

Geological Survey of India

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The Geological Survey of India (GSI) was established in 1851 with the objective of locating mineral resources including coal. Since its inception, GSI has continued to grow and diversify into various geoscience activities, and delivered significant contributions in the area of geosciences. After independence, the activities of GSI in mineral exploration as well as baseline surveys have increased manifold in order to sustain the momentum of national economic development. Over the years, the department has not only grown into a huge repository of precious geoscientific data applied in various developmental fields in the country, but has also attained the status of a geo-scientific organization of international repute. The principal function of GSI relates to creation and updation of national geoscientific data and mineral resource assessment and conducting multifarious geotechnical and geo-environmental studies. With its headquarters at Kolkata, GSI has six Regional offices at Lucknow, Jaipur, Nagpur, Hyderabad, Shillong and Kolkata and offices in almost all states of the country. The Geological Survey of India is an attached office to the Ministry of Mines, Government of India. Following the High Powered Committee (HPC), 2009 recommendations, the activity of GSI has been restructured in the Mission-mode under the Mission-Region Hybrid structure. GSI has stridden a long way from its primary task of geological mapping and resource surveys as mandated at the time of its foundation and, slowly and steadily, it approaches the different field of Earth sciences in order to meet the growing demand of the industrially and economically advancing India and its ever increasing societal needs and the consequent infrastructure requirement.

As outlined in the National Mineral Policy-2008, GSI, in addition to its accredited function as principal agency for geological mapping and regional mineral resource assessment of the country, renders the additional responsibility of drawing up action-oriented plans towards these ends in close cooperation with all other agencies engaged in this task. It also has to cooperate with Ministry of Earth Sciences in exploration and exploitation of India's Exclusive Economic Zone (EEZ). The exploration activities of GSI have been prioritized keeping in view the thrust

accorded by the Government of India, the directives given by the Planning Commission, the recommendations of Central Geological Programming Board (CGPB) and State Geological Programming Boards (SGPB) and the requests received from State Governments as also the other stakeholders. GSI has also been identified as the nodal agency for archiving of the Reconnaissance Permit (RP) reports and dissemination of the RP report data after the lock-in period of two years.

GSI's work under mineral exploration programme is mainly confined within the limits of 'reconnaissance' and 'prospecting' though in some cases it also encompasses 'general exploration' following UNFC Geological axis. GSI has oriented its activities on mineral search and assessment with special emphasis on deficient commodities of high value (e.g. gold, diamond, PGE, etc.), strategic minerals (molybdenum, tungsten, RM/REE) and also minerals of high demand like basemetal, iron ore (haematite and magnetite), energy minerals, e.g. coal, lignite and different industrial minerals including limestone for steel industry, etc. With fast depletion of easily accessible and shallow or near surface ore bodies, GSI has appreciated the need for locating 'deep seated' and 'concealed/hidden' mineral bodies and has laid down emphasis on exploration for locating concealed and deep-seated mineral deposits in known mineral belts and also in identifying new prospective areas for intensified mineral search.

Mineral Find (New Finds Included)

Geological Survey of India had carried out mineral investigations (for the period from 2009 to 2012) in different parts of the country for various mineral commodities, which include energy minerals like coal and lignite, non-ferrous minerals like basemetal and bauxite, strategic minerals like molybdenum, tungsten, rare metal, precious mineral commodities of gold, PGE, diamond, ferrous minerals like iron ore, manganese ore & chromite, fertilizer minerals of apatite and phosphorite, and industrial minerals like limestone, gypsum, graphite, glass sand, talc-steatite & fullerene. These investigations have resulted into generation of additional resources of coal & lignite, iron ore, manganese, gold, PGE, basemetals (zinc & copper), molybdenum, limestone, talc-steatite and apatite.

Coal and Lignite

The total updated geological resource of Indian coal for the coal seams of thickness 0.9m and above and up to 1200m depth stands at 293.5 billion tonnes (as on 1/4/2012), the mined out reserve. The total lignite resource of the country stands at 41.9 billion tonnes. The production and export of coal is increasing. From the year 2009 onwards, GSI had augmented resources of coal in the states of West Bengal, Jharkhand, Odisha (earlier called Orissa), Chhattisgarh, Madhya Pradesh and lignite resources in the states of Tamil Nadu and Rajasthan. The details are as follows:

- * An additional resource of 1638.52 million tonnes of coal has been estimated through regional exploration in 2008-09 from Raniganj & Birbhum coal fields of West Bengal, Sohagpur & Pench valley in Madhya Pradesh and Mand-Raigarh & Korba coal fields in Chhattisgarh. In addition to this, a resource of 0.19 million tonnes of lignite has been assessed from Bikaner, Rajasthan.
- * An additional resource of 3420.98 million tonnes of coal has been estimated through regional exploration by GSI in 2009-10 which includes resources from Brahmani coalfield (Pokharia-Paharpur & Gosaipahari-Siulibana) in Jharkhand, Mand-Raigarh, Tatapani-Ramkola, Hasdo-Arand and East of Birsampur coalfields of Chhattisgarh. In addition to this, a resource of 0.51 million tonnes of lignite has been estimated from Bikaner, Rajasthan.
- * GSI has estimated coal resources of 2641.63 million tonnes by way of regional exploration in the Raniganj coal field (Nabasan) in the state of West Bengal, Talcher coal field (Jamujhari- Brahmanbil) of Odisha, South Karanpura coal field (Binja, East Bokaro, Muditoli) in the state of Jharkhand, Hasdo-Arand, Mand-Raigarh, Tatapani- Ramkola coal fields of Chhattisgarh and in Sohagpur & Singtauli coal fields of Madhya Pradesh. In addition, a resource of 125.759 million tonnes of lignite was estimated from Birbhum coal field (Mahalla) of West Bengal, East Coast Lignite field (Bogalur) of Tamil Nadu and West Coast Lignite fields (Phalki) of Rajasthan in 2010-12.

Molybdenum

Molybdenum ore is categorized as a scare commodity and the domestic demand is met by import of metal, alloys and concentrates. The total all India resources is 19.28 million tonnes as on 1/4/2010 (provisional) in which the contained MoS₂ is 12,640 tonnes which is under remaining resources category. GSI had carried out investigation for molybdenum

in the state of Tamil Nadu and an inferred resource (333-UNFC) of 2.74 million tonnes of molybdenum ore with an average grade of 0.102 % Mo has been estimated in Vellampatti area of Dharmapuri district.

Gold

The gold ore is categorized as a scare commodity and the total all India resource of primary gold ore is about 390 million tonnes. The production of gold is decreasing and the domestic demand is mostly met by import. Keeping this in view, GSI carried out investigation in the states of Jharkhand, Bihar, West Bengal, Andhra Pradesh, Karnataka, Kerala, Rajasthan, Uttarakhand, Chhattisgarh and Uttar Pradesh and consequent upon this endeavour the following resources were augmented in the states of Chhattisgarh, Uttar Pradesh, Jharkhand, Karnataka and Rajasthan from the year 2009 onwards.

- * A resource of 0.09 million tonnes with average grade of 0.93 g/t of gold was estimated in Baghmara block, Sonakhan area, Raipur district of Chhattisgarh.
- * A resource of 0.053 million tonnes gold ore with average grade of 3.03g/t gold has been estimated in Soanapahari area, Sonbhadra district, Uttar Pradesh.
- * A resource of 2.28million tonnes gold ore with average grade of 0.699g/t gold has been estimated in Sonadehi gold prospect in Chhattisgarh.
- * A resource of 3.15 million tonnes of gold ore with average grade of 1.526 g/t gold has been estimated from Sindauri East Block, Ranchi district, Jharkhand.
- * A resource of 0.25 million tonnes with 2.55 g/t Au was estimated from Ajjanahalli Block-C of Tumkur district, Karnataka.

