DEEP CONTINENTAL STUDIES (DCS) PROGRAMME (2003-2004)

Deep Continental Studies (DCS) Programme is a collaborative, multi-disciplinary Earth Science Research Programme aimed to develop understanding of the deep crustal configuration and related processes of the Indian Lithosphere. During the year of report, efforts were made for integrated geological and geophysical studies along selected transects or study areas. Few geotransects across critical areas of tectonic significance were chosen to intensify the studies. These transects are NW Rajasthan Shield, Nagaur-Jhalwar transect, Central Indian Craton, South Granulite terrain and NW Himalayan geotransect (HIMPROBE).

The DCS programme is steered by Programme Advisory and Monitoring Committee (PAMC) set up by Department of Science & Technology. During the period of the 3 meetings of the PAMC were organized and 18 new projects were considered and 23 ongoing projects were reviewed. The following projects were sanctioned.

I. New projects sanctioned on various themes/topics.

?? Ultra-High Pressure metamorphism in Tso-Morari region.

?? Petrological, geochemical and isotopic evolution of the lower crust and mantle of the Eastern Dharwar Craton: constraints from eclogitic-peridotitic xenoliths from kimberlites Petrological, geochemical and isotopic evolution of the lower crust and mantle of the Eastern Dharwar Craton: constraints from eclogitic-peridotitic xenoliths from kimberlites.

?? Geophysical studies in North Eastern Indian region by using magnetotelluric Techniques.

?? Structure and evolution of the South Indian craton & mobile belts from deep seismic profiling and other geophysical & studies .

?? Evolution of Precambrian mantle in subcontinental NW India: clues from geochemistry of basic dykes

?? Major intracontinental shear zones of South India and their role in Gondwana assembly: Goechronological and geochemical constraints.

?? Integrated study on crustal evolution and mineralization processes in the Hungund-Yadgir transect, East Dharwar Craton, South India.

?? Analysis of deformation fabrics in granitoids of Chhota Udaipur Alirajpur region from anisotropy of magnetic susceptibility (AMS) studies – Implications for Proterozoic tectonic events in southern parts of Aravalli Mountain belts.

?? Broadband exploration of the Indian Continental lithosphere for imprints of Deccan volcanism

?? Broad Band Seismometer and Long period magnetotelluric Surveys over Laccadive Ridge and barren Island

II RESEARCH HIGHLIGHTS.

1. HIMPROBE TRANSECT

Considering that Northwest Himalayan region provides unique coverage of almost all tectonic units from the Indo-Gangetic Plains to the loftiest Ladakh and Karakoram ranges, it was considered appropriate to launch an integrated programme on a priority basis. Accordingly, NW Himalayan geotransect programme (HIMPROBE) was conceived as a long-term multidisciplinary multi-institutional research endeavor under Deep continental studies (DCS) programme of the Department of Science and Technology. The main focus of the HIMPROBE programme is to investigate the geodynamic processes in the youngest mountain belt across the Himalaya in a 100km wide corridor along Hoshiarpur Mandi-Leh-Karakoram transect (Fig.1)

Multi-disciplinary geological/geochemical and geophysical investigations were carried out by various agencies to delineate structure and tectonics of NW Himalaya. These studies include P-T constraints of Korakoram metamorphic belt, Rb-Sr biotite ages, Nd-, Sr- isotopic and geochemical constraints and geophysical investigations including gravity magnetic and long period magnetetolluric studies.

In order to collate and integrate various achievements under the above transect a Workshop on Himalayan Tectonics (HIMPROBE) has been organized at Department of Earth Sciences, Indian Institute of Technology, Roorkee during Oct. 16-17th , 2003. About 30 presentations were made on various aspects of studies. The salient achievements made under the HIMPROBE programme are given bellow:

?? **Studies on Eclogites and coesites in Tso-Morari region**

Eclogitic rocks occur as lenses within the Puga gneisses of the Tso-Morari crystalline complex. The eclogitic rocks display restricted variation in SiO_2 abundances (~ 45 to 48 wt%) indicating basaltic composition. The studies suggest that Tso-Morari eclogites, presently occurring as lenses in the host Puga gneisses, probably represent fragmented dykes related to the N-MORB-OIB type magmatism of the Neo-Tethyan ocean that have traversed through the northern margin of the Indian plate represented by the gneisses of the Tso Morari crystalline complex.

