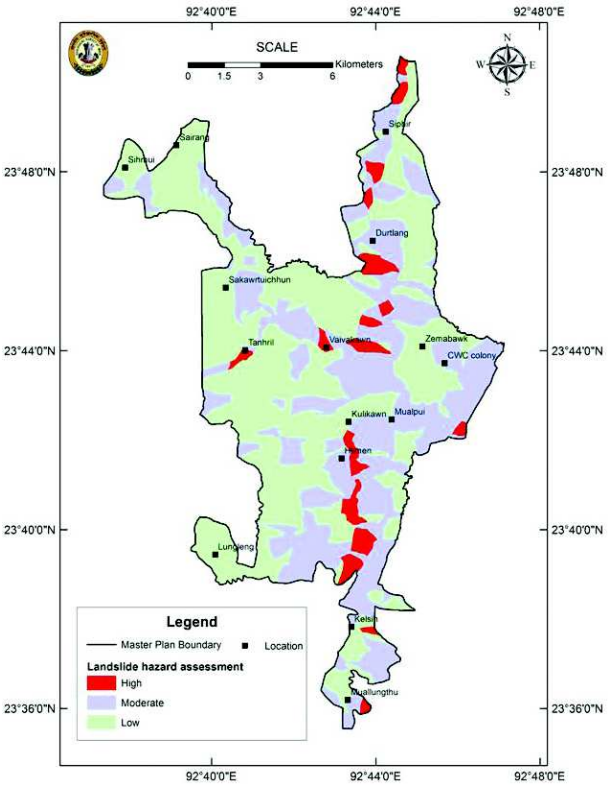
Seismic studies at GSI include, macro-seismic survey (post-earthquake damage survey for assigning intensity), seismic hazard microzonation, micro-seismic (after shock) survey, GPS monitoring for crustal movement, and seismic observatories. GSI focused in studying active fault (source region) and seismic microzonation of urban agglomeration in various geological domains of the country. Active fault mapping including some interplate and intraplate faults emphasises the relevance of studying the nature of source region of earthquake.

During this period GSI monitored active fault and seismic hazard microzonation studies. The studies includes, unravelling the most plausible seismic structure of the Shillong Plateau and monitoring of MBT and MCT west of Bam fault in Arunachal Pradesh; Seismic hazard assessment of Pune (Maharashtra), Trichur (Kerala), Aizwal (Mizoram), Gangtok (Sikkim) and Greater Surat of Gujarat. In addition to this, active fault studies around foothills of Mishmi Block of Arunachal Himalayas. In addition (1) macro seismic survey in parts of Meghalaya, Assam, Nagaland and Arunachal Pradesh (2) detailed geological and geotechnical investigation in Aizwal and (3) post-earthquake study in Meghalaya were also taken up. During 2013-14, seismic hazard risk study of Baroda and Kohima city, geodynamic active fault mapping and seismic microzonation were taken up. Further, Seismic hazard microzonation of Satara, Koyna and Warna areas, Maharsastra; Darbhanga Urban Agglomeration, Darbhanga District, Bihar; Amritsar Urban Agglomaration, Punjab; Greater Baroda town, Gujarat; Active fault mapping along selected domains of West Patna Fault, Bihar was taken up to assess the seismic hazard.

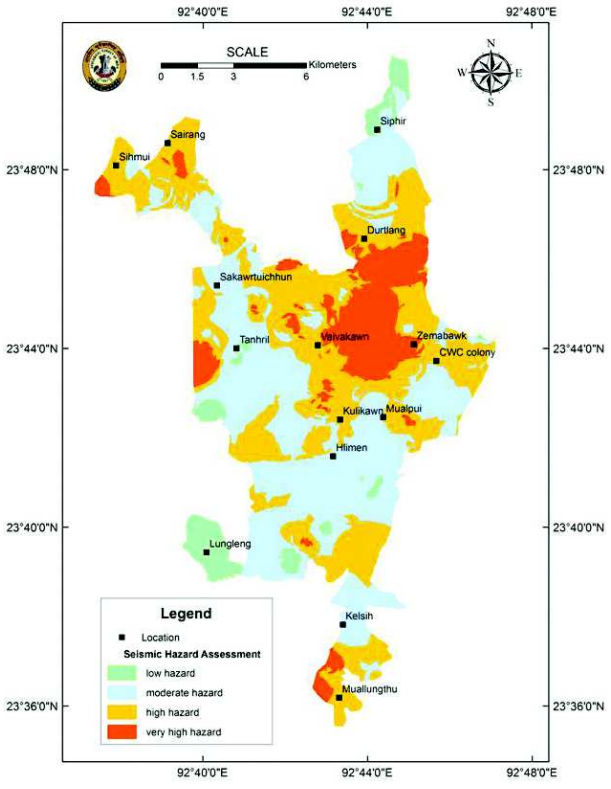
In order to understand the seismicity pattern, nature of faulting and sub-surface heterogeneity in the entire Tripura Fold belt and its adjoining areas, a comprehensive seismic monitoring was carried out by establishing temporary seismic network, consisting of 9-seismographs (5- Broad Band and 4-Short



Tectonic map of Tripura fold belt showing the distribution of earthquakes. Green triangles denote station locations and solid circles located earthquakes



Landslide Hazard Assessment Map of Aizwal town, Mizoram



Seismic Hazard Assessment Map of Aizwal town, Mizoram

Period), installed at different locations of Tripura state. A total of 246 earthquakes (M<5.0) were located and the data set was plotted as epicenter map shown. It was found that most of the earthquake magnitudes (M_L) are in the range of 2.0 to 4.0 and a few earthquakes are of magnitude more than 4.0. Focal depths of located earthquakes showed variation from 5 km to 150 km. Preliminary observation indicated cluster of events in and around Sylhet fault, orienting towards NW direction from Khowai (KHW) seismograph station.