All these Resources are categorized under inferred category (333-UNFC) and need detailed exploration to enhance the confidence level of estimation.

- * In Delwara west Block, Bhukia Gold Belt, Banswara district, Rajasthan, an indicated resource (332-UNFC) of 50.13 million tonnes with 2.06 g/t of gold has been estimated.
- * A resource of 1.932 million tonnes of gold ore with an average grade of 3.978 g/t gold has been estimated from Gundelpara Block, Bhukia gold prospect, Banswara district, Rajasthan.
- * NW & SE of Gundelapara village, Banswara district, Rajasthan, a reconnaissance resource (334-UNFC) of 0.063 million tonnes of gold ore with 1.148 g/t has been estimated.

The deposits around Gundelapara occur in small clusters. Exploration coupled with mining is an attractive proposition as most of these deposits have been explored only up to shallow depths and there are indications of further continuity of the ore bodies to deeper levels.

Platinum Group of Elements (PGE)

PGE is a scarce commodity and the resources are classified in terms of ore and metal. The total all India resource is 16.2 tonnes. Answer to the internal demand solely depends on import. GSI carried out investigation for PGE in the states of Tamil Nadu, Karnataka, Kerala, Maharashtra, Manipur, Odisha and Andhra Pradesh from the period 2009 onwards. In consonance with this pursuit, PGE ore resource has been estimated from C1 sector of Chettiyapalaiyam Block in Sittampundi complex in Namakkal district of Tamil Nadu. A reconnaissance resource (334-UNFC) of about 0.252 million tonnes with an average grade of 1.44ppm of (Pt+Pd) over an average width of 1.37m has been estimated in the 1.1 km long C1 sector of Chettiyapalaiyam Block.

Basemetal

The copper, lead and zinc ore is classified as deficit commodities with total all India resources of 1394 million tonnes and 522 million tonnes respectively. The production of copper is fluctuating. From 2009 GSI carried out investigation for basemetals in the states of West Bengal, Sikkim, Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Himachal Pradesh, Haryana, Meghalaya and Jammu & Kashmir and, as an outcome of these investigations, resources were augmented in the states of Haryana, Madhya Pradesh and Rajasthan, the details of which are furnished below:

- * North of Gangutana block, Mahendragarh district, Haryana, a resource of 2.96 million tonnes with 0.34% Cu has been estimated. This inferred category resource (333-UNFC) needs detailed assessment through higher stages of investigation.
- * A resource of 0.98 million tonnes of zinc ore with 1.10% Zn has been estimated in Jangaldehyri Block in Chhindwara district of Madhya Pradesh. This deposit along with other small deposits like Muariya, Bhuyari, Dehalwara, Koparpani, Bis-khan-khari, Ghisi in the area need detailed exploration, feasibility studies and economic viability studies for small-scale exploitation (cluster mining) which may also be facilitated by setting up of concentration plants nearer to the group of deposits to make it economical.
- * In Mahawa block, Sikar district, Rajasthan, an inferred resource (333-UNFC) of 1.89 million tonnes

of copper ore with 0.35% Cu and 0.20 million tonnes of lead ore with 0.33% Pb has been estimated.

- * In Danva Block, Sirohi district, Rajasthan, an inferred resource (333-UNFC) of 26625 tonnes of copper ore with 0.33% Cu has been estimated. In addition, 20720 tonnes of gold ore with 0.73 g/t Au has also been estimated.

Iron Ore

Iron ore is an abundantly available mineral with 25,250 million tonnes of all India total resources and projected life index of 57 beyond 1/4/2012. Its production and export is increasing. Earlier the resource and reserves were calculated based on 55% Fe as cut off to produce mineable ore. Consequent upon the lowering of threshold value of iron ore by IBM, GSI is carrying out investigation in lease free, non-forest areas for assessment of low-grade iron ore (+45%Fe) for augmentation of the iron ore resources. From 2009 onwards, GSI had carried out investigation for iron ore in several states of the country, which resulted in augmentation of resources in the states of Odisha, Chhattisgarh, Tamil Nadu and Karnataka. The details are as follows:

- * A resource of 46.2 million tonnes at 55% Fe has been augmented in Ghoraburhani-Sagasahi area in Sundergarh district of Odisha. The resources of this deposit are categorized under indicated category (332-UNFC), which warrants feasibility and economic viability studies from point of view of exploitation.
- * A resource of 13.93 million tonnes of iron ore with 37.54% to 43.11% Fe has been estimated from Kelur area, Tirrunnamalai district, Tamil Nadu. The resources of these deposits are under inferred category (333-UNFC) and needs detailed exploration to upgrade the deposit to the higher confidence level.
- * In Aridongri area of Kanker district, Chhattisgarh, a total inferred resource (333-UNFC) of 10.01 million tonnes with a grade of 62.28% Fe has been estimated.

Manganese Ore

The manganese ore is an adequately available commodity in India with 379 million tonnes of total all India resources with a projected life index of 80 beyond 1/4/2012. GSI carried out investigation for manganese ore in the states of Odisha, Maharashtra and Madhya Pradesh. These investigations generated additional resources in the state of Odisha from the year 2009 onwards. The details are as follows:

- * A total resource of 10.625 million tonnes with 20%

to 30% Mn has been estimated from Bonai-Keonjhar belt, Kendujhar district, Odisha. These resources are under inferred category (333 - UNFC) and need detailed exploration to enhance the confidence level of the resource base. In view of occurrence of large proportion of low-grade manganese ore in eastern India, the effective measures of upgrading the grade through beneficiation have been worked out.

Apatite

Apatite is a deficit mineral commodity and its production is decreasing. The all India total resources of apatite as on 1/4/2010 (provisional) are 24.23 million tonnes, of which 2.09 million tonnes are reserves and the balance 22.14 million tonnes are under Remaining Resources Category. GSI investigated for apatite in the state of West Bengal and estimated a low-tonnage reconnaissance resource (334-UNFC) of 65,914 tonnes of apatite with 15.25% P₂O₅ in Beldih Block of Purulia district.

Limestone

Limestone is an abundantly available commodity with the total all India resources of 175,345 million tonnes as on 1/4/2005. The production of limestone is increasing. However as resources of low-silica grade is less, its demand is mostly met through import. The resources for cement and B.F. Grade are abundant. The projected life index beyond 1/4/2012 is 272.

GSI investigated for limestone in the states of Rajasthan, Gujarat, Sikkim, Andhra Pradesh, Tamil Nadu and Meghalaya and as an outcome of these estimated resources of SMS and cement-grade limestone in the state of Rajasthan are as follows:

- * A resource of 235.28 million tonnes SMS-grade limestone and 336.07 million tonnes cement-grade limestone has been estimated in Miniyun ki Dhani of Jaisalmer district, Rajasthan. The resources are categorized under inferred category (333-UNFC) and need detailed exploration to enhance the confidence level of resource inventory.
- * A reconnaissance resource (334-UNFC) of 441.7080 million tonnes of SMS-grade limestone and 514.8470 million tonnes of cement-grade limestone have been estimated in Minyun ki Dhani (East), Jaisalmer district, Rajasthan.

Talc

The total all India resources are placed at 312.33 million tonnes as on 1/4/2005. The production and export of talc and steatite is decreasing. GSI had carried out investigation in Gok-Karmi Talc prospect in Darjeeling district of West

Bengal and a reconnaissance resource (334-UNFC) of 59,085 tonnes has been estimated.

Ground and Marine Survey/Mapping

Creation and updating of National Geoscientific Information and Knowledge base through ground, marine and airborne surveys had been one of the main objectives of GSI in the period from 2009 to 2012. Growing emphasis on concept-oriented thematic geologic mapping on progressively larger scales coupled with geochemical and geophysical mapping of the geologically mineral potential areas remained the strategic tools adopted towards achieving this objective.