The preservation of coesite – carbonate within eclogite rock from the Tso- Morari Crystalline Complex (TMC), Ladakh, reveal the history of subduction of crustal material

into the deeper mantle depths. The presence of carbonates along with UHP- index mineral assemblages suggest peak metamorphism i.e. P>39 kbar and T>750 ^{o}C, indicating that crustal material has gone up to the depths of >120 Km. Traditional thought for the formation of diamond only in the Kimberlite pipe has been revolutionized by the discovery of metamorphic diamond, particularly linked with subduction process. The peak metamorphic assemblages of TMC eclogite *Coesite + Dolomite = Diopside*, *Coesite + Magnesite =Enstatite* , along with trapping and influx of supercritical fluids like CO_2, H_2O ,CH_4 and N_2 may provide valid explanation for origin of micro diamonds

?? **P-T constraints of eclogites from Tso-Morari Crystallines.**

The Tso-Mmorari crystallines from a metamorphic crystalline within the Himalayan belt in the eastern Ladakh, which is bounded by Paleozoic Tethyan Sedimentary Zone in the South and Indus Tsangpo suture Zone (ITSZ) in the north. The thermobarometic analysis for amphibole rich assemblage suggest that there have been developed in reducted P-T condition of peak metamorphism with no heating during exhumation, indicating that Tso-Morari eclogites have undergone medium temperature and high pressure peak metamorphism due to continental subduction of the Indian plate beneath the Eurasian plate along Indus suture Zone.

?? **SHRIMP U-Pb ages of Ladakh Batholith**

The Ladakh Batholith is Trans-Himalayan Batholithic complex of calc-alkaline type that extends for 2500 km and 20-80 km wide pluton along the Himalayan Fold belt and nearly covers 65% of the exposed area in the Ladakh Himalaya.

SHRIMP U-Pb data from near the lower most exposure of Ladakh Batholith close to Igu village indicate a rim/grain age of 58.4 Ma from 7 points analysis on 7 grains, however, one point given an age of 53.5 Ma. The granitoids of Ladakh Batholith data from the main Ladakh batholith on its northern face near Tsoltak yielded a rim/grain age of 60.1 Ma of 22 points from 25 analysis on 23 grains, however, no older cores have been observed in ages as well as from the CL images.

?? **Electrical structure in the NW Himalayan region**

Magnetotelluric studies in the NW Himalaya were aimed at obtaining the information on the deep crustal structure over the entire cross section of the Himalayan collision belt in the Siwalik Himalaya and the higher Himalaya. The results depicted the Ladakh and Chushul Batholiths as high resistively bodies to the north of ITS with a depth extent of about 12 kms. To the south of the Tso Morari crystallines, a high resistivity zone is delineated, with a depth extent of about 20 km. The low resistivity observed in the ITS and Tso Morari, seems to extend southwards beneath this high resistivity block, underlain by another high resistivity block at a depth of 40 Kms.

?? **Long Period Magnetotelluric Measurement in NW Himalaya.**

Five component MT measurements have been under taken along a profile from Sarchu to Panamik across the Indus Tsangpo Suture in NW Himalaya. The measurements have been carried out over a long period upto 10,000 s much longer than conventional MT surveys to probe deeper earth strata. The preliminary results depict an electrical anisotrophy in the uppermost 100 kms. This has been attributed to the presence of Graphite preserved in shear zones. Detailed modeling of MT data is underway.