Seismic and Landslide Hazard Assessment of Aizwal town, Mizoram was taken up. A Landslide hazard assessment map was prepared in this connection, which indicated that 5% of area is under high hazard, 41.3% of area is under moderate hazard and 53.7% of area is under low hazard categories respectively. The spatial distribution of the respective hazard zones thus obtained will aid in land use planning strategies and disaster mitigation. An integrated seismic hazard assessment map using different parameters was generated on a GIS platform, which revealed that 13% of area is under relatively very high hazard, 39.1% of area is under relatively high hazard, 42.3% of area is under relatively moderate hazard and 5.6% is under relatively low hazard categories respectively.

Studies on Landslides

National Landslide Susceptibility Mapping Programme (NLSM) was taken up to prepare seamless landslide susceptibility maps on 1:50,000 scale. Landslides of different types are frequent in geo-dynamically active domains in the Himalayan and Arakan - Yoma belt of the North-Eastern parts of the country as well as in the relatively stable domains of the Meghalaya Highlands. The types of studies being undertaken by the GSI, include regular update on the landslide database of the entire Region. Further, GSI has covered major part of urban agglomerations, road corridors of the vulnerable hilly terrain in NE India through macro scale landslide susceptibility mapping. GSI undertakes site specific landslide investigation for assessment of any distress zone on the hill slopes, comprehensive understanding of the processes and

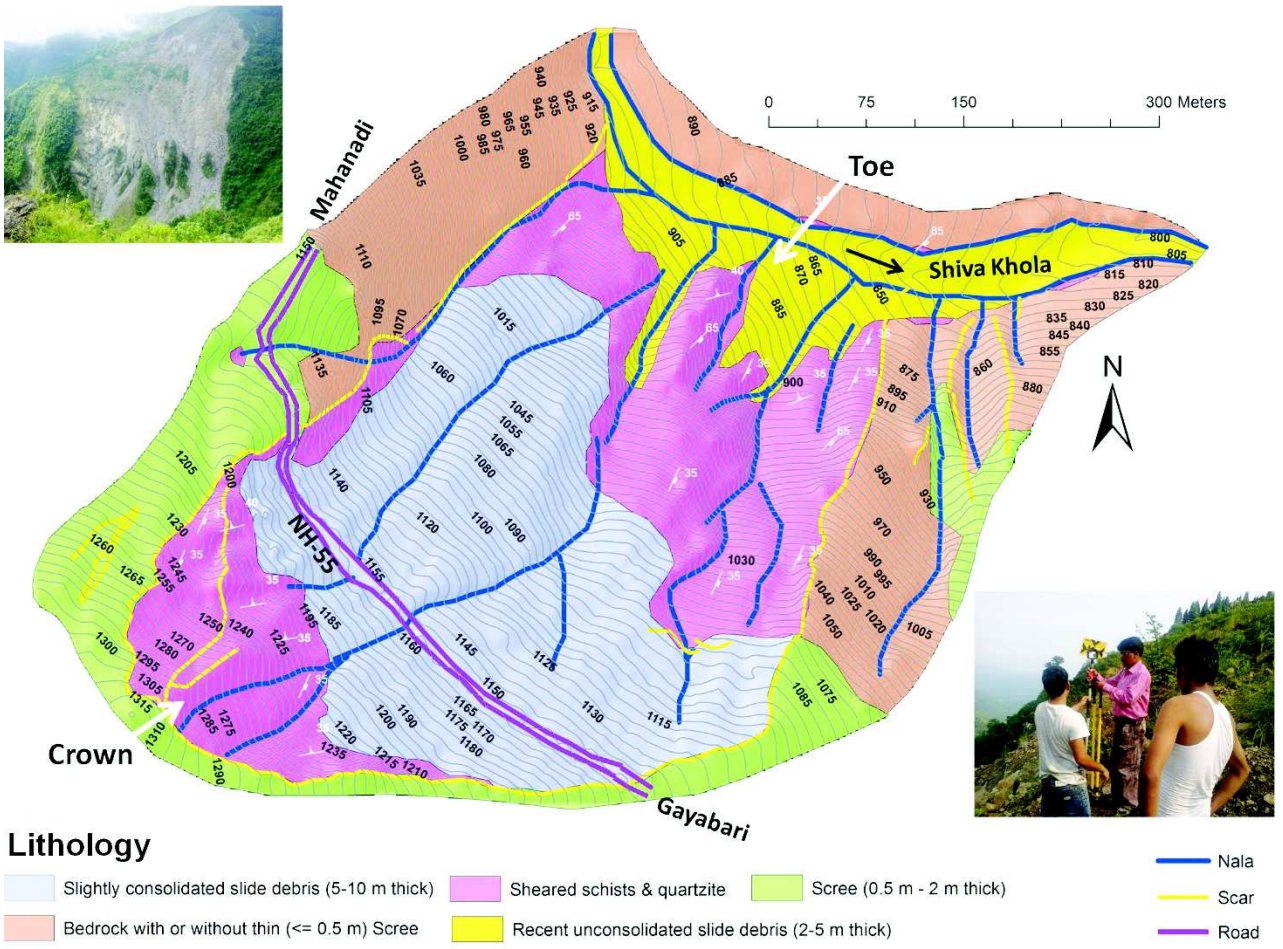
formulation of both short and long term mitigation measures. The total extent of landslide monitoring involves quantification of the slope movement and determination of threshold value (for initiation of slope movements) through collection of surface and subsurface data using total station, rain gauge, in place inclinometer, piezometers, etc. The state of art is remotely controlled sensors. The monitoring also aimed at developing a quantitative model indicating depth and nature of failure surface and critical condition for initiation of mass movement. All the above workouts will be utilized for formulating mitigation measures and early warning system for some selected slides.