Specialized Thematic Mapping (STM) programmes (generally on 1:25,000 scale) addresses unresolved issues identified during first generation geologic mapping, i.e., Systematic Geological Mapping on 1:50,000 scale, involving stratigraphy, tectonic set-up, crustal evolutionary trend, metallogeny/ore localization, etc. It incorporates additional parameters, enhancement in quality and density of existing parameters and also systematization of the data element/data subsets in accordance with the present status of knowledge. From 2009 to 2012, an area of 40,153 sq km was covered under Specialized Thematic Mapping in different geological domains, against the planned target of 35,000 sq km. In the XII Plan (2012-13 to 2016-17), GSI plans to cover about 80,000 sq km by thematic mapping programmes.

STM was carried out across varied and important geologic locales/domains of the country, e.g., Deccan Plateau of Nagpur district, gneiss-supracrustal terrain of the Western Bastar Craton, Archaean gneiss, Nandgaon Group, Dongargarh Granite of Maharashtra; Bundelkhand Gneissic Complex, unclassified Mahakoshal Belt and older granite gneiss of Madhya Pradesh; Lahraud-Basna-Singhanpur Granite Greenstone Belt, Pandadah-Khairagarh, Amgaon, Nandgaon Belt, Chhotanagpur Granite Gneiss and metasediments of Chhattisgarh; Munger-Rajgir metasedimentary belt and around Gaya-Rajgir area of Bihar; unclassified metamorphics, Chhotanagpur Gneissic Complex and Gondwana Supergroup rocks of Jharkhand; Eastern Ghats Mobile Belt, greenstone sequence, Iron Ore Group of rocks, craton-mobile belt interface (crustal accretion) and Badampahar – Gorumahisani belt of Odisha; Central Crystalline Group, Siwalik belt in Uttarakhand; Bundelkhand granitoids, Bijawar Group of rocks and Siwalik Belt of Uttar Pradesh; Siwalik belt in Haryana, Punjab and Himachal Pradesh; Krol Group of Himachal Pradesh; geological and geomorphological mapping of NCT Delhi; volcanic rocks of Shyok Tectonic Belt (STB), Ladakh, Jammu & Kashmir; Lesser Himalayan sequences of Arunachal Pradesh,

Precambrians and Shillong Basin of Meghalaya; Middle and Upper Barail and Middle Bhuban Formation of Mizoram; gneiss/granite terrain, Penganga Group of Pakhal Basin of Andhra Pradesh; E-W corridor from Hirisave to Mangalore and granitoids of Karnataka; granulite and associated rocks, Kinattukkadavu-Kangeyam Sector of KKC Tectonic Zone of Tamil Nadu; Bhavani Shear Zone and Moyar Shear Zone of Kerala; metavolcano-sedimentary assemblages, of Bhilwara Supergroup, Alwar-Jaipur basin of the North Delhi Fold Belt, Jaisamand Granite & Chavand Granite, Delhi Supergroup of rocks, southern part of the Pur-Banera belt and Malani Igneous Suite of Rajasthan; coastal dynamic and neotectonic studies in Gulf of Kachchh and Aravalli Supergroup of Gujarat.

The spin-off exploration programmes from the previous STM items are the testimony of the efficacy and utility of this type of mapping endeavours and a total of 16 such programmes were taken up by GSI in the period. Some prominent among those are gold investigation in Kanganapalle, Andhra Pradesh; Cu and associated precious metals in Mundiawas-Khera, Rajasthan, Amlimal area, Gujarat, Naidilli-Dighori and Lal Heti-Dugala, Maharashtra; Iron ore in Baliadihi-Damurda-Champuasahi area and Damurda-Champuasahi area, Odisha; tungsten mineralisation in quartz veins in Wyndhamganj area, Uttar Pradesh; basemetals in Karoi-Rajpura area, Pur-Banera Belt, Nim ka Thana belt, Mahawa Block, Rajasthan; PGE mineralisation in the ultramafic-mafic rocks of Sulthan Bathery-Mananthavadi area of Kerala, Solavanur and Karappadi blocks, Mettuppalayam mafic-ultramafic complex, Tamil Nadu; Kankvali-Janali area, Maharashtra; polymetallic mineralization, Pali, Rajasthan.

The primary aim of the GSI's National Geochemical Mapping (NGCM) is to obtain a complete set of geochemical baseline maps of the entire landmass of the country so that the regional mineral assessment programme of the country can be undertaken effectively. With near exhaustion of target area for mineral prospecting delineated on the basis of ancient workings, outcrops of oxidized ore bodies, etc., it has become imperative to look for hidden/concealed deposits and the geochemical anomaly signatures can provide important leads in delimiting possible locales of subsurface deposits. Associated with it come the additional benefits, in the form of the soil fertility assessment, resolving public health issues, establishing valid geochemical baselines for environmental studies and understanding the chemistry of the environment. Data generated through geochemical exploration purposes are also used to resolve controversies in the process of correlation of geologic units, and for many other purposes. GSI has been gearing up its infrastructure facilities in the last few years to take up the enormous challenge of covering

country's length and breadth. Preparation and distribution of standard reference samples, development of trained manpower, standardizing field sampling techniques, multi-element analytical methodologies and devising a unified data quality monitoring procedure, etc., are the major initiatives taken towards this end.

During the period from 2009 to 2012, an area of 1,35,245 sq km were completed by geochemical mapping against the set target of 1,80,000 sq km. NGCM programme, since its inception in 2001-02, has completed about 2,48,268 sq km till March 2012. Chemical laboratories of GSI are now equipped with the state-of-the-art equipment and the analytical result of the samples generated during the period 2002-2009 are now available, which are being processed. Some highlights of the interpreted data are as follows: in Rajasthan, Gyangarh, Bhim areas located in Toposheet No. 45K/2 shows high concentration of Pb-Zn, Au values show anomalous zones with EW trend in 45K/6, two new high-anomaly zones of Zn, one falling in NE-SW trending "Agucha lineament" along the boundary of 45K/6 and K/7 and the other zone along the contact of BGC-Hindoli Formation (45K/12); in Gujarat, anomalous values of Al_2O_3 (9.64% to 16.63%), TiO_2 (2.2% to 3.16%) and Cr (572ppm to 882ppm) are noticed in Toposheet No. 41E/3 & E/4; the Cu values near Jaloda and Unarwa are anomalous and peaked around Unarwa area in 46F/15. Cu values also show positive correlation with Ni, Cr, TiO_2 and V concentrations in the area. Prominent SiO_2 anomaly zones with SiO_2 varying from 96.75% to 97.75% were picked up in stream sediments around Jiyajuri in T.S. 83B/15 of Assam. Anomalous values of Ba: 199-2264ppm, Rb: 22-261ppm, Sr: 2-621ppm around Nongpoh are characteristic of porphyritic granite exposed in T.S.78 O/13 Meghalaya. In West Bengal, Au anomaly is found varying between 7ppb and 95ppb to the north of Rudra area and 3, 6,16 ppb northwest of Kuilapal in 73J/9, anomalous concentrations of Nb-188ppm, Sr-432ppm and P_2O_5 -0.34% are recorded near Beldih in 73I/8. Some anomalous concentrations noticed in Maharashtra are of Cr (73-164ppm), Ni (35-93ppm), V (89-421ppm) Cu (35-231ppm), Zn (40-126ppm) and Pb (16-78ppm) in toposheet 55P/5 and a significant anomaly pattern for Cu around Dongargaon-Tambekhani area, Pahungaon, Tas, Pular-Parsadi belt and Nerla-Adyal area. Conspicuous Pb anomalies are also recorded at Kolari, Pular & Kitari areas, north of Nerla. The samples collected over the augen gneiss of Betul Gneissic Complex, central India do show anomalous values of Cr: 76-238ppm, Cu:117-296ppm V:225-474ppm and Zn:70-135ppm in Madhya Pradesh. Toposheet No. 56D/15 and southern part of toposheet no. 56D/8 of Karnataka have yielded anomalous concentrations of gold (0.135 ppb) and strontium (3240.235 ppb). In Tamil Nadu, the entire

58J/5 and the southern-most part of 58I/8 and also the northern most part of 58I/8 are characterized by high uranium (upto 9.66 ppm), thorium (upto 170 ppm) and REE concentration. Geochemical mapping in and around Thrissur area of Kerala, covering toposheet 58B/2 brought out incidences of gold. During the XII Plan, about 2,83,500 sq.km area spreading over 405 number of toposheet is likely to be covered under Geochemical Mapping.