?? **New Schemes developed for Bouguer and terrain reductions with variable densities**

Normally in Gravity data processing, Terrain and Bouguer Corrections are applied with uniform density but in real cases, need for deployment of variable densities arises. Areas of N-W Himalaya are characterized by high elevation and severely tectonized zones, which pose challenging problems for geophysical data processing in general and gravity data, in particular. The gravity data processing, especially Bouguer and terrain corrections (combined mass correction) need to be specially made honoring the sample density measurements along different profiles. For this purpose, a new gravity data reduction method has been developed. Effectiveness of the designed procedure has been demonstrated on two gravity profiles along Mahe-Sumdo-Tso Morari and Rumtse-Upshi-Karu-Panamik pertaining to Ladakh Himalaya.

?? **Development of Global optimization strategies to interpret gravity anomalies for deep continental studies.**

Gravity Data Inversion schemes for delineation of crustal structures using global optimization techniques, viz., simulated annealing (SA) and genetic algorithm (GA) have been developed. Application of SA is demonstrated by inverting the gravity data over 600km long Udipi-Kavali profile of Peninsular India. On the other hand, GA is used to invert the gravity data over Nagaur-Jhalawar geotransect across the Aravalli mountain.

2. Nagaur – Jhalawar Geotransect, India.

?? As part of the integrated studies completed above transect, studies on modeling of gravity data were carried out. It may be mentioned that the Nagaur - Jhalawar geotransect runs for about 470 km across the Aravalli mountains in the Central India with a NE-SW trend. The Bouguer anomaly profile exhibits a conspicuous high in the central part, between 100 –250 km from Nagaur, known as the central gravity high (CGH) and a steep gradient on NW segment where as a gentle slope in the SE part. The derived model (Fig. 2) shows smoother variation in the interfaces compared to the results of the other two cases. The shallow interface shows a steep fault at the northwestern boundary of CGH. The lower crust shallows up to nearly 10km from the surface. Down warping of Moho below CGH and adjoining region results in the thickening of the lower crust.

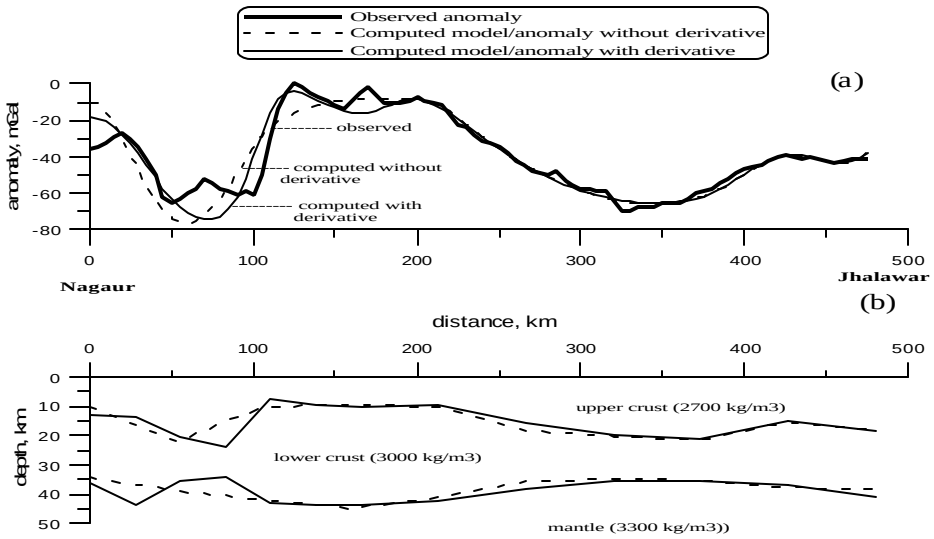

Fig.2

Figure 2. Inversion of gravity data over Nagaur-Jhalwar geo-transect. Densities of upper crust, lowe crust and mantle are 2700 kg/m3, 3000 kg/m3 and 3300kg/m3 respectively.

