University appreciated the holding of such a workshop to coincide with the *Earth Day* Celebrations. He also appreciated the role played by the geoscientific community in augmenting the mineral inventory of the country. He stressed the need to preserve the ecological balance for the sake of posterity.

Five invited speakers from various organizations delivered state of the art lectures on selected areas. Dr. M. Ramakrishnan, Sr. DDG (Retd.), GSI, delivered a talk on Dharwar Craton and Archaean geology with emphasis on tectonics. Shri S.V. Srikantia, Director (Retd.), GSI, delivered a talk on 'Structural patterns of Archaean and Phanerozoic orogens: a comparison between Himalayas and Dharwars'. In the afternoon session, Prof. T.C. Devaraju, Professor Emeritus, Karnatak University spoke on the Platinum Group of Elements (PGE) and rare metal mineralisation in the Dharwars in which he highlighted SEM and EPMA data of PGE of Hanumalakonda-Channagiri area, Shimoga district, Karnataka obtained in collaboration with Finnish scientists.

Dr. Y.J. Bhaskar Rao of NGRI delivered a talk on the Crustal Evolution in Southern India: Constraints from geochronology and Nd, Sr isotopes. This was followed by a talk by Dr. T.R.K. Chetty, also of NGRI, on the tectonic framework of Precambrian of Southern India based on remote sensing data with a detailed account of the Eastern Ghats of Andhra Pradesh, where an anastomising shear zone pattern could be delineated in the Sileru-Vamsadhara-Nagavalli lineamnt zones. He also gave an account of the possible orotectonic connection with other members of the East Gondwana continent.

Dr. M. Jayananda and Dr. Narahari Rao moderated the programme. The deliberations ended with vote of thanks by Prof. B.C. Prabhakara. The entire programme was well arranged and attended by geoscientists of all the organizations based in Bangalore.

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MILLENNIAL-SCALE RAPID FLUCTUATIONS IN THE ARABIAN SEA MONSOON AND OXYGEN MINIMUM ZONE (OMZ) DURING THE LATE QUATERNARY*

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Extended Abstract

The discovery of rapid climatic oscillations (Dansgaard-Oescheger cycles and Heinrich Events) over the Greenland and the north Atlantic has been one of the most important recent findings in palaeoceanographic research. The millennial-scale climatic shifts have also been reported in a variety of records (marine and terrestrial) from the southern hemisphere high latitudes. Unlike for high latitudes, little is known about the possibility of such rapid climatic oscillations in lower latitudes. The origin and nature of rapid climatic oscillations remain an enigma: in the first instances such oscillations cannot be explained by conventional orbital forcing mechanism that apply to longer time-scale; secondly recent studies suggest that millennial oscillations recorded in Greenland and Antarctic ice cores could be out of phase (Blunier et al. 1998). An important piece in the puzzle is the timing and nature of millennial oscillations in low latitude regions.

Recently, increased attention is being bestowed on a possible link between low latitude (monsoonal) climate and global climate changes. Broecker (1994) considered water vapour, as the most important global greenhouse gas that triggered climatic changes in the past. An intensified monsoon is a source of significant amount of moisture to the higher atmosphere, thereby producing the positive feedback to rapid climatic change.

In the Arabian sea, the monsoonal wind system produces a pronounced seasonal and spatial pattern in surface oceanic circulation and biological productivity. Because of monsoon driven upwelling, Arabian Sea is one of the most biologically productive areas in the world's

**Lecture delivered at the monthly meeting of the Geological Society of India at Bangalore on 27 March 2002.*

oceans. Most of the annual production on a basin-wide basis occurs during the summer monsoon. Such upwelling produces severe oxygen depletion in upper intermediate waters and the Arabian sea oxygen minimum zone is one of the most pronounced in the world's oceans. The large denitrification rate in the Arabian Sea is a direct consequence of high annual biological production and poorly ventilated water masses that enter the basin from the south. A swing in monsoonal climate is likely to produce large-scale changes in biological productivity, OMZ intensity, and denitrification and surface salinity. The Arabian sea margins offer excellent sediment records to document change of environments during the late Quaternary. We have constructed high resolution records of $\delta^{18}O$, % organic carbon and $\delta^{15}N$ in a very good quality core collected from the Indian margin (lat.15°N; long. 72°E, W.D. 840 m) showing sub-orbital cycles in productivity, denitrification and salinity (Holocene only) driven by fluctuations in monsoon strength during the last 35,000 years. The time framework is constructed based on oscillations in $\delta^{18}O$. The geochemical record shows that change in organic carbon and $\delta^{15}N$ are synchronous. The lighter value of $\delta^{15}N$ mainly occur during 11.3-12.7 Ka (YD)**, 15.59-17.25 Ka (H1)***, 23.64-25.25 Ka (H2) and 30.6-33.8 Ka (H3) periods and matching with low organic carbon content. These millennial scale oscillations characterizing low productivity during stadials of D-O cycles and Heinrich Events are attributed to a weaker monsoon. A simultaneous decline in $\delta^{15}N$ and organic carbon contents during the cold periods indicates decrease in upwelling intensity and the flux of organic carbon to sediments resulting in the increased oxygenation of water column and diminished denitrification. On the other hand, the heavier values in $\delta^{15}N$ can be attributed to the intensification of the OMZ resulting in enhanced denitrification, which results in N-isotope fractionation and upwelling of heavy nitrate.

The fluctuation in the Oxygen Minimum Zone intensity also results into variation in Aragonite Compensation Depth (ACD) with resultant preservation of aragonitic (pteropod) shells. Best preservation of pteropod shells is recorded during 16.5 Ka, 24.5 Ka and 31.6 Ka. Such aragonite spikes have also been reported in the western Arabian Sea. The ACD in the modern northern Arabian Sea lies within the OMZ at about 500 m (Berger, 1978). Water in the OMZ is undersaturated with respect to aragonite. The enhanced pteropod preservation suggests a substantial weakening of the OMZ. Comparison between C_{org} and $\delta^{15}N$ profiles shows that aragonite maxima correlate with minimum in C_{org} and $\delta^{15}N$. This indicates that a deep ACD is associated with reduced productivity and decreased denitrification. The deep convective turnover mixing of cold oxygenated water across the thermocline associated with the enhanced winter monsoon intensity has been considered as a plausible cause for the aragonite maxima and corresponding C_{org} mimima during stadials. The Holocene isotope record shows century scale cyclic variations in $\delta^{18}O$ exceeding >0.5%. The heavy $\delta^{18}O$ spikes in the Holocene are suggestive of high salinity events resulting from reduced southwest monsoon and its associated fresh water source.

** YD – Younger Dryas; *** H1, H2, H3 – Heinrich Events

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