Geophysical Mapping (GPM) is a national programme of GSI with the objective to cover the entire nation systematically in 1:50,000 scale with gravity, magnetic (TF) and spectral surveys. The prime objective of these surveys is to deduce the geology and structure of the area by interpreting the gravity and magnetic anomalies. It is also envisaged to study the physical properties of rocks by collecting the representative rock samples of the area surveyed. This would greatly help in modeling and deducing the geology and structure in third dimension. In case of GPM too, areas with mineral potential are identified covering about 1500 toposheets as priority areas falling in entire Indian Shield area, the Indo-Gangetic plain, the Eastern and Western Ghat areas, Deccan trap covered areas, etc. This also includes the obvious geologically potential areas for minerals so that while deducing mineral occurrence potential of a probable area, thematic geologic maps, geochemical anomaly maps and geophysical anomaly maps can be studied in conjunction and a consolidated baseline data bank of the particular area can be developed. Besides the mineral prognostication, the data generated by this mapping are useful in the demarcation of potential hazard areas from environmental point of view.

From 2009 onwards, a total of about 1,02,798 sq km were covered under GPM. Since its inception, GPM has covered about 1,73,016 sq km till March 2012. During the XII Plan, about 2,23,250 sq km area spreading over 320 number of toposheet is likely to be covered under GPM.

Geological Survey of India has expanded its geological activities to seabed survey and offshore mineral exploration during the last four and half decades. Marine Surveys of GSI in XI Plan (2007-08 to 2011-12) was focused on i) seabed mineral resource evaluation by high-resolution marine survey, systematic mapping of seabed within the territorial waters, ii) geotechnical mapping for development/management of port, harbour, pipe line installation, Single Buoy Mooring (SBM) Systems, etc., iii) offshore mineral resource exploitation, iv) geochemical scans in potential areas of gas hydrate occurrences, and iv) appraisal of sites for Ocean Thermal Energy Conversion (OTEC) emerging area for Non-Conventional Energy Resources.

During the period 2009 and 2012, offshore survey was carried out by the Marine & Coastal Survey Division of GSI with the help of the three research vessels, namely, R.V. Samudra Manthan, R.V. Samudra Kaustubh and R.V. Samudra Shaudhikama. GSI is in the process of acquisition of one state-of-the-art ocean going vessel as a replacement of RV Samudra Manthan, which is expected to be delivered by September 2013; another coastal geotechnical vessel with drilling capability of 30m in shallow water (within 6 to 30m isobath) is also under process of acquisition.

From 2009 to 2012, GSI carried out a total of 68,853 sq km mapping by swath bathymetry within EEZ, 33,773 lkm of bathymetry and 36,924 lkm of magnetic survey. GSI has provided basic metadata of prospective blocks for placer mineral occurrences on 5' X 5' grid, based on the results of various investigations carried out both in East Coast and West Coast to Ministry of Mines, Government of India for further policy decisions. Two cruises off Kollam have indicated probable offshore resources of relict sand of about 184 million tonnes over an area of 180 sq. km extending to a subsurface level of 1.5m and located 25-40 km away from the coast. Five EEZ maps in 1:50,000 scale (two off Car Nicobar and Nicobar Islands in Andamans and two off Goa and one off Mangalore in the Arabian sea) and one TW maps on 1:50,000 scale off Gopalpur-Malud, Odisha have been published. Research projects on the evolution of Indian monsoon and identification of abrupt climatic change during late Quaternary of marine sediment cores have indicated that microfaunal and paleo-sea surface estimates from the planktonic foraminifera census data could be utilized to identify the monsoonal climatic evolution in the Bay of Bengal during the last Glacial-Interglacial transition. Study of sediments from Central Andaman Trough/Spreading Centre has been carried out and evidences of recent volcanic and hydrothermal activities are found which corroborate the view of formation of Andaman Sea by initiation of spreading of Central Andaman back-arc basin.

Societal Programmes

GSI conducted investigations to cater to the specific societal needs covering aspects of:

Engineering Geology

- * Water resource development for hydel power, generation, control and irrigation,
- * Communication network: feasibility, construction and maintenance of roads, railway lines, tunnels and airstrip under landslides and soil erosion.

Earthquake Geology and Seismic Studies

Geoscientific studies of natural hazards come under the

purview of GSI with a view to restrain and mitigate the loss of life and property. The emphasis of GSI in this regard is collection and synthesis of geological information and data both for the source region and site of interest to surmount the disastrous effects. GSI has focused on the study of active faults (study of source region) and seismic microzonation (site of interest) of urban agglomerations in various geological domains of the country. Besides, observational seismology (Jabalpur/Nagpur), post-earthquake macroseismic survey, microseismic and other geophysical survey like seismic structure of Shillong Plateau, observational seismology, etc. have remained normal assignments in the ambit of seismic studies of GSI. Active Fault Mapping, including seismotectonic assessment of some interplate and intraplate faults/active faults, underscores the relevance of studying the nature of source region of earthquakes, behaviour of the faults and its recurrence interval and provides crucial clue for understanding perspective scenario. Seismic microzonation involves subdividing a zone/site prone to earthquake hazards into microzones, which would supposedly behave in a similar way in case of impending earthquake. Urban planning and building rules are to be guided by the results of seismic microzonation study for a safer society.

Active fault mapping and related hazard studies were carried out by GSI in the entire Himalayas and its foothills, Son-Narmada-Tapti-Purna Valley, Kutch and Suruli-Ar Shear zone, Tamil Nadu, etc. for delineating seismogenic characteristics, estimating recurrence interval etc. From 2009 onwards, geodetic monitoring using DGPS has been taken up by GSI across Mismi and Lohit Thrust in Arunachal, along foothills of Assam- Bhutan border, along major thrusts in Darjeeling-Sikkim Himalaya and in Andaman and Nicobar Island. These studies aimed at understanding the geodynamics of the crust in the area and its bearing in seismogenesis. Active fault studies and geodetic survey using DGPS are presently also being attempted in the eastern part of Son-Narmada South Fault (SNSF), Frontal Belt in Kala Amb area, HP & Haryana, along MFT, MBT and MCT in Darjeeling-Sikkim Himalaya and adjoining foot hill regions. DGPS survey in Andaman Group of islands is being carried out to compute ground deformation parameters in the light of repeated earthquake affecting the region in quick succession since the Great Andaman – Sumatra Earthquake of 26th December 2004.

Geological Survey of India has been conducting Seismic Hazard Microzonation studies in different urban centres in the high-hazard areas, which aimed towards preparation of predictive-scenario earthquake hazard maps of major urban agglomeration. GSI mainly prepares first cut microzonation maps based on geotechnical studies with

limited site response studies. From 2009 till date, such studies have been completed in the cities of Jammu, Greater Bharuch, Vijaywada, Chennai. Further studies are being carried out in Greater Surat Town, Gujarat, Jorhat Urban Agglomeration, Assam, Vijayawada Urban Agglomeration, A.P, Jalandhar Urban Agglomeration, Punjab.

