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A positive $\delta^{13}C$ carb anomaly in Paleoproterozoic carbonates of the Aravalli Craton, Western India: support for a global isotopic excursion

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Abstract

Carbon isotope measurements, carried out on carbonate samples from different localities of the early Proterozoic Aravalli Craton, Western India, yield positive $\delta^{13}C$ values up to +11.20‰ PDB. This widespread, isotopically anomalous carbonate province, reported from this subcontinent, coincides with the appearance of stromatolites and the development of 'red beds'. These observations support a global paleoenvironment change during the Paleoproterozoic, as reported from other parts of Gondwanaland including the Kapvaal Craton, Africa, and the Sao Francisco Craton, Brazil.

Keywords: Paleoproterozoic; Stromatolites; Gondwanaland

1. Introduction

The isotopic composition of carbon in carbonate rocks is relatively well preserved and allow us to track the variations of $\delta^{13}C$ of carbonate-reservoir carbon with time. Limited but significant data on the biogeochemical cycle of carbon in the geologic past have been provided by studies of carbon isotope variations in limestones and dolostones and their metamorphosed equivalents (Schidlowski et al., 1976; Veizer and Hoefs, 1976; Knoll et al., 1986). Earlier studies indicate that Precambrian carbonate rocks have a much higher incidence of samples anomalously rich in $\delta^{13}C$ (Schidlowski et al., 1976; Knoll et al., 1986; Derry et al., 1992) compared to moderate variations of $\delta^{13}C$ in most Phanerozoic limestone world wide.

The data from carbonate sediments deposited between 2.6 and 1.6 Ga indicate that the isotopic composition of marine carbon underwent a very large positive excursion between approximately 2.22 and 2.06 Ga, as reported from Africa (Lomagundi Formation; values as high as +13‰ PDB; Schidlowski et al., 1976), the Fennoscandian Shield (Melezhik and Fallick, 1996), Scotland (Baker and Fallick, 1989a), and North America (Schidlowski et al., 1983; Mirota and Veizer, 1994). The presence of anomalously heavy carbonates in the Transvaal Supergroup, however, suggests that this interval may have begun before 2.22 Ga (Buick et al., 1998). High $\delta^{13}C$ values over this interval likely reflect changes in the mass balance of sedimentary carbon between oxidised and reduced reservoirs (Schidlowski et al., 1976; Knoll et al., 1986), which may have several causes including global increase in the fraction of carbon buried as organic matter and/or high sedimentation rates (Derry et al., 1992).

The available $\delta^{13}C$ data for Palaeoproterozoic carbonate sediments show that the positive excursion in these carbonates was probably world wide (Baker and Fallick, 1989a,b; Buick et al., 1998; Maheshwari et al., 1999; Melezhik and Fallick, 1996; Melezhik et al., 1997; Mirota and Veizer, 1994), possibly leading to an increase in atmospheric oxygen levels (Karhu and Holland, 1996). This possible global increase in atmospheric oxygen levels may have brought biological, as well as environmental changes. Increased oxygen levels clearly resulted in development of 'red beds'. Additionally, Semikhatov and Raaben (1994) have observed an increase in the number of stromatolite morphologies during the period under discussion. The Jatulian stromatolite explosion is also synchronised with a positive $\delta^{13}C$ shift of Jatulian age carbonates (Melezhik et al., 1997). It is unclear, however, whether this reflects evolution or increasing preservation of carbonates on cratons.