In India, about 0.42 million km^2 or 12.6% of land area, excluding the snow covered terrains, is prone to landslide hazards. Out of this, 0.18 million km^2 falls in North East Regions and Eastern Himalayas, 0.14 million km^2falls in North West Himalayas (Uttarakhand, Himachal Pradesh and Jammu & Kashmir); 0.09 million km^2 in Western Ghats and Konkan hills (Tamil Nadu, Kerala, Karnataka, Goa and Maharashtra) and 0.01 million km^2 in Eastern Ghats of Aruku area in Andhra Pradesh. In India, the risk to landslides is high due to the ever increasing population and growth of hydropower and related infrastructures in the above-mentioned mountainous areas.

- Till date, GSI has already covered 65000 km^2 landslide prone areas under its ongoing National Landslide Susceptibility Mapping (NLSM) programme.
- GSI undertakes site-specific landslide investigation and provide inputs for formulating both short and long term mitigation measures at the request of road maintaining authorities (e.g., Public Works Departments, BRO), State Governments
- GSI regularly updates the landslide data base of the entire country through landslide inventory work; maintains a web enabled interactive map service for landslide inventory in its portal (http://www.portal.gsi.gov.in/gismap/landslide/index.html).
- Maintains a metadata of government-funded landslide projects of other stakeholders and also regularly undertakes landslide awareness programmes/workshops in different landslide-prone states.
- Presently engaged in collaborative programmes on landslides with other national (National Remote Sensing Centre-NRSC, Defence Terrain Research Laboratory-DTRL) and international (Natural Resources, Canada – NRCan) agencies on site specific landslide monitoring, landslide hazard mapping.

GSI undertook macro-scale (1:50,000) landslide susceptibility mapping in Khasi and Jaintia hills, Meghalaya. The studies helped in assessment of the criticality of slope in terms of failure along selected stretches of Mylliem - Dauki sector of the East Khasi hills and West Jaintia hills district of Meghalaya. The slope mass at many places are found to consist of boulders of 5-15 m3 size resting isolated on various kind of slope. As such the granite slopes are largely self-supporting and does not show any active or reactivated slope failures.

Detailed geotechnical investigation of 14th Mile slide near Gayabari on NH- 55, Darjeeling District, and WestBengal was completed through 1:1000 scale geological mapping to understand its activity, morphometry, lithology and failure mechanisms. This slide is an example of a large, retrogressive rockslide in Darjeeling Himalayas**.** It exhibits exceedingly high rate of retrogression with its crown attaining increase in relief of about 240 m in last 9 years (2003 – 2012). Due to these retrogressive movements, about 430 m long stretch of NH-55 and the Darjeeling Himalayan Railway track (an UNESCO World Heritage Site) has been completely washed away rendering closure of this communication route to Darjeeling town since 2010. The main failure mechanisms of this landslide include a) wedge sliding caused due to intersection of differently oriented joints within a moderately steep topography, and, b) planar sliding along the foliation-parallel planes dipping towards Shiva *khola* near the toe. The main causal factors of this retrogressive rockslide are a) passage of MCT through the study area leading to weakening and shearing of the host rock-mass, b) unfavourably oriented and closely-spaced foliation planes and other joints, day lighting in a moderately steep topography, and c) ingress of uncontrolled drainage/seepage into the affected slope during monsoon increasing the pore water pressure of slope forming material. Suggested mitigation measures include a) increasing the shearing strength



Detail map of the Gayabari Landslide, Darjeeling District, West Bengal in 1: 1000 scale

and reduction of the shear stress of slope forming material by providing a number of intermediate benches, b) managing surface drainage for controlling pore water pressures and heavy recharging of fragile/ unconsolidated slope forming material by providing catch water, chute and toe drains and c) restoring and strengthening the NH-55 road cum railway bench by further widening.

Desert Geology

Geoscientific studies on desertification and its impact assessment was carried out in Ajmer-Pushkar marginal area of Thar Desert with the objective to evaluate the geoscientific factors causing desertification and its impact assessment. To combat desertification problem in the area, various measures are suggested such as construction of gully plugging structures in gully erosion areas, plantation of fast growing and deep rooted xerophytes in grid fashion over the windward slope of the dunes and construction of shelterbelts around dunes for their stabilization, prohibition of grazing over vulnerable dune areas, strip cropping and agricultural practices with sprinkler system to be adopted in inter-dunal areas with encouragement for crops requiring less water.

Costal Environmental Studies

Quaternary Geological and Geomorphological mapping of Penner Basin in Karnataka was taken up based on IGCP-581 project, to determine the chronology of various geomorphic surface, climate and tectonics linkages in the Penner Basin and to establish soil-chrono-stratigraphy in relation to basin tectonics. Other studies were (1) Study of coastal processes in Ganjam - Paluru sector, Ganjam and Puri districts of Odisha. (2) Studies to decipher the strand line evolution of Digha coast, West Bengal and (3) Geoenvironmental appraisal of coastal and inshore

zone along Kakinada-Bangarampeta Coast, Andhra Pradesh.

Public Health Hazard Studies

Programmes have been taken up to identify nature, magnitude, area, frequency and cause of the health hazards, for appropriate remedial measures. Thus e.g. fluorosis studies in Rajasthan, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Punjab, Haryana, Jammu & Kashmir and Tamil Nadu; water quality studies in Uttar Pradesh and West Bengal; Arsenic contamination studies in West Bengal, Uttar Pradesh, Bihar, Rajasthan; manganese and nitrate pollution studies in Uttar Pradesh; Kidney stone propensity in selected areas of Uttar Pradesh, goitre endemicity along the foot hill zones of Uttarakhand and tribal belt of Uttar Pradesh and stomach cancer studies in Tamil Nadu. Chemical and stable isotopic characterization of groundwater in important towns of Northeastern India and toxicological effects/health hazards due to metals/trace elements/industrial effluents, etc. in Andhra Pradesh were also taken up.