GSI carries out post-earthquake damage surveys (macroseismic survey) following all major earthquakes for preparing Earthquake Intensity Maps. The 18th September 2011 Sikkim Earthquake was studied by Geological Survey of India and Earthquake Intensity Map for the region was prepared. Besides MEQ studies of the aftershocks and study of earthquake induced landslides were also undertaken.

GSI has developed expertise in operating Broadband Seismic Observatory (Jabalpur, Nagpur) and Geodetic GPS observatory (Jabalpur, Lucknow) along with campaign mode DGPS survey for studying ground deformation/crustal motions (conducted in Andaman, Assam, Arunachal Pradesh). GSI Seismic Observatories continuously record global, regional, local seismic events. Efforts are being made to connect all the seismic observatories of GSI through V-SAT.

GSI operates temporary local seismic network for monitoring seismicity (micro-seismic studies) and takes up studies on seismology and seismic tomography.

The digital version of the Seismotectonic Atlas of India And Its Environs (2000) published by GSI can be accessed through GSI web portal (www.portal.gsi.gov.in).

Landslide Studies

Geological Survey of India, declared as the nodal agency by the Government of India for undertaking and coordinating landslide investigation and formulation of mitigation measures, has been entrusted with the formulation of strategy/methodology for any type of landslide investigation in the country and formulation of a landslide hazard risk mitigation code to be followed by all the Government/Non-Government and other user agencies. The National Disaster Management Authority (NDMA) constantly support and interact with GSI for reaching this goal. The landslide risk mitigation study conducted by Geological Survey of India includes: Pre-Disaster Study that envisages a) landslide hazard zonation mapping on different scale as per the demand of user agencies, b) preparation of landslide inventory and Post-Disaster Study that involves a) Detailed site-specific study of landslide for identifying causative factors and suggesting most suitable remedial measures, and b) landslide monitoring/real-time monitoring by instrumentation for the development of an early warning system for some conspicuous slides.

GSI has covered major part of the vulnerable hilly terrain in India (covering nearly 56,000 sq km) through macroscale landslide susceptibility mapping. These maps are made available to the appropriate authority in the Government for perspective planning and environmental regeneration of the fragile hill slope. Since the methodologies adopted or being adopted for generation of these maps need constant development, required research and interaction with national and international institutes for development of terrain-specific methodologies were undertaken by GSI. In recent time, Geological Survey of India in collaboration with ITC, Netherlands has successfully developed suitable methodologies for landslide susceptibility, hazard and risk analysis in Eastern Himalayas.

However, the site-specific studies are the major area of activities of Geological Survey of India in which the affected and adjoining areas of a particular landslide is being evaluated through detailed mapping and stability analysis to identify the nature and kind of distressing, causative factors, failure mechanism, and thereafter formulating comprehensive mitigative measures. In the last four years, GSI at the request of road maintaining authorities has undertaken innumerable site-specific landslide investigations in the affected hill slopes across India aimed at formulation of short- and long-term mitigation measures for containing the distressing in the hill slopes. The site-specific investigations were completed in the states of Sikkim, West Bengal, Karnataka, Tamil Nadu, Kerala and Goa.

Besides the above-mentioned site-specific studies, in recent times, GSI has taken up monitoring of a few conspicuous, recurring landslides in the states of West Bengal, Sikkim, Tamil Nadu and Maharashtra. The total gamut 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 state-of-the-art instruments (like total station, rain gauge, in place inclinometer, piezometers, etc). 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. Some of the landslides, which GSI has attempted to monitor utilizing geodetic monitoring using DGPS and total station and geophysical probing and surface rainfall measurements, include 9 mile slide zone in Sikkim., 40 km slide on NH-31A, Darjeeling district, West Bengal, Hospital landslide complex, Coonoor, Nilgiri district, Tamil Nadu and Dasgaon slide, Raigad district, Maharashtra. For taking up comprehensive

instrument aided monitoring in some of the selected landslides, collaboration with Geological Survey of Canada was made through visit of Canadian experts in India and Indian geologists to Canada.

Site/Theme Specific Geo-environmental Studies

Studies of urban/industrial growth centres have been taken up to generate baseline data for use in different aspects of facilities and infrastructure, geo-seismological, geotechnical and geomorphological issues in different urban centres.

Studies related to geo-environmental appraisal and archaeological importance was conducted in Uttar Pradesh and Uttarakhand. Studies related to tourism development in geomorphological domain and assessing geo-tourist potentials of Uttarakhand and Mount Abu area in Gujarat were carried out alongwith geo-ecological studies of mangrove forests of Krishna, Godavari, Pennar deltas and coastal lagoons of Coringa area and Nagapatanam, Lankaranidiba, Plokayatippa, Nachugunta, Pulicat, Lolleru, Goguleru and Pandi areas. During investigation of coal, geoenvironmental appraisal studies of Hasdo-Arand and Sohagpur coalfields and block wise geoenvironmental appraisal were taken up.

Geo-environmental Impact Assessment Studies

Impact assessment studies covering mining, industries, agriculture and engineering projects have been taken up.

- * Geoenvironmental appraisal in areas around industrial growth centre, Bodhjungnagar, West Tripura, has been carried out. The environmental hazards, identified in the area are due to anthropogenic as well as geogenic processes. The anthropogenic effluent waste along with foul/toxic odour of H₂S gas from the rubber industry is released in the lungas and flows down and affects/degrades soil fertility. The effluent-rich *nalas* pollute the surface and subsurface water and indirectly affects human and animal health. The geogenic hazard includes iron contamination of ground water. The Tippam Group of rocks is rich in iron ore due to which the sub-surface water is contaminated with iron. The iron content in the water ranges from 2.52ppm to 8.93ppm, which exceeds the permissible limit of 1 ppm (BIS 1991).
- * Geoenvironmental impact assessment of mining in the Beas and Pabbar river beds/terraces for sustainable exploration of minor minerals in Kullu and Shimla districts, Himachal Pradesh. The investigation has been carried out to study the effects of excessive riverbed mining and suggest the

scientific ways of mining from Aut to Manali in Kullu district along Beas river and between Chirgaon and Snail along Pabbar river.

- * Geo-environmental appraisal of Malda town, West Bengal and its environs. The area is mainly restricted towards the north and northeastern part of Malda town and is mainly comprised of older alluvium represented by Baikunthapur Formation.
- * Geoscientific studies of calcrete occurrences in selected fluvial and lacustrine basins in Thar desert of Rajasthan. The investigation has been taken up to characterize Quaternary calcretes in dry land environment of Rajasthan and their geomorphic and geological settings and to elaborate on genesis, palaeoclimate and economic section.
- * Studies on Quaternary laterites in the western districts of West Bengal - their geomorphology, stratigraphy, genesis and implications for climate change has also been taken up.

Costal Environmental Studies

- * *Study of coastal processes in Kendrapara and Jagatsinghpur districts of Odisha:* The work was on evaluation of coastal response to various geological processes operating on the coast. The study involved remote sensing interpreted map with field checks for delineation of shoreline changes, geological and geomorphological mapping (1:10,000), repeat beach profiling, measurement of wave parameters and sediment and groundwater sampling around Ambiki-Siali beach sector. The study establishes the landward migration of the shoreline by 200-350m from 1930 position indicating coastal erosion/sea transgression in three sectors.
- * *Study of coastal processes in Ramachandi-Tundahar sector, Puri district, Odisha:* Investigation in Ramachandi-Tundahar sector indicates that there is no significant change of shore line in between Kanpur in north to Chandrabhaga in south since 1930 position, but there is a considerable change of river mouth morphology of Kushabhadra and Prachi rivers.