3. Fractal studies for enhance delectability of geophysical anomaly by optimal design of gravity/magnetic surveys in Jabera-Damoh, Vindhyan basin

The study area Jabera-Damoh, lying between latitudes 23^0-25^0N and 79^0-81^0E longitudes is considered as 'high risk-high reward' frontier area for hydrocarbon exploration. The total area covers a wide range of Palaeo Proterozoic to Quaternary geological features.

The fractal dimension of network surveyed till date is computed to be 1.63, which reveals that the coverage is dense in the area. The 2-D Radial Spectral Analysis using gravity data has been carried out. The results of radially averaged spectrum analysis are shown in Figure 3. Three linear segments are identified in a plot of radial frequency vs. log spectrum (Figure 3). The three different slopes observed in the plots are interpreted in terms of depth to the interfaces. The depth values obtained from the slope of these linear segments are 19.95 Km, 9.6 Km and 4.48 Km respectively. The value corresponding to the third segment viz. 4.48 Km corresponds to the basement depth near Jabera area, and correlates very well with the value obtained by the ONGC well located near Jabera. The other two values are interpreted as depths to deeper interfaces in the area.

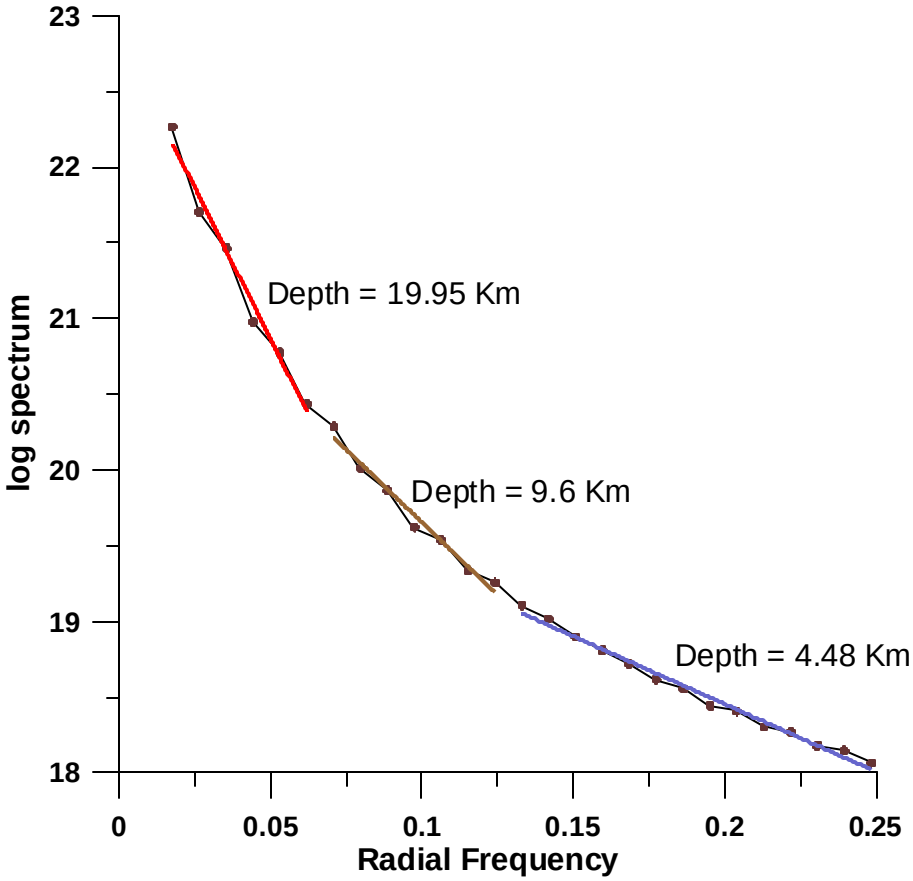

Fig.3

Figure 2:A plot between log spectrum and radial spectrum Slope of curve gives depth to interfaces