Groundwater contamination studies of shallow aquifers in parts of urban and suburban areas of Agra, Uttar Pradesh revealed the presence of fluoride concentrations more than permissible limit of 1.5 mg/l (as per BIS, 2005 and WHO, 2006) in 25.4% samples (97 out of 382 samples). Most of the samples showing higher fluoride concentration are from Older Alluvium. About 80% samples are found to have iron concentration more than the desirable limit of 300 ppb for potable water. The ferruginous sandstone of the Vindhyan Supergroup may be one of the reasons responsible for high iron concentration in the groundwater of the area.

Geoenvironmental appraisal usingheavy metal concentration of groundwater of Bhatinda & Mansa Distrticts Punjab revealed presence uranium, selenium and iron along with fluoride (concentration) . Studies on arsenic contamination was taken up to map (Give map) the arsenic distribution pattern in ground water on 1:50,000 scale in existing tube wells, to delineate high-arsenic incidence areas and to delineate in detail the arsenic-high and arsenic-low ground water zones in specific areas and also to prepare the inventory of medically affected population and areas. An area of 1000 sq. km has been covered in parts of Naogaon and Marigaon districts, Assam.

Snout map of Hamthah Glacier, Lahaul & Spiti District, Himachal Pradesh

Glaciology

Glacio-geomorphological mapping was carried out in Kargil, Leh and Lahul-Spiti on 1:5000 scale. The glacial and pro-glacial areas in Drung glacier, Kargil, Jammu and Kashmir; Parang, Parang East (Padma) and Samudra Tapu glaciers in Lahaul and Spiti, Himachal Pradesh were covered for generation of primary base line data.

Long term monitoring of Mass Balance of Hamtha glacier, Lahul and Spiti district was studied. The components of studies include assessment of annual mass balance, glacier flow movement, meteorology, snout monitoring, glacier boundary and geomorphological mapping on 1: 5,000 scale on Hamtah glacier. The net mass balance for the year 2013-14, has been of the order of (-) 4.8061×106 m 3 of w.eq. with a specific net balance of (-) 1.4859 m w. eq. Glacier flow movement studies of the available stakes indicated minimum and maximum horizontal flow velocity of the order of 12.638 m and 25.690 m respectively. Monitoring of the glacier snout on 1:5,000 scale revealed that the glacier has receded by 7.08 m during 2013-14 and vacated an area of 0.0088 sq kmsince 2013. During the last fourteen years, between 2000 and 2014, the glacier has receded by 155 m, vacating an area of 0.05434 sq km. Glacier boundary demarcation was done using Landsat ETM + data, which will be validated with limited field check during the next field season.

Three glaciers in the gap areas of remote tribal districts of Kargil and Leh in Jammu & Kashmir and Lahaul & Spiti District in Himachal Pradesh were

also monitored in order to generate primary baseline glacier recession data. The studies indicated that since 1965, the snouts of Pin and Nisti glaciers have retreated by 621 meters, at an average rate of 12.3 m/yr, and 722 metres at an average rate of 14.7 m/yr respectively. The retreat of Batal glacier, from 1962 to 2014, was found to be 375 m with annual average rate of 7.2 m/yr. During the period, Pin, Nisti and Batal glaciers have vacated 0.18 sq km, 0.48 sq km and 0.12 sq km.

Polar Studies

GSI participated in the 32nd and 33rdIndian Scientific Expedition (November 2013-March 2014) to study the Schirmacher Range and Larsemann Hills Regions of East Antarctica. The studies taken up were. (1) Glaciological Studies in Central Dronning Maud Land, East Antarctica during the 32nd Indian Antarctic Expedition (Nov 2012- March 2013), (2) Geological mapping of the Grovnes area, Larsemann Hills, East Antarctica to establish a correlation of lithostratigraphic and tectono-metamorphic evolutionary history with the Bharti promontory (3) Geological studies in nunataks between Schirmacher Oasis and Wohlthat Mountains to establish the continuation of East African Orogen (EAO) in CDML (4) Remote sensing study for identification of sites for long term glaciological studies in Larsemann Hills, East Antarctica (5) Geological mapping (1:10000 scale) in the central part of Schirmacher Range, East Antarctica to constrain its tectono-metamorphic evolution and place in the Gondwana configuration (6) Sedimentology and clay mineralogy of lake sediments from Schirmacher Range, East Antarctica with implications on the palaeoclimatic history (7) Glaciological Studies in Central Dronning Maud Land, East Antarctica during the 33rd Indian Antarctic Expedition (Nov 2013- March 2014) (8) Tectono-metamorphic evolution of the Fisher area, Larsemann Hills, East Antarctica (9) Glaciological Studies in the Larsemann Hills, East Antarctica for assessing the impact of climate change (10) Integrated monitoring of Vestre Broggerbreen Glacier, Svalbard Arctic (on expedition basis) (11) Study of macro and microstructures in the ductile shear zone of the west Spitsbergen fold thrust belt with implications on the tectonic evolution of the Svalbard area of Arctic Region.

Glaciological Studies in Central Dronning Maud Land, East Antarctica during the 33rd Indian Antarctic Expedition (Nov 2013 - March 2014).The Dakshin Gangotri Glacier snout has shown continuous recession since 1996 with an average annual recession of 1.59 m per year from 1996 to 2013. Measurements during the 33rd InSEA indicated that the snout has shown less recession in the year 2013-14 in comparison to the previous (2012-13) year. The average annual recession of DG snout during the period of 2013-14 is 0.29 m which was 0.92 m during 2012-13.