In this study, we discuss the results of carbon and oxygen

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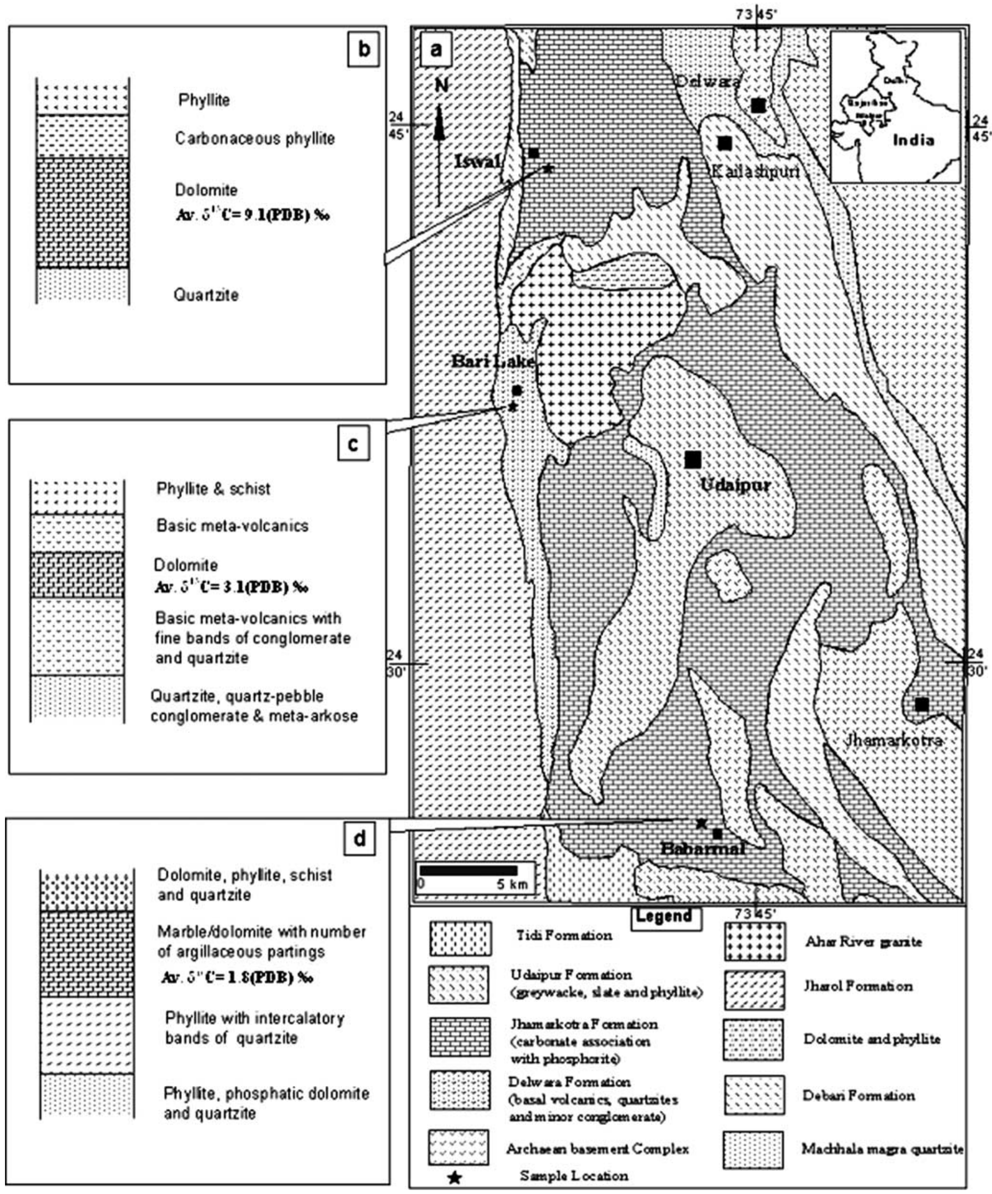

Fig. 1. (a) Geology of Paleoproterozoic Aravalli Supergroup, Western India (modified after Roy et al. (1988)); (b)–(d) stratigraphic column of study areas (b, Iswal; c, Bari Talab; d, Babarmal).

isotopic compositions of carbonates from Iswal, Babarmal and Bari Talab areas of Palaeoproterozoic Aravalli Craton, Western India. The carbon isotope data of carbonates from the Iswal area (Maheshwari et al., 1999) are also incorporated and discussed in the present work in order to reconstruct regional paleoenvironment of this part of the Indian subcontinent. An attempt has also been made to compare the results with reported world wide positive δ^{13}C excursion in Palaeoproterozoic marine carbonate successions.

2. Geological framework

The Paleoproterozoic Aravalli Supergroup of NW India (Fig. 1), which overlies the Mewar Gneissic Complex (~3.3–2.6 Ga; Roy and Kroner, 1996), is a thick pile of low grade metamorphosed and complexly folded clastic sediments, along with minor carbonate, phosphate and interlayered basic volcanic rocks. Phyllite, mica schist, migmatite, meta-graywacke and meta-siltstone constitute the bulk of the Supergroup. Other less prominent associated rocks are quartzite, meta-conglomerate, basic meta-volcanics and phosphatic/sulphide bearing dolostones. Two contrasting lithofacies associations (1) a shale/sand/carbonate assemblage and (2) a carbonate-free shale with thin bands of arenite represent shelf and deep-water facies, respectively (Poddar, 1965; Roy and Paliwal, 1981).

Strata of the Aravalli are well exposed over a distance of 350 km. The width of the outcrop belt in the north is about 40 km, gradually fanning out to 150 km in the south. The eastern margin of the outcrop marks a first order erosional unconformity with the underlying rocks of the Bhilwara Supergroup and represents one of the most ancient strandlines (2500 Ma; Gupta et al., 1980) in this basin. The present disposition of the strandline is arcuate in shape, with NW–SE trends in the south gradually veering to NE–SW and then acquiring an almost E–W trend in the north. To the west, the Aravalli Supergroup is overlain by strata of the Mesoproterozoic Delhi Supergroup (Roy and Kataria, 1999). To the south, the Aravalli outcrop is lost below the cover of the Deccan Traps and overlying Tertiary sediments.