4. The magnetotelluric studies along the Goa-Dharwar-Raichur profile in the Dharwar craton

The magnetotelluric data collected along the Goa-Dharwar-Raichur profile in the Dharwar craton were interpreted. The geoelectric cross section obtained by the two dimensional inversion (Fig.4) shows a high resistivity upper crust with several east dipping resistivity patterns at depth of 5 – 25 km, indicative of a compressional tectonic regime in the Dharwar craton. A prominent east-dipping thrust extending from shallow surface near the Chitradurga schist belts (station 12) to depth of about 20 km beneath station 15 and even beyond seems to correspond to an inter cratonic suture along which the west Dharwar craton subducts beneath the east Dharwar craton.

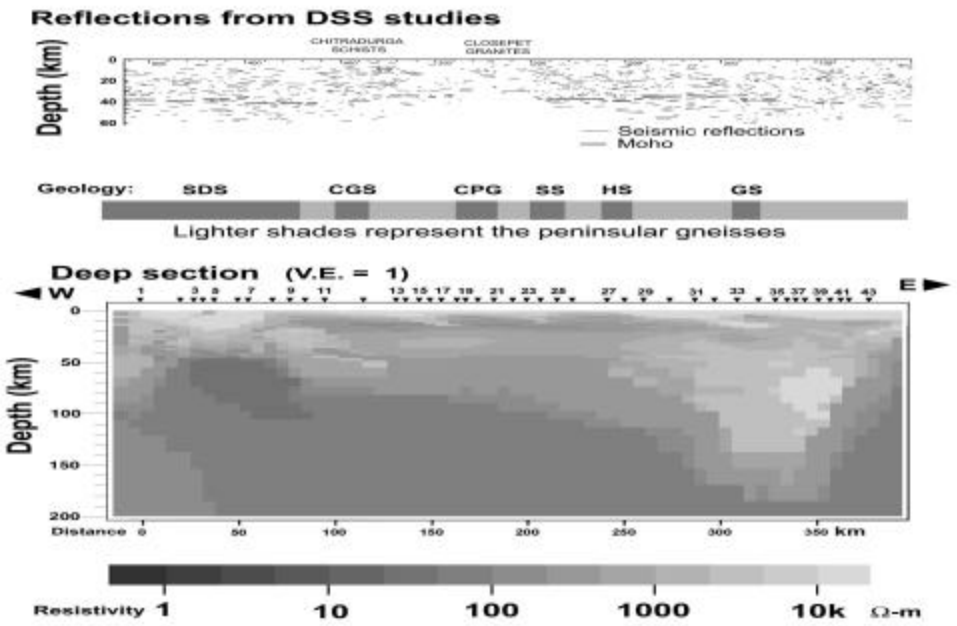

Figure. 6 Deep geoelectric cross section. Also shown on the top part are the seismic reflections obtained from the DSS studies along the Kavali-Udipi profile shown in Fig.1, located about 200 km south of the MT profile. SDS: Shimoga Dharwar schists, CGS: Chitradurga-Gadag schists, CPG: Closepet granites, SS: Sandur schists, HS: Hutti schists and GS: Gadwal schists.

Fig.4

5. Database Management System for the Precambrian Ore Deposits of India- A Web ready GIS Approach

The Project was initiated to (i) build a database of information about Precambrian Ore Deposits in India and their geological context (ii) provide public access to a digital database with maps, photographs, graphs and data with possibility of retrieving information.

Four hundred and eight ore deposits/occurrences have been located on the combined crustal domain cum tectonic map. The different metal associations have been distinguished by using different colours and different symbols (Fig. 5).

Detailed geological maps for different cratons such as Dharwar, Singhbhum, Central, Aravalli, Bundelkhand, NE Himalaya and Western Himalaya have been prepared. Database management system for the Northwestern Indian Shield and the Dharwar craton. Shown below is the Dharwar geology with all the gold occurrences (Fig. 6) as an example.