Transect Geological Mapping (1: 10000 scale) was taken up in the central part of Schirmacher Range, East Antarctica to constrain its Tectono-Metamorphic evolution and place in the Gondwana Configuration. An area of about 3.0 sq km was mapped on 1: 10,000 scale in the central portion of the Schirmacher Oasis during 33rd InSEA. The rock types exposed along the transect consists of an interbanded sequence of quartzo-feldspathic gneiss, pyroxene granulite, meta-mafic and meta-ultramafic rocks with intrusives like lamprophyre, dolerite dykes and quartz veins. Three tectonothermal episodes have been recorded in the study area.

Integrated monitoring of Vestre Broggerbreen Glacier, Svalbard Arctic was taken up on expedition basis. In concurrence with the regional decreasing trend of ice volume in Arctic region, the Vestre Broggerbreen glacier (divided into two parts as VB-I and VB-II) has shown overall negative net annual surface mass balance (0.94 ± 0.4 m weq) during the year 2013. VB-I and VB-II glaciers show average annual ablation 166.95 cc weq and 106.95 cc weq considering uniform ice density of 0.9 gm/cc respectively. The Eqilibrium Line of Ablation (ELA) of VB-I and VB-II lies at less than 340 m and at more than 290 m above msl for the period 2012-13 respectively.

Glaciological Studies in Central Dronning Maud Land, East Antarctica during the 34th Indian Antarctic Expedition indicated that the average annual recession of the DG glacier snout is 1.31 m for 2014-15, which is more than the data (0.92 m) obtained in 2013-14 (the data was collected from the Dakshin Gangotri glacier snout.

Petrology

The multifarious petrology related research work carried out in Geological Survey of India has two major objectives: (1) understanding the ore genetic conditions which may help in prospecting and exploration and (2) deducing the tectonothermal or sedimentological evolution history of different geological terrains of India to build up the tectonic evolution history of this land in context of changes in global tectonic scenario. Integrated research approaches under both these objectives have produced valuable database and new understanding in domains of ore geology and terrain evolution.

While surface ore deposits are known and much exploited over time, the global thrust at present is in understanding the genetic behavior of economically important minerals and application of such knowledge, where ever possible, in finding new ore deposits or subsurface extension of older known occurrences. The ore related research in last few years in GSI was focused mainly on PGE, Au, REE and base metal sulfides. For example, the Pt-Pd bearing Mettupalayam mafic-ultramafic complex within the Moyar-Attur-Bhavani-Cauvery shear system was studied through extensive drilling and exploration. Extensive petrogenetic and ore genetic modelling studies showed that both chromitite and PGM-hosting suphide were products of magma mingling related sulfur super saturation and therefore, chromite, a phase easily identifiable in field, will help as an index mineral for locating PGM bearing horizons.

Gold genesis from Sindauri-Ghanshyampur area near Ranchi district carried out through integrated fluid inclusion and petrogenetic studies brought out that the gold, which occurs as solid solution in sulfarsenide minerals, are magmatic gold and have not been affected by any significant secondary remobilization or localized enrichment. Similar fluid inclusion studies in addition to carbon-oxygen-sulfur isotope analyses from Ajjanahalli Gold Prospect of Karnataka suggest mixing of gold bearing magmatogenic hydrothermal solution with cooler and less saline fluid as a causative factor for sulphide immiscibility and precipitation. Studies on tungsten genesis in quartz veins of Agargaon suggest involvement of chlorine in leaching and transportation of tungsten and also evolution of the ore-forming fluids by mixing between a high-temperature, high-salinity magmatic water and a low-temperature, low-salinity aqueous meteoric phase. Source characteristics of base metal mineralization in Betul Belt through stable isotope analyses approach has provided evidences for variable mixing of magmatic sulphur leached from volcanics with those derived from sea-water sulphate in this area leading to formation of this VHMS type deposit. Other ore related research works in recent years in GSI include ongoing studies in Mangampeta barite deposits that have brought out evidences for volcanic nature of the carbonaceous tuffs and characterization of heavy minerals occurring around Kalinadi and Netravati River estuaries in West coast of Karnataka.

The other major research dimension in GSI involves understanding of terrain evolution and their relationships with global tectonics. Recent studies on tectonothermal evolution of the mafic granulites of Bhavani Complex carried out not only conforms occurrence of a late Archaean suture between the SGT and the southern part of Dharwar Craton (DC) but also has, for the first time, provided evidences of superposed Palaeoproterozoic and Pan African P-T paths at different metamorphic grades. Fluid inclusion based studies in the Biligirirangan granulites from the Northern Granulite Terrain (the area south of Fermor line and north of Moyar-Attur shear zone) suggest significant CO_2 rich fluid flux in the lower continental crust as one of the causative factors for charnockitization.

Petrography and geochemical studies of Mawpyut mafic-ultramafic suite from Jaintia Hills of Shillong plateau revealed two regional lineaments controlled post deformational emplacement in the Shillong Group of rocks. Petrogenetic studies have also been carried out in the Bidasar ophiolite suite in trans-Aravalli region and in the plutonic and volcanic rocks in Munger Group around Rajgir and Gaya

Studies on granitoids of Bhiwani and Mahendragarh districts of Haryana suggested their intrusion during the later phase of Grenvellian orogeny (903-850 Ma). Geochemical studies of Andaman ophiolites indicate polygenetic emplacement representing both MORB (subducting Indian plate) and supra subduction zone magmas (overriding SE Asian plate). This compressive regime was subsequently changed into an extensional regime for fore-arc sedimentation. The chromitites of North Andaman have crystallized from Cr – enriched melt

injected into the upper mantle whereas melt – rock interaction at mantle depth is the sole process for Middle Andaman Chromitites.