The lower Aravalli Group contains a metamorphosed volcanic-arenite sequence, the Delwara Formation, at its base. The Delwara Formation passes upwards into the Jhamarkotra Formation, a sequence of dolomitic carbonates (or marble) showing lithofacies changes to argillaceous dolomite, carbonaceous phyllite (black shale) and mica-phyllite (Roy et al., 1988). Stromatolitic phosphorite forms a persistent horizon of this carbonate sequence in the valley of Udaipur. The physical continuity and lithological similarities of different dolomitic marble occurrences tentatively representing the Jhamarkotra Formation are traceable for a total distance of 200 km from Kelwa in the north to beyond Parsola in the south (Roy et al., 1988). The study areas under consideration have been correlated and incorporated tentatively as the Jhamarkotra Formation on the basis of lithological similarities and primary sedimentary structures by Roy et al. (1988). The lower Aravalli Group (Delwara and Jhamarkotra Formations) is separated from the upper Aravalli Group (Udaipur Formation; Fig. 1) by the presence of red beds. Aravalli rocks in the study areas have undergone polyphase deformation and Greenschist facies-grade regional metamorphism (Sharma, 1988). The low metamorphic transformation in studied carbonates is supported by carbonate, which at places, retain their primary sedimentary character.

The age of the Aravalli Supergroup is not well constrained. The Aravalli Supergroup is characterised by the presence of phosphatic stromatolites (Banerjee, 1971; Chauhan, 1979; Choudhary and Roy, 1986), the occurrence of red beds in the succession, dominance of dolomitic rocks over the calcitic limestone (Roy et al., 1988), and the occurrence of the black shale facies. Many of these features are common to many Precambrian successions of the world. The Aravalli rocks are found to unconformably overlie 2500 Ma granitoids of the Banded Gneissic Complex/ Mewar Gneiss (Wiedenbeck et al., 1996). Jhamarkotra Formation dolomites from the Iswal region give a two-stage model Nd age of 2.1 Ga (Sreenivas et al., 1999), suggesting a Paleoproterozoic age for lower Aravalli Group strata.

The geological areas under study belong to a complicated stratigraphic framework. A complicated structural history of the region prevents a definite conclusion with regard to the chronological order of carbonates within the three study areas, which are all presently grouped under the Jhamarkotra Formation. The Iswal area (Fig. 1(b)) is situated NNW of Udaipur city. The area comprises a sequence of basic meta-volcanics associated with quartzite, arkosic dolostones, calcitic marble, carbonaceous phyllite and conglomerate. Iswal dolomites are grey and buff coloured, finely crystalline and thinly to massively bedded. The interlayered meta-sedimentary rocks occupy the crest lines of narrow N–S trending ridges, while the basic volcanics occupy the flanks of the intervening valleys.

Bari Talab rocks (Fig. 1(c)) are exposed on the western side of Udaipur and are represented mainly by meta-volcanics, quartz pebble conglomerate, meta-arkose, quartzite, chlorite phyllite, meta-siltstone, chert and carbonaceous phyllite with bands of dolomite that are siliceous at the base. Carbonates from the Iswal area overlie Delwara volcanics, whereas, Bari Talab carbonates are closely associated with basic volcanics similar in composition to the Delwara volcanics. This observation suggests the possibility that Bari Talab carbonates are older than the Iswal carbonates.

The Babarmal carbonates are exposed south of Udaipur city and are represented by phyllite, quartzite and calcitic marble (Fig. 1(d)). Phyllite with intercalated bands of quartzite and phosphatic dolomite form the basal part of the formation and is overlain by a marble horizon, which was previously mapped as younger to Jhamarkotra Formation due to lithological similarities (Heron, 1953). This succession has now been included in the Aravalli sequence due to its interfingering and gradational relationship with Aravalli rocks. The Babarmal marble is fine-grained, pure, saccharoidal and homogeneous dolostone without silicification. The marble is stratified in beds of small thicknesses. The presence of underlying phosphatic dolomite and the overall absence of Delwara volcanics in the Babarmal area (Fig. 1(d)) support a younger stratigraphic position for Babarmal carbonates than that of the Iswal and Bari Talab carbonates.

3. Sampling procedure and analytical methods

Whole-rock carbonate samples were collected at close intervals along stratigraphic profile through strata representing the Jhamarkotra Formation, lower Aravalli Supergroup, in all the three areas studied. The meterages of the individual samples are provided in Table 1. Iswal dolomites are grey and buff coloured and finely crystalline and samples were collected at an interval of approximately 3 m. The carbonate from Babarmal is fine-grained, pure, saccharoidal dolostone without silicification. The Bari Talab dolostones are fine-grained and siliceous. The carbonates were collected at an interval of approximately 4 m along the stratigraphic sections chosen around Bari Talab and Babarmal.