Public Health Hazard Studies

Programmes have been taken up to identify nature, magnitude, area, frequency and cause of the health hazards, for taking appropriate remedial measures. Some such items comprise fluorosis studies in Rajasthan, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Punjab, Haryana, Jammu & Kashmir and Tamil Nadu; water quality assessment 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, goiter 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.

- * Study of arsenic and heavy metal pollution in and around known polymetallic sulphide mineral belts and gold prospects and lignite belt, Dausa, Banswara, Udaipur, Nagaur, Bikaner and Barmer districts, Rajasthan was taken up. High arsenic content mostly occurs in groundwater from hand pumps tapping aquifer rocks namely, schist, dolomitic marble, calc silicate and keratophyre. Arsenopyrite and pyrite occurring within these rocks are the possible source of arsenic contamination in groundwater.
- * Geoenvironmental appraisal of arsenic-prone areas in parts of Ghazipur and Mau districts, Uttar Pradesh has been taken up in collaboration with Central Ground Water Board (CGWB) by geological and geomorphological mapping to find out arsenic minerals occurring in sand particles, if any, and their assemblages, the geochemical processes responsible for release of arsenic in ground water and the magnitude of arsenic contamination in groundwater.
- * Incidence of fluoride in surface and ground water in parts of Gaya and Aurangabad districts, Bihar. The famous Bihar mica belt extending over 160 km in length from Gurpa in Gaya district through Nawada, Jamui and Munger districts is reportedly having high concentration of fluoride in groundwater. The fluoride content in groundwater varies between 0.11-14.60ppm against the permissible limit of 0.6-1.5ppm. In surface water, fluoride content ranges from 0.03-2.91ppm. Zones of high fluoride have been identified.
- * Study of high fluoride incidence in groundwater of Bamongola, Gajol and Ratua-II blocks, Malda district and Tapan block of South Dinajpur district, West Bengal has been carried out. Although there has been no report of fluorosis or any ailment related to high fluoride in the area, some high-fluoride sectors have been identified where fluoride concentration exceeds the desirable limit of 1.5 mg/l.
- * Investigation of high fluoride incidences has been conducted in Purulia-I, Purulia-II, Raghunathpur-I,

Raghnathpur-II, Hura, Jaipur, Kashipur and Para blocks of Purulia district, West Bengal. Out of 75 post-monsoon water samples from the affected blocks, 13 samples with high fluoride values with the highest value of 5.40mg/l from Patamputra village of Purulia-I block have been recorded.

Geothermal Studies

Monitoring of pre- and post-monsoon thermal manifestations, southeast of Kadma, Mahendragarh district, Haryana revealed sub-surface geothermal activity along the Un-Nangalamala ridge exposing massive bedded quartzite of the Alwar Group of the Delhi Supergroup. In tube wells with depth beyond 150m, temperature has been found to vary from 42°C to 57°C. Chemical analyses of thermal waters from tube wells indicate marginal decrease in values of pH, EC, TDS, HCO₃, Mg and SiO₂ and marginal increase in values of Na, Ca, F, Cl, SO₄ and PO₄ from pre- to post-monsoon period.

Investigation has been done to study the hot water flow from boreholes drilled during exploration of coal in Mahallah area, Birbhum district, West Bengal, where hot water flow of 50° to 58°C at the rate of 60 litres per minute was reported. Highest temperature recorded in boreholes was 71°C from depth of 678m. The thermal waters are alkaline with <10ppm sulphate and high HCO₃. In the thermal water, chloride content ranges from 100ppm to 250ppm, sodium from 124ppm to 266ppm, chloride from 9ppm to 12ppm with silica content upto 78ppm. The study reveals that the area may be considered as a new geothermal prospect of low to intermediate (<125°C) reservoir temperature.

Research and Development

Petrology

Petrological studies are being pursued at various laboratories of Central Facilities, Regions, Operations and State Units of GSI as research items and as specialized thematic projects under the Annual Field Season Programme. The highlights of these projects undertaken during are given below:

- * *Study the growth of secondary minerals from melilite after reaction of alkaline and acidic solution in hydrothermal condition.* Hydrothermal experiments on synthetic gehlenite composition were carried out to study the secondary alteration products in presence of alkaline and acidic aqueous solution.
- * *Delineation of Pleistocene-Holocene boundary and characterization of subsurface alluvial/deltaic sediments of the Bengal delta in and around Kolkata:* The Quaternary Bengal delta comprises sand, silt and

clay with subtle variations in colour, grain size and mineralogy. The top Recent sediments are very thin and developed locally. This is successively followed downward by Holocene grey sediments and then Pleistocene yellow to brown, oxidized sediments. The size, shape and mineralogy of the sediments shows a little variation across the Pleistocene-Holocene boundary. The Holocene sequence is characterized by grey, fine sand in comparison to yellow to brownish grey, fine to medium or occasionally coarse sand in Pleistocene sequence. The former shows abundance of muscovite and biotite, whereas the latter is generally coated with Fe-oxyhydroxide and shows concentration of illite. So far, from the existing knowledge, the depositional model is established subject to corroboration by OSL dating.

- * *Tectonism, magmatism and crustal evolution of the northeastern Himalayas in parts of Tawang and West Kameng districts, Arunachal Pradesh.* The Bomdila granite cores are clearly within paramagnetic and non-magnetic or ilmenite type granite (Ishihara, 1977, Gleizes *et al.*, 1993). The major paramagnetic phase in Bomdila granite is biotite. Magnetic foliation worked out is correlated with regional mesoscopic foliation recorded from different comparable outcrops of Bomdila gneiss and it is observed that they are coinciding in most of the cases. However, deviation of magnetic foliation is also recorded in some cases and this may be due to effects of later deformational events.
- * *Mineral Chemistry and Fluid Inclusion Studies of Rongjeng and Sindhuli granites, Meghalaya.* The work is continuing.
- * *Physical characterization, petrology and geochemistry of the Barren Volcanic Island: an active stratovolcano in Andaman Sea.* Western, southwestern, southern, northern and central part of the volcano and the base of the erupting cinder cone were studied. The volcanic products of the recent eruption are lavas and pyroclastic flows. Compared to the violent eruption observed during 2005 to 2009, the eruption at present is continuing with a lesser intensity. The eruption is pulsative and explosive type (strombolian).
- * *Petrochemical characterisation of fenites associated with alkaline intrusives of South Purulia Shear Zone and North Purulia Shear Zone.* The syenite body represents a sigmoidal, elliptical body with a general 320° trend, making an angular relationship with the general East-West trending South Purulia Shear Zone. Several varieties of

syenites were identified. The sigmoidal shape also suggests that the syenite body was probably emplaced during the development of South Purulia Shear Zone. Riebeckite- and richterite-bearing alkali feldspar-rich syenite and richterite-epidote-rich syenites suggest the presence of fenites. The main syenite is characteristically acmite, alkali feldspar (albite and orthoclase), nepheline and epidote (piedmontite-bearing rocks with apatite and sodalite as accessory phases. Well-preserved grain refinement, recovery recrystallisation textures are characteristic of this deformed syenite.

