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information of the area, conduct shipborne investigations in critical areas, map geomorphic elements and crustal structure and suggest tectonic model to explain the unusual intraplate deformation in the area.

REVIEW OF PREVIOUS GEOPHYSICAL AND GEOLOGICAL STUDIES

The Indian Ocean floor was less studied compared to the other World oceans. Intense geological and geophysical investigations were carried out in this region only since the International Indian Ocean Expedition (IIOE) during 1959-1965. Scientific ships from 13 countries, including USSR and India, participated in the IIOE. The main results of the study were compiled in Geological and Geophysical Atlas of the Indian Ocean (1975).

In the Central Indian Basin (CIB), basic geophysical and geological data were collected during IIOE cruises of the R/V *Vityaz* (Shirshov Institute of Oceanology, USSR Academy of Sciences), the R/V *Vema* (Lamont-Doherty Geological Observatory, USA) and the R/V *Argo* (Scripps Institution of Oceanography, USA). These Institutes have continued the studies even after IIOE up to the end of sixties along with other Institutes. Results of the investigations were published in 1975 as an Atlas. (Geological and Geophysical Atlas of the Indian Ocean, 1975).

The intraplate deformation in the Central Indian Basin was studied first by Eittreim and Ewing (1972) from seismic reflection profiles. High seismic activity was reported in this area (Gutenberg and Richter, 1954; Stover, 1966; Sykes, 1970).

The next important development in the study of the Indian Ocean floor was during DSDP. The sites 215 and 218 of DSDP and 717, 718 and 719 of ODP Leg116 in the northern CIB and sites 214, 216 and 217 of DSDP and 757, 758 and 756 of ODP on the Ninetyeast Ridge were drilled during DSDP (Von der Borch et al. 1974; Cochran et al. 1989). Underway geophysical investigations provided essential data, which were later used to determine age of onset of intraplate deformation (Moore et al. 1974). The National Institute of Oceanography, India has deployed ORV *Sagara Kanya* and many other research vessels as part of the national polymetallic nodules programmes and international and Indo-Russian bilateral collaboration programmes and generated considerable amount of geological and geophysical data. The data were analysed to understand crustal structure and tectonics of the region. (Qasim and Nair, 1988; Kamesh Raju et al. 1993; Krishna et al. 1995).

The geophysical study exclusively for the intraplate deformation was undertaken by the Shirshov Institute of Oceanology in 1976 during the 58th cruise of the R/V *Vityaz* (Neprochnov, 1976) and continuous seismic reflection profiles (CSP), magnetic and gravimetric data were collected from

the deformation area. Results of this cruise along with data of the 54th cruise of the R/V Vityaz and other available data were compiled in the monograph "Geology and Geophysics of the Seafloor in the Eastern Indian Ocean". Based on the new geophysical and geological cross-sections and maps, critical views on the tectonic hypothesis were put forth and earlier views on the tectonic evolution of the region were revised.

Studies since 1980 provided new information on the stratigraphy and structure of the northern Bengal Fan (Curry et al. 1982; Liu et al. 1982, Rao and Rao 1986, Curry and Munasinghe 1991; Murthy et al. 1993; Ramana et al. 1994; Gopala Rao et al. 1994). In a comprehensive study mainly based on multichannel seismic (MCS) sections, Gopala Rao et al. (1997) have resolved some of the ambiguities in the evolutionary history of the fan. They have delineated the Continent Ocean Boundary (COB), assigned an early Cretaceous age to the oceanic crust beneath the fan and inferred some rift-related NW-SE fracture zone in the Central Bengal Fan.

They also identified four major unconformities (the lower Eocene, upper Oligocene, upper Miocene and upper Pleistocene) which were related to the major geological events of collision of Greater India with Asia; lowered sea level changes (a global phenomenon); uplift of Himalayas; onset of intraplate deformation and eustatic sea level changes and lowered sea levels respectively. Multibeam bathymetric, gravity and magnetic studies of the Central Indian Basin revealed the 79°E Fracture Zone and its morphologic features related to its coupling at Ridge-Transform-intersection (Kamesh Raju et al. 1993). The geophysical studies of Krishna et al. (1995) in the northeast Indian Ocean revealed the presence of three new fracture zones along 84°E, 84.5°E and 88°E. Abandoned spreading centres mapped between 86°E FZ and 92°E FZ are interpreted as the western extensions of the Wharton Ridge. Their activity ceased at 42Ma age (anomaly 19) resulting in the merger of the Indian and Australian plates as a single Indo-Australian plate.

An extensive compilation of the vast geological and geophysical data on the intraplate deformation zone of CIB was presented initially by Weissel et al. (1980). They constructed a simplified tectonic map of the study area and discussed results of previous decade which led to better understanding of the geology and tectonics of the region, correlation of sediment and basement deformations with high seismicity, high heat flow and gravity anomalies. They proposed a mechanical model of lithospheric thickening generated by continental collision along the Himalayas. Further studies on heat flow measurements in the CIB were carried by Geller et al. (1983).