The alkaline rocks form a separate and independent field of extensive research not only for their high REE potential but also for their varied and often unusual petrogenetic history. Recent research in alkaline rocks from Geological Survey of India include tectonomagmatic study and petrogenesis of Padu-Nongryngkoh layered composite dykes and associated lamprophyres of Jaintia and East Khasi Hills district, Meghalaya which indicated plume-induced low-degree partial melting within the lithospheric mantle prior to emplacement of Sylhet Traps. Petrogenetic modeling of the alkaline rocks of Sidhi district within the Central Indian Tectonic Zone (CITZ) suggests very small degrees of partial melting of a phlogopite-garnet lherzolite and magma contamination. The fennites of South Purulia Shear Zone (SPSZ) and North Purulia Shear Zone (NPSZ) have also been taken up for research along with other alkaline rock suites like the lamproites and associated intrusives of Damodar Valley Coalfield and lamprophyres and carbonatites from northwest Indian Deccan volcanic province. Morphological characterisation and mineral inclusion studies of Panna Diamonds from Madhya Pradesh indicated two distinct populations of diamonds suggesting that the source kimberlite has sampled more than one diamondiferous horizon. The inclusions indicate that the diamonds are both peridotitic and eclogitic in origin.

Geochronology and Isotope Geology

Studies on Crustal Evolution

1) IGCP 599-linked research: Tectono-metamorphic evolution of the transitional zone between East and West Dharwar Craton (EDC & WDC) revealed presence of contrasting structural, metamorphic and geochronological signature between the Chitrdurga belt in the west and Kunigal belt in the east across the crustal scale Chitradurga Eastern Margin Shear Zone. U-Pb zircon dating indicate a 3.2-3.25 Ga age of older basement in Yediyur-Kunigal sector of Karnataka and a 2700 Ma youger granitic event in the eastern block.

2) In the southern marginal area of the Singhbhum Craton with EGMB, U-Pb zircon ages of 3315±29 Ma and 3328±40 Ma, representing older phase of Singhbhum Granite.

3) Granites from Chhotanagpur Granite Gneissic Complex (CGGC) in Gaya and Rajgir District, Bihar yielded U-Pb zircon ages of 1765±21Ma and 1729±43Ma.

4) Well constrained age of basement (~2.5 Ga) and upper age limit (1.7 Ga) of Aravalli Supergroup in Western Indian Craton has been determined by U-Pb zircon dating. Older inherited 3 Ga zircons were also recorded in the gneiss.

5) Provenance study by rapid dating of detrital zircon in Isotopic Ratio mode in Sikkim Himalaya helped in establishing similarity in provenace in the sequence on both sides of MCT

Environmental Studies

1) First inventory made on Pb- isotopic fingerprinting Indian Gondwana Coal representing all the major coal belts of the country. This has got important bearing on any anthropogenic lead pollution work. Pb content of 90% of Gondawana coal lies between 30-77ppm but their Pb isotopic signature falls within Distinctly narrow ranges-

   Raniganj, Jharia, Talcher & Ib Vally Coalfields: 206/207 Pb between 1.1664 and 1.24897 and 208/206 Pb between 2.0066 and 2.1655; Rajmahal and Godavari Valley Coalfields: 206/207 Pb between 1.2167 and 1.3986 and that of 208/206 Pb between 1.9182 and 2.0554

2) Anthropogenic Lead pollution study in the Kolkata city (urban India) using Pb isotopic signature in different environmental matrices has been carried out for the first time in India. The Pb isotopic signature from (a) Eight commonly consumed food items (b) Uncontaminated sediment (c) contaminated sediments of Dhapa (d) Street dust of Kolkata (e) Rain water (f) Diesel and (g) Indian Lead Ore from Rajasthan indicate common Pb source for all these items.

Himalayan Geology

1) Research on one Trans-Himalayan Granite pluton of India, Lohit Plutonic Complex (LPC)

revealed significant dates of some the major components of LPC. Some of these dates are reported for the first time from India. U-Pb zircon ages of the Diorite indicate prominent Cretaceous age (117 - 101 Ma). The zircons of diorite yielded high positive $\varepsilon_{Hf}(t)$ values of +12 to +17, indicating juvenile depleted mantle source. These diorites are the result of Pre-collisional Andean type subduction of Neo-Tethyan Oceanic lithosphere.One Oligocene age of 33 Ma from Leucogranite of Tuting area, Arunachal Pradesh has been reported for the first time from Indian part of LPC.

Palaeontology

The objective of Palaeontological research is to examine the traces of life on earth through time to understand the evolving biosphere and thereby also provide relevant information which help in reconstruction of past land, ocean and environment. In GSI, the palaeontological work is mainly focussed on carrying out palaeobiogeographic, biostratigraphic and palaeoclimatic studies apart from studying the taxonomic diversity.

The palaeontological researches in Geological Survey of India for the last four year have been spread from Neoproterozoic (500 Ma–600 Ma) to Quaternary time period. The most notable findings are listed below.

The Neoproterozoic rocks of Chambaghat Formation of Krol Group of Himachal Pradesh have yielded phosphatized spherical microfossils which have been identified as resting egg and different developmental stages of animal embryo namely *Megasphaera* and *Parapandorina.* The study also revealed demosponge like extant *Chalina* and extinct *Otavia*. The Neoproterozoic eggs and embryos might have a relationship with associated metazoan demosponge.