- * *Characterization and petrogenesis of the ophiolites of Middle Andaman and South Andaman and their evolution in the active Andaman-Java subduction complex.* The tectonite unit is represented by highly serpentinised harzburgite with crude foliation defined by the alignment of pyroxene grains. This unit shows well-developed slicken-sided surfaces. The transitional peridotite are highly serpentinised and chloritised harzburgite where the relics of olivine and orthopyroxene are set in altered mass of serpentine and chlorite, the melt-rock interaction effects along with the presence of amoeboid / irregular-shaped chromite suggests mantle origin of these rocks in the overriding plate of the subduction zone.
- * *Petrography and geochemistry of mafic-ultramafic suite of rocks with emphasis on evolution and associated mineralization of Mordongri area in eastern part of Betul Belt, Chhindwara district, Madhya Pradesh.* Mordongri mafic-ultramafic suite of rocks is exposed in the eastern part of the Proterozoic Betul belt. The main rock types include quartz-mica schist, meta-rhyolites, meta-basalt, granites and mafic-ultramafic suites marked by layered hornblendite-gabbro sill, hornblendite and gabbroic anorthosite dykes. A conspicuous layering in individual rock unit is defined by the variation in grain size and mineralogical composition. Syn-to-post kinematic granite intrude all the major lithounits in the northern part.
- * *To carry out petrological and ore mineragraphic studies of the mafic rocks with an aim to test its PGE potential.* Samples have been collected from the sills across the expanse of the Tadpatri Formation of rocks exposed in the south-western part of the Cuddapah basin.
- * *Petrological characterisation and PGE potential of ultramafic-mafic bodies in northern part of Gadwal and Peddavura Schist Belts, Andhra Pradesh:* In this part of the Dharwar craton three distinct suites of

granitic rocks are exposed, with linear outcrops of Gadwal greenstone belt consisting of metabasalt and banded haematite quartzite, pegmatites, quartz veins, and dolerite dykes. Several northwest-southeast trending bodies of ultramafic-mafic rock of meta-gabbro and meta-pyroxenite occur from Tippadampalli in the southeast to Narayanpet in the northwest and were sampled.

- * *Geological and geochemical investigation of granitoid bodies of Aravalli Fold Belt, NW India with emphasis on their tectonic significance:* To resolve the controversial stratigraphic status of several gneissic bodies hosted by the Aravalli Fold Belt, specialized thematic mapping was carried out covering an area of about 300 km² on 1:25,000 scale in Udaipur district, Rajasthan. Chavand and the Jhalara granite were studied with a view to identify the various phases of granitic activity, their tectonic significance and to elucidate the basement-cover relationship.

Geochronology and Isotope Geology

Research projects initiated: 1) Determination of whole rock Rb-Sr ages of Jahazpur Granite and felsic volcanics of Hindoli Group. 2) Delineation of Pleistocene- Holocene boundary and characterization of subsurface alluvial/deltaic sediments of the Bengal Delta in and around Kolkata (collaborative item with Central Petrological Laboratories, CHQ, Kolkata).

Strontium was extracted from suitable samples of three Jahazpur Granite and one Hindoli volcanics suite for isotopic analysis.

Radiocarbon dating of four sediment samples from borehole cores near Kolkata completed for delineation of Pleistocene- Holocene boundary in Bengal Basin reveal ages of 6931± 87 ybp, 11224± 94 ybp, 12356± 252 ybp and 10626± 89 ybp.

One bulk sample from white stalagmite from the Syndai cave of Meghalaya revealed a ¹⁴C age of 5696± 36 ybp as part of the pilot project on geospeleological studies.

Luminescence Dating Laboratory, Faridabad has studied palaeoclimatic changes in selected river basins in Satluj valley (Himachal Pradesh) Alaknanda valley (Uttarakhand) and Indus valley (J&K) in Himalayas. A total of 66 samples have been analyzed for optically luminescence (OSL) dating.

Paleontology

- * *Palynological and microfaunal study of volcano-sedimentary beds associated with Malwa traps for environmental assessment, stratigraphic correlation*

- and paleogeographic implications of marine incursion as envisaged during Maastrichtian-Palaeocene.* Work includes palynofloral studies for stratigraphic correlation and assessing influence of volcanism. The associated microfauna is studied to interpret the depositional environment and climatic changes. Studies in the Baklyapura section revealed dominance of sponge spicules and diatoms (pinnate) associated with mycorrhizal fungi. The Gujarmohana section shows abundance of mycorrhizal fungi.
- * *Palynostratigraphy of sediments associated with Deccan Continental Flood Basalt sequences of Nanded-Yeotmal region.* The project aims at establishing the palynostratigraphy of sediments associated with the Deccan continental flood basalt of Nanded-Yeotmal region. Work involves determination of age, stratigraphic correlation and environmental interpretation. The Javarala section revealed presence of pollens of *Normapolles* sp., microrrhizal fungi, *Concentricites*.
 - * *Systematics, diversity and biogeography of some major group of macro-invertebrates from the Upper Cretaceous-Tertiary sediments of Meghalaya Basin with special emphasis on diversity.* The research objective is to do taxonomic studies of the invertebrates, make palaeoenvironmental interpretations and carry out biogeographic analysis.
 - * *Study of the invertebrate fauna from marine Permian sequences of central India.* Marine invertebrate fossil, *Praeundulomya* sp. and many broken shells of bivalves, have been recovered from the upper part of Talchir Formation, near Shahpur, Tawa valley, Satpura basin. The fossil assemblages have been recovered from the black shale, which contains carbonate layers.
 - * *Detailed taxonomic study of foraminifera (both larger and smaller) of the Subathu Formation for biostratigraphic zonation and palaeoclimatic inference, (Dist. Solan, Himachal Pradesh):* The project is to study the foraminiferal population and its morphological variations using SEM. The study includes biozonation and palaeoclimatic interpretations. Thin section and SEM study revealed presence of different foraminifera species *Assilina laminosa* and *Nummulites*.
 - * *Palynostratigraphy of coaliferous Gondwana sediments in Naurazabad (north) area, Johilla Coalfield, M.P.:* The project involves palynological zonations, palynostratigraphy of the Gondwana sediments and delineation of stratigraphic status of the unclassified subsurface sediments.
 - * *Search for large and smaller vertebrates and study of faunal diversity in the Tiki Formation, South Rewa Gondwana Basin, Madhya Pradesh.* The project is to study the mega- and micro-vertebrates in the Tiki Formation involving reevaluation of the stratigraphic sequence and correlation of other late Triassic non-marine sequences of the world. During this period, a large phytosaur skull, jaw fragments of metaoposaurus amphibian and rhynchosaur, one fish jaw, one dinosaur tooth along with other post-cranial bones were collected. Screening of bulk samples have yielded shark teeth, tooth of *Ceratodus* sp. (fish) and jaw fragment of a lizard like reptile.
 - * *Composite palaeontological, stratigraphic and palaeoclimatic studies of Quaternary coastal deposits and fluvial sequences of north Andhra Pradesh:* The project is to intensify the search for Quaternary fauna, to establish the biostratigraphy and interpret the Holocene high-sea strands in the coastal tract and to interpret the palaeo-climate.
 - * *Palaeontological, palaeoclimatic and biostratigraphic studies of Cretaceous bryozoans from the Cauvery Basin in parts of Tiruchirappalli, Ariyalur, Cuddalore districts of Tamil Nadu and Pondicherry district of Pondicherry.* The project aims at the study of bryozoans in the Cretaceous, in order to establish the biostratigraphy and palaeoclimate.
 - * *Palaeontological studies of Mesozoic sediments of the Upper Gondwana sediments of the Pranhita-Godavari Valley in Karimnagar and parts of Adilabad districts, Andhra Pradesh:* The project is for searching various groups of Mesozoic vertebrate fauna from the Carnian, Norian, Rhaetian and Liassic formations of the Pranhita-Godavari Valley in Karimnagar and parts of Adilabad districts and to evaluate the changes in the composition of the fauna of the Triassic and Jurassic. A partially preserved reptilian skull was collected from the lower Jurassic Kota Formation near Mulkalpet, in Pranhita-Godavari Valley, Andhra Pradesh.
 - * *Taxonomic revision and new description of Late Cretaceous a belisaurid theropods from central India and phylogenetic relationship with particular reference to recently described specimens from Charles Matle's collection of theropods from Lameta of Jabalpur:* Phylogenetic study of small theropod specimen from Pisdura, Lameta and comparison with

Indosuchus raptorious GSI K37/685, GSI K/685, GSI K/690; *Indosauius matleyi* K 27/565 and *Laevisuchus indicus* from Jabalpur Lameta and *Rajasaurus narmadesis* from Kheda, Lameta is being carried out.