A total of 52 carbonate samples were collected. CO_2 was extracted from carbonates in a high vacuum line after reaction with phosphoric acid at 25 °C, and cryogenically cleaned, according to the method described by Craig

Table 1
Isotope data for Precambrian carbonates of Aravalli Supergroup, India

Sample	Location	Stratigraphy (m)	$\delta^{18}O$ (PDB)	$\delta^{13}C$ (PDB)
G-1	Iswal	0	−12.43	8.39
G-2	Iswal	3	−10.02	9.56
G-3	Iswal	6	−10.83	10.72
G-4	Iswal	9	−11.74	11.2
G-5	Iswal	12	−11.24	10.11
G-7	Iswal	15	−8.21	11
G-8	Iswal	18	−10.32	8.81
G-9	Iswal	21	−11.58	7.12
G-10	Iswal	23	−8.21	9.87
G-11	Iswal	26	−8.53	8.89
G-12	Iswal	29	−8.35	9.33
G-13	Iswal	32	−8.64	8.46
G-14	Iswal	35	−8.06	9.34
G-15	Iswal	38	−8.5	10.05
G-16	Iswal	41	−10.22	8.77
G-17	Iswal	44	−10.2	8.48
G-18	Iswal	47	−10.46	6.8
G-19	Iswal	50	−10.46	6.56
G-20	Iswal	53	−8.96	9.3
G-21	Iswal	56	−9.39	9.41
G-23	Iswal	59	−10.99	8.64
BBM-1	Babarmal	0	−8.4	2.06
BBM-2	Babarmal	4	−7.11	1.84
BBM-3	Babarmal	8	−7.16	1.78
BBM-4	Babarmal	12	−6.94	2.03
BBM-5	Babarmal	16	−7.08	1.95
BBM-6	Babarmal	20	−6.22	2.82
BBM-8	Babarmal	24	−9.62	1.54
BBM-9	Babarmal	28	−9.64	1.54
BBM-11	Babarmal	32	−6.04	2.81
BBM-12	Babarmal	36	−6.32	3.19
BBM-13	Babarmal	40	−8.31	1.2
BBM-14	Babarmal	44	−7.49	1.4
BBM-15	Babarmal	48	−7.41	1.42
BBM-16	Babarmal	52	−7.41	2.4
BBM-17	Babarmal	56	−12.11	0.05
BBM-18	Babarmal	60	−8.07	1.28
BBM-19	Babarmal	64	−7.02	1.5
BBM-20	Babarmal	68	−7.09	1.48
BBM-21	Babarmal	72	−8.66	2.34
BBM-22	Babarmal	76	−10.03	1.96
BBM-23	Babarmal	78	−8.96	1.87
BBM-24	Babarmal	82	−8.97	1.88
BT-2	Bari Talab	0	−16.39	3.02
BT-3	Bari Talab	3	−15.48	4.36
BT-4	Bari Talab	6	−12.56	2.61
BT-5	Bari Talab	9	−14.84	2.72
BT-6	Bari Talab	12	−15.44	3.5
BT-7	Bari Talab	15	−15.72	3.89
BT-8	Bari Talab	18	−16.04	2.61
BT-9	Bari Talab	21	−13.72	1.99

(1957). CO_2 gas released by this method was analysed for O and C isotopes in a double inlet, triple collector V.G. ISOTECH mass spectrometer located at NEG-LABISE, UFPE, Brazil. The reference gas Borborema Skarn Calcite (BSC) was calibrated against NBS-18, NBS-19 and NBS-20, has a $\delta^{18}O$ value of -11.28 ± 0.004‰ PDB and $\delta^{13}C = -8.58 \pm 0.02$‰ PDB. The results are expressed in the δ-notation in parts per thousand in relation to the international PDB scale.

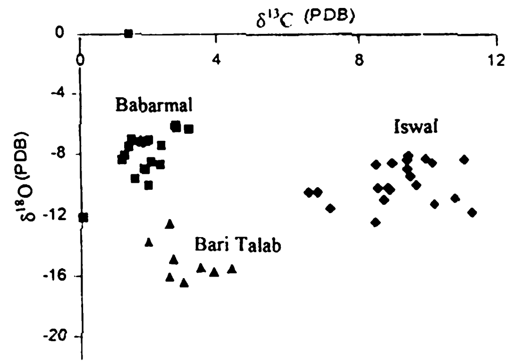

Fig. 2. Cross-plot of $^{13}C/^{12}C$ versus $^{18}O/^{16}O$ for Aravalli carbonates Iswal (◆), Bari Talab (▲