The Early Cambrian Chert Member of Tal Group have also yielded globular to subovoidal microfossils and are identified as animal eggs like *Olivooides* and *Archaeooides* and embryos like *Pseudooides*. Signatures of an array of ancient life from parts of Marwar Supergroup of Rajasthan ranging across Vendian- Tommotion time span have been obtained in the form of a sizeable assemblage of Ediacaran biota preserved on biomats of the Sonia Formation (Artiya Kalan and Dujjar sections) of Jodhpur Group (lowermost unit) and an association of various trace fossils and body fossils of arthropods (probably trilobites), discoid organisms and annelid and bivalve shell impressions from the Nagaur Group (Dulmera section; topmost unit). The intermediate Bilara Group has yielded plenty of stromatolites.

The marine Permian rocks of central India and extra peninsular areas have been studied extensively during the last four years led into discovery of a new fossiliferous conglomerate patch in the extension of two and half km north-east of Manendragarh principal fossil locality and about one and half km east of village Chainpur on the right bank of Hasdo River near Chainpur-Chirimiri road bridge. The first record of agglutinated foraminifera from the Badhaura Formation were identified as *Trochammina* cf. *mehli* Conkin, *Ammobaculites beveridgei* Conkin, *A. lisae* Conkin and Conkins, *A.pyriformis* Gutschick and Treckman, *A. leptos* Gutschick and Treckman, *Rectocornuspira* sp.Warthin, *Calcitornella aff. elongata*Cushman and Waters, *Reophax* (?), *Lagenammina* sp. 1, *Lagenammina* sp. 2, and *Trochammina* sp.

The diversity dynamics and palaeobiogeography of Middle and Upper Jurassic brachiopods have been studied in a global context. The brachiopod genera present in the Callovian of Kutch are *Kutchithyris**, *Gibbirhynchia, Rhactorhynchia, Cryptorhynchia, Sphenorhynchia**, *Bihendulirhynchia**, *Rhynchonelloidella**, *Aulacothyris* of which only four (*marked) continues in the Oxfordian (Upper Jurassic). In the Jaisalmer Basin together with *Kutchithyris* another terebratulid genus *Bihenithyris* appears in the Callovian and continues to the Oxfordian. In the Kimmeridgian and the Tithonian of the Kutch and Jaisalmer basin, brachiopods are relatively less in number and diversity; the terebratulid and rhynchonellid community being represented by *K. euryptycha*, *G. nobilis*, *Somalithyris* and *Acanthorhynchia*. Thus, the brachiopod community in western India, reveal a decrease in diversity and number from the Middle to Upper Jurassic. The palaeotemperatures calculated from the oxygen isotopic ratio, reveal a decrease in temperature from the Middle to Upper Jurassic which may have an effect on the brachiopod diversity. The temperature in the Late Callovian was ~ 18°C that decreased in the

Oxfordian, remaining around 14°C-16°C and continuing to be cool (15.5°C) till the Tithonian.

The palaeobiogeographic study was taken up with an aim of understanding the provinciality and causes migration in Jurassic brachiopods by studying their distribution patterns in northern and southern margins of Tethys from the Callovian of Amparambato, Morondova Basin, Madagascar and the Tataouine Formation of Tunisia and northern part of Tethys, i.e, the Upper Bathonian to Lower Callovian Bagamshah Formation of Iran (specimens kept at Geozentrum, F.A.Universitat, Germany) and literature comparison with other regions of the Ethiopian biogeographic Province revealed that both provincialism and cosmopolitanism were prevalent in the Middle Jurassic. New record of characteristic geographically widespread taxa, like *Daghanirhynchia*, a characteristic Ethiopian brachiopod genus which was till date thought to be absent in the Indo-Madagascar realm and now been revealed in the Lower Callovian of Amparabato, Madagascar as well as Kutch and Jaisalmer and the Madagascar *Daghanirhynchia* population revealed evolutionary relationship with an Upper Bathonian rhynchonellid assemblage from Jaisalmer, as revealed by their similar growth rate in their ontogenetic trajectory. Species level similarity is also recorded between Kutch and Madagascar e.g., *Torquirhynchia pseudoinconstans, Kutchithyris dhosaensis, K. euryptycha*.

The findings has important implication in the Jurassic palaeobiogeography of the southern Tethys as it implies continuation of the shallow shelf environment without any barrier, from the Kutch and Jaisalmer basin to the Morondova Basin during the Upper Bathonian-Lower Callovian.Study of late Cretaceous continental tetrapod fossils from Lameta Formation- an international collaborative programme under MoU between GSI and University of Michigan Museum Palaeontology (USA).

Emphasis was given for micropalaeontological studies in pelagic sediments associated Ophiolite Group, Mithakari Group of Andaman Islands. The upper part of the Mithakhari Group is dominantly arenaceous, represented by conglomerate-coarse grained sandstone-calcareous sandstone-shale exposed at Kalipur, Durgapur, Ross and Smith Island towards the eastern part of the North Andaman have yielded larger foraminifers viz. *Nummulites-discorbinus*, *N. pengaronensis, N. lehneri, N. stamineus*, *Assilina spira*, *Discocyclina hayensi*, *Asterocyclinastellata* and *Eoannularia* sp. and smaller benthic foraminifers like *Calcarina* sp. *Nodosaria* sp., *Discorbis* sp., *Elphidium* spp. Twenty-nine (29) radiolarian taxa *viz. Acrosphaera* sp., *Cryptomphorella macropora, C. conara* , *Alieviumgallowayi, A. Superbum, Pseudoaulo-phacusparguerensis, P. Lenticulatus, Spherostylu-slanceola, Obesacapsulasomphediai, Theocam-peapicata, Dictyomitrakoslovae* and *Amphipyn-daxtylotus* of Campanian - Maastrichtianage have been identified within chert bodies associated with ophiolites.Quaternary biostratigraphic and palaeoclimatic studies were also carried out in coastal Andhra Pradesh, Kerala, Gujarat and Gangetic Alluvium of Uttar Pradesh.