- * *Palaeobiological study of Tertiary sediments of Andaman Islands to establish biostratigraphy and interpret depositional palaeoenvironments*: The project aims at establishing biostratigraphy with the help of micro, mega and ichnofossils and to establish the environment of deposition. Studies carried out in the southern part of Middle Andaman reveal the, Ichnogenera – *Planolites*, *Kekia*, *Thalassinoids*, *Skolithos* and *Teichichnus* from Mithakhari rocks. which indicate shallow-water deposition. Smaller benthic foraminifera assemblage which includes *Bolivina* spp., *Nodosaria* sp., *Cibicides* sp. etc has been noted and a red chert sample has yielded radiolarian.
- * *Ichnological study of the Bay of Bengal coast in West Bengal and Orissa for depicting the temporal effects of Recent and sub-Recent sea level changes on coastal geoenvironment, ecology and biodiversity*: The project aims at establishing the ichnocoenoses, ichnological zones, their overprinting/interactions in relation to time, sea level and coastal ecospace and for futuristic geotechnical and geo-environmental applications of the ichnological database. Comparative study of IRS P6, IRS 1C, IRS 1D, LISS III and toposheet data from 1968-2005 of the Bakkhali-Frazergunj coast reveals a steady landward shift of the high water line/ low water line indicating sea level rise in the study area. Studies reveal that excessive anthropogenic activities in the Mandarmoni- Digha coast are affecting the coastal morphology and ecosystem.
- * *Detailed studies of Neoproterozoic and Early Cambrian Eggs/Embryos from Chambaghat Formation Krol Group and basal part of Tal Group in Lesser Himalaya of Himachal and Uttarakhand*. The phosphatic lenses have been systematically studied and sampled for locating eggs/embryos in the Neoproterozoic Chambaghat Formation (Krol Sandstone) of the Krol Group in the Himachal Lesser Himalaya.

IT Service

GSI has created an internet-driven service system and is enhancing its capacity to disseminate data and enable seamless, ubiquitous, secure and personalized delivery of GSI services. GSI has GIS-based IT services for facilitating service delivery, information availability and enabling

availability of public spatial data.

GSI Portal provides a multi-dimensional and subject oriented view of the database and is in the process of creation of an integrated data repository. The main features of this data warehouse include: (a) user friendly interface, (b) Dynamic/pull down menus, (c) search-based report, (d) secured web access, (e) notice/bulletin board, (f) complete metadata, (g) parametric and dynamic report in exportable format. GSI has established:

- * Local area Network (LAN) in all offices and a Wide Area Network (WAN) built with MPLS IP VPN technology connecting all of its office through LANs.
- * A web Portal (www.portal.gsi.gov.in) hosted from the Data Centre at CHQ, Kolkata disseminates updated information regarding organization, recent findings, geological information through static and dynamic maps and reports.
- * Enterprise GIS to serve the static information, dynamic map data and other workflow based office automation applications (MIS) to serve organizational data.
- * Organizational e-mail, IP Telephony and Video-Conferencing facilities for communication.

Dissemination of Information

The dissemination of information Policy of GSI aims to provide an enabling provision and platform for providing proactive and open access to the data generated in GSI.

The guiding principle of Dissemination of Information Policy of GSI solely being that the data/information gathered by the Department should facilitate promotion of investment in mineral exploration, assist in infrastructure planning, natural hazard management and advice on several other societal issues such as environment, health and research, etc.

The scope of the policy is to facilitate the access to GSI-owned shareable data and information in both human-readable and machine-readable forms through both web network and its network of offices all over the country in a proactive and periodically updateable manner, within the framework of various related Policies, acts and rules of Government of India, thereby permitting wider accessibility and use of public data and information.

The vast volume of geo-scientific data gathered over last 160 years called for efficient management by the way of a centralized digital archive, which could be accessed and shared with the broader community over an information highway. To achieve this, GSI-built an Organization-wide

network and Enterprise Portal, primarily to cater to its intra-organizational needs and also to disseminate information to public.

GSI Portal is utilized as a tool for dissemination of the following information to public.

- * Activities and projects (Field Season Programme) of GSI.
- * Associated geoscientists (CV, specialization, experience etc).
- * Products like Unpublished Project Reports, Publications (Records, Memoirs), Maps (Geological Quadrangular Maps, District Resource Maps etc.).
- * 1:2 M geological map and Seismotectonic Atlas of the country as an interactive web map service.
- * Contents of popular interest viz. Case studies, Photo gallery, write-up on Indian geology, Geotourism, Opinion Poll on various issues, etc.
- * Tenders, notices, important documents (Manuals, Standard Operating Procedures, etc), news items, etc.
- * Online workflow-based business transactions: Java-based customized web applications cater to online office transaction – a step towards paperless office. Several modules viz. Payroll, Field Season Programme, Personnel (HR), PQS, Laboratory Management system, Claims, etc. are in place.
- * A facility like e-mail under *gsi.gov.in* domain is extensively utilized for inter-organization communication as well as communication with the outer world. Discussion forum is utilized for exchange of ideas, views among geoscientists.

A new initiative called Online Core Business Integrated System (OCBIS) is in its emerging stage. It is envisaged to be an integrated system with suitable MIS and data workflow mechanism to facilitate proper execution of Core Business processes in GSI. The system will seamlessly integrate:

- * Geoscientific and administrative processes/dataflow in Missions and support systems.
- * Integrate all available data in a spatial environment

Recent Research Publications

Anirudhan, S., Prathimon, P.T. and Narayanan, S.P., 2010. Geochemistry of Kallakudi Limestone (Early Cretaceous) in Dalmiapuram, Trichinopoly District, Tamil Nadu. *Gondwana Geol. Mag., Spec. v. 12, p. 199-208.*

allowing search and exploration using attribute-based and AOI based queries.

- * Enable geoscientists in field and laboratories to explore, observe, consult and make decisions using the spatial data service [which serves existing data in the form of maps, reports and publications; Integrate with the existing FSPMIS (Field season project management information system), LMS (Laboratory Management system) and HRMS (Human resource management system) and other transactional systems].
- * Enable workflow-based data collection, review, analysis, storage, report generation and dissemination; preserve all versions of data/documents pertaining to a field project since its inception to completion; disseminate integrated MIS report through the Web Portal and mobile devices for real-time collaboration and interaction among stakeholders.

Human Resource Development

- * Training programmes encompassing Orientation Course for Geologists, Geophysicists and Chemists, Basic Courses, Refresher Courses, workshops, Advanced Course on specialized aspects, and ISRO- and DST-sponsored programmes, programmes based on the recommendations of state DGMs and Government agencies, and courses for foreign countries based on MoU were successfully completed. GSI also coordinates Indian activities related to IGCP programmes and uses this as a vehicle to enhance the human resource potential and capacity building of the country.

Significant Contributions

The geoscientific data acquired by Geological Survey of India from various field and laboratory-based investigations are disseminated to the scientific community through various categories of publications. like Memoirs (143 nos.), Records (253 nos.), Bulletins (119 nos.), *Palaeontologia Indica* (14 nos.), Special Publications (83 nos), Miscellaneous Publications (95nos.), Catalogue Series (6 nos.), Indian Geoscience Abstracts, Manual Series, Indian Journal of Geosciences (a quarterly geo-scientific journal -122 nos.), GSI News and Brochures.

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