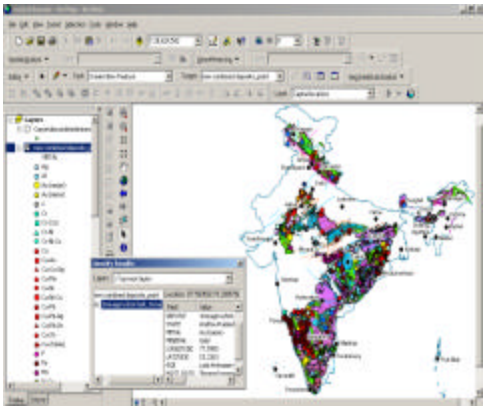

Fig.5

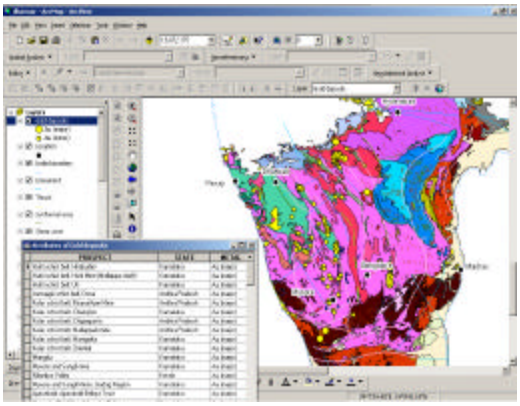

Fig.6

6. Geochemical, tectonothermal evolution and mineralisation of Narayanapet-Gadwal schist belt, A.P.

Major elements by using XRF, trace and REE were determined by using ICP-MS facility at NGRI. The data indicate a variety of volcanic rocks ranging from boninites, tholeiites, Nb-enriched basalts, andesites, dacites, rhyolites and adakites.

Geochemical signatures of the arc are dominated by slab dehydration, wedge melting with minor slab melting, generating adakites. Partial melting of TTG riding on the slab give rise to the rhyolites within the crust (at a shallower depth). The HFSE source dragged upto the depth could possibly have mixed with Nb enriched mantle component yielding Nb enriched basalts. These data on the metavolcanics of Gadwal schist belt indicate that the subduction processes around 2.7 Ga and the products of partial melting of wedge, slab and the residue left after earlier melt extraction have been involved in generating the magma most similar to what we are getting in modern oceanic island arcs.

7. Age, Sr-Nd isotopic and geochemical studies of kimberlites from the Jharia, Raniganj and Bokaro, Eastern Indian.

Geochemical and isotopic studies has been carried out on kimberlites. Sr-Nd-Pb isotopic results ($^{87}Sr/^{86}Sr_i$: 0.70535 to 0.70561; $?_{Nd}(T)$: -2.6 to –3.2; $^{206}Pb/^{204}Pb_i$: 17.88 to 18.07) on co-eval (116±2 Ma) Group II kimberlites from flood basalt province in the Jharia basin demonstrate their similarity with the recently identified pristine Kerguelen plume basalts from the Kerguelen Plateau/Archipelago and Broken Ridge. This suggests that the Kerguelen hotspot could indeed be responsible for the ~117 Ma magmatic activity in Eastern India also.

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8. Studies on the origin of the Cardamom hills Charnockite massif

The Cardamom hill charnockite massif, located at the central part of the Southern Indian granulite belt, has remained as one of the least studied sections. Field studies have documented a variety of rock types in the Cardamom massif. All charnockite variants and representatives of mafic granulites, metapelites and granite have been collected.