In eighties more geological and geophysical expeditions were organized by Soviet scientists in the Indian Ocean. During the 25th cruise of the R/V Dmitry Mendeleev (1980) many geological samples for the study of the bottom sediments as well as several regional underway geophysical profiles (bathymetry and CSP) across the CIB were collected (Milanovsky et al. 1982;

Levchenko et al. 1985). Geophysical data and sampling during PICES submersible dives were collected at the Afanasy Nikitin Seamount (Levchenko, 1990). Limestones with gravel sampled from top of the seamount by submersibles indicate the seamount's subaerial environment in the geological past.

Several expeditions on board the R/V Pegas and the R/V Morskoy Geofizik were also carried out in 1982-1983 by the Institute of Marine Geology and Geophysics, Far-East Scientific Centre, USSR Academy of Sciences for study of the Eastern Indian Ocean intraplate deformation area (Popov et al. 1985; Sychev et al. 1987). Bathymetric, magnetic, gravity, seismic reflection and seismic refraction with sonobuoy and airgun as well as heat flow data were carried out.

Studies of the intraplate deformation since 1984 consisted of geophysical and geological investigations in comparatively small areas (polygons) (Neprochnov, 1985). The following expeditions of the Shirshov Institute of Oceanology - the 22nd cruise of the R/V Professor Shtokman (1989) and the 20th cruise of the R/V Akademik Mstislav Keldysh (1990) along with the cruise of the R/V Robert Conrad (1986) were carried out in the area. The first multichannel seismic reflection profiles were collected in the intraplate deformation area during the 28th cruise of the R/V Charles Darwin (1987). (Bull, 1990a; Bull and Scrutton, 1990 & 1992) and the results are also discussed in this monograph.

The ODP 116 Leg of the D/V JOIDES Resolution investigations were planned to study the intraplate deformation (Cochran et al. 1989) at the sites 717-719. About 1300 to 2000 m long cores were drilled at the sites in the distal Bengal Fan near 1° S and 81°24' E, which provide a complete record of sedimentation from the lower Miocene. The drilling data include seismic logging, measurements of heat flow and underway bathymetric, magnetic and seismic reflection data which revealed some of the peculiarities of the intraplate deformation. In particular, the unconformity "A" in seismic records corresponding to the onset of the deformation was dated biostratigraphically occurring between 7.5 and 8.0 Ma (Cochran, 1990). Unfortunately, neither the oldest drape sediment nor basement could be sampled at the well locations.

The deformation in the northeastern Indian Ocean, far from the plate boundaries is well documented from experimental geophysical data. The crustal deformation is very clearly seen on seismic reflection profiles on two spatial scales (Eittreim and Ewing, 1972; Weissel et al. 1980; Geller et al. 1983; Levchenko et al. 1985; 1990; Neprochnov et al. 1988a; Bull and Scrutton, 1990; 1992; Murthy et al. 1993b). First, broad scale deformation is represented by long-wavelength (100-250 km in width and 1-3 km relief) undulations of the oceanic basement and mostly overlying sediments. Second, small-scale deformation is represented by faulted blocks, 5-20 km in width superposed on the broad undulations.

The broad deformation is well reflected in free-air gravity field as anomalies of 30-80 mGal as well as in geoid images as undulations up to 4km in amplitude (Weissel et al. 1980; Stein et al. 1989). The gravity anomalies, indicate lack of isostatic equilibrium beneath the broad basement highs, and evidence for lithospheric buckling under horizontal compression (Weissel et al. 1980; McAdoo and Sandwell, 1985). McAdoo and Sandwell (1985) interpreted the broad scale deformation in an E-W lineated pattern from linear geoidal undulations in the SEASAT data.

High heat-flow is another geophysical parameter which point to significant intraplate tectonic activity in this part of the Indian Ocean. Localized heat flow of more than 50 mWm⁻² above regional background, typical for the oceanic lithosphere of late Cretaceous - early Tertiary age has been measured in the northern Central Indian Basin (Weissel et al. 1980; Geller et al. 1983; Cochran et al. 1989; Stein and Weissel, 1990). It is characterized by nonlinear gradients (Geller et al. 1983) and suggested to have been generated by hydrothermal circulation along fault planes (Cochran et al. 1989).

Widespread tectonic deformation of sediments and basement is consistent with a near-equatorial E-W trending seismic zone in the Central Indian Ocean (Levchenko, 1985 & 1989; Wiens et al. 1985). The high present-day intraplate seismicity evidences the region as unique among oceanic basins (Stover, 1966; Sykes, 1970; Stein and Okal, 1978; Bergman and Solomon, 1980; 1985; Levchenko, 1985 & 1989; Singh, 1988c). Teleseismic focal mechanisms indicate maximum N-S compressive stress.

In general, one can understand that the structural style of the intraplate deformation and its manifestation from gravity field as well as from abnormally high heat flow and seismicity, appear to be associated with the tectonic deformation. But, the deep structure of crust and upper mantle, which was determined by limited seismic refraction studies is still unclear beneath the broad scale basement deformation. However, Neprochnov et al. (1988a) suggested uniform crustal folding, while Leger and Loudon (1990) preferred crustal thickening at the same area. In our opinion, the study of the deep structure beneath the deformation is the most important task in the northern Central Indian Basin, which could explain the origin of the intraplate deformation.