IT Service

An attempt was made to create an exploration model in a part of Singhbhum Shear zone through prospective maps to find out new target areas for copper, gold and associated minerals. Data generated by GSI through 50K Mapping, National Geochemical Mapping (NGCM), National Geomorphology & Lineament Mapping (NGLM) & National Geophysical Mapping (NGPM) were collated. Predictive maps showing relative favourability in respect of commodities like Cu, Au, As, Sb, Co and Ni were prepared. Two prospective models are developed, one for Copper and another for Gold and other mineral commodities. In both the models (Index Overlay and Fuzzy Gamma), highly favourable zones appear in different sectors as small to medium patches in the study area. The model developed for copper (Cu) shows the probable presence of highly favourable zones for copper mineralisation around Singhbhum shear zone, and corroborates with the already established and existing copper mines/Cu mineralised zones around Tamadungri, UkamPahar, Nandup. On the contrary, the model developed for Au and other associated commodities show a favourable linear zone in the SW parts of the study area around Kalhudih-Tiring-ChhotaRamgarh, besides other small favourable zones in the form of small patches. The spatial distributions of predicted high favourability zones are found consistent with conceptual models of metallogenesis in the study area.

Another project was taken to Integrate the available geological, geochemical, geophysical, aerogeophysical, photogeological data of parts of 53D degree sheet to identify target areas of mineralization. All the evidence maps of lithology, structure, geochemical, geophysical and lineaments were converted into rasters and modelling was done in Boolean, Binary Evidence, Index Overlay and Fuzzy logic to target mineral potential zones of the study area. DEM were generated for the study area and drainage network and micro watershed using ArcGIS 10.2. The sample points were overlain on the micro-shed and the area of influence was digitized for each sample points. Evidence maps were prepared followed by Factor maps of Geological layers, Geophysical layers and Geochemical layers.

The confidence level of the model was checked and validated with the previous reported mineral deposits in the study area. New areas such as Mandola - Madhogarh, Budin –Nimbi – Serohi - Nangal and Dhani – Raghunathpura – Nasibpur - Sheikpura were identified from the integration programme for detailed study.

NGLM and Related Service

National Geomorphological and Lineament Mapping (NGLM) is a national project in which GSI is collaborating with ISRO as a key member for content validation. To preserve the data in the database server, a multi-user geo-database has been developed with the help of 'state-of-the-art' GIS technologies.

NGCM and Related Service

The IT Division has designed a spatial database to capture and store National Geochemical Mapping (NGCM) data.

Map Service for Marine data of Territorial Water (TW): A new feature dataset and related map service for Marine Data pertaining to the Territorial Water (TW) at scale 1:50K has been integrated with the multi-user geo-database.

To make the activities of the Project NGLM visible to the general public and for understanding the status of the project, a new link called "National Mission on Geomorphology & Lineament Mapping" has been created in the home page of the GSI portal (www.portal.gsi.gov.in).

Noteworthy attempt in this regard is the initiation of Online Core Business Integrated System (OCBIS) project, which will ensure fast data handling in a common digital and spatial platform suiting to the needs of Govt. and Non-Govt. agencies and once launched it is going to be first of its kind in India. All necessary efforts have been taken up to participate in National and International initiatives like NSDI and 'One Geology' programme. The prime objective of OCBIS project is to build an integrated repository of all data being collected by GSI, its holistic management and dissemination to the stakeholders. GSI shall take up the implementation of Phase-III of the portal through the OCBIS from F.S. 2015-16.

Geological Survey of India Training Institute

Geological Survey of India Training Institute (GSITI) was established in 1976 with the prime objective of orienting new recruits. GSITI basically serves in bridging the gap between academic knowledge and the professional approach particularly of newly inducted geoscientists, to create efficiency. This is achieved by exposing practicing geoscientists to new developments in fields related to their specialization. At present GSITI gives periodical in-service training at various hierarchical levels to all the employees (scientific/administration) in order to equip individuals to shoulder the expected higher responsibilities. The training programmes are designed based on training needs assessment/state/regional requirement and requests from other countries as per foreign policy etc.

Trainings are conducted under the following categories

- Entry level training: Designed for new recruits about responsibilities that they are expected to execute on assuming charge. It is residential and of long duration. Newly Geologists of other organisations are also accommodated based on requests.
- Middle level: This is promotionlinked (institutional training) for all employees at various levels It is usually of 4/8 weeks duration.
- Short term Thematic Training: It is designed to build professional competency including leadership development. It is given once in 1 or 2 years and is usually for 1-2 weeks duration.
- Apart from this GSITI also conductsCourses

for International participants (Digital Image Processing System, Geographic Information System), Advance Courses (GIS/ NGCM/ GP), Refresher Courses (Petrology/ Ore Microscopy/ Mineral exploration and mapping etc), Special (need-based) Training Programs viz.,G1-G2 stage exploration programmes, Degree Awarding Courses, ISRO and DST-sponsored training programs for outside participants, workshops etc.

Human Resource Development

Human Resource Development (HRD) Division of GSI aims to create a system that can continuously identify, nurture and enhance the capabilities of available human resources. A number of HRD policies have been formulated in recent years to strengthen and invigorate the Human Resource capital of GSI.Officers are encouraged to pursue their chosen field of expertise by posting them in specialised divisions and facilitating their interaction with scientific community outside the organisation by sending them periodically for outside trainings, seminars and workshops. Specialisation and capacity building have been given major emphasis to achieve excellence in the field of Geoscientific research.The total sanctioned personnel strength of GSI is 12,369 of which 48% constitutes the scientific stream.

Publications

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