Most significant observations recorded are evidence for polyphased nature of the Cardamom massif and occurrence of arrested charnockite. The geochemical data has documented a chemical division of the cardamom charnockite into two major groups. The two groups strongly separate out on Zr concentration. Both groups have strong characteristics of derivation from magmatic sources. High zirconium types (Zr= 250-770 ppm) bear strong resemblance to C-type magmas in having high concentration of K (~5%), P, Ba (~2112 ppm), Ti (~0.8%) and low concentration of Ca. Low zirconium type (Zr=121-250 ppm) is characterised by low K (~2.4%), Ti (0.5%) and Ba (~990 ppm). The field, petrological and geochemical data so far available suggest that Cardamom massif is a home for at least two crust-building events witnessed by the southern granulite terrain. U-Pb zircon and monazite dating and EPMA dating of monazites document significant age differences within the Cardamom massif and a complex pattern of Pan-African and Proterozoic ages.

III. Manpower Development.

Contact Programmes

Under the Deep Continental studies Programme of DST National Workshop on paleomagnetism and Rockmagnetism was held at Cochin during 9-11th Jan., 2002. During the said workshop it was suggested that tow contact programmes on (I) Application of Anisotropy Magnetic Susceptibility and (II) Paleomagnetism and Rockmagnetic research, may be organized. Accordingly, the following contact programmes have been organized.

(i) Contact Programme on Application of Anisotropic Magnetic Susceptibility in structural Geology/Tectonic Investigations was organized during march 10-21st, 2003 at Allibagh

(ii) A total of 22 candidates were trained on various aspects of Anisotropic Magnetic Susceptibility.

One of the recommendations during the panel discussions was to provide intensive training for 6 bright young students at National Laboratories where the Anisotropic Magnetic Susceptibility studies are being undertaken. These candidates will be trained at Indian Institute of Technology, Kharagpur, Indian Institute of Geomagnetism, Bombay and Wadia Institute of Himalayan Geology, Dehradun.

?? **Contact program "palaeomagnetic and rock magnetic research"**

A fifteen-day contact program on palaeomagnetic and rock magnetic research was organized at the Centre for Earth Science Studies (CESS), Trivandrum during June 16-30, 2003.

The main thrust of the program was oriented towards introducing and familiarizing the conventional, as well as new techniques of palaeomagnetic and rock magnetic investigations among the young researchers from universities and scientific organizations. The course intends to demonstrate the use of this subject for determining the evolution of the Earth's crust and attempts to draw attention on various principles and practices of palaeomagnetism and rock magnetism in a consistent and up-to-date manner. Ultimately the program is hoped to help to build up expertise in the field of palaeomagnetic and rock magnetic research in India. Total 36 young researchers were trained.

IV. New Initiatives

Pilot Project on " Broadband Seismometer and Long period Magnetotelluric Surveys over Laccadive Ridge and Barren Island".

Recognising the importance of delineating sub-surface structures beneath Arabian Sea and Bay of Bengal, the Department of Science and Technology and PAMC-DCS played a proactive role in formulating the above pilot project with Indian Institute of Geomagnetism and National Geophysical Research Institute as collaborative agencies. The project has been recently sanctioned and expected to deploy broad band seismometer and long period magnetotelluric arrays over Laccadive Ridge and Barren Island.

V. National Facility on Isotope Geology and Geochronology established at Indian Institute of Technology, Roorkee.

The above facility was inaugurated by Prof. V. S. Ramamurthy, Secretary, Department of Science and Technology, New Delhi on 19th May, at Indian Institute of Technology, Roorkee. It is fully functional and operational and cater to the needs of geoscientists.

VI. Publications:

?? Tectonics of Southern Granulite Terrain Kuppam-Palani Geotransect (Editor: M. Ramakrishnan, Geological Society of India, Memoir 50, 434p, 2003)

?? Indian Continental Lithosphere: Emerging Research Trends (Editor: T. M. Mahadevan, B. R. Arora and K. R. Gupta, Geological Society of India, Memoir 53, 479p, 2003)

?? DCS Newsletter (January Vol.13 No.2, August Vol.13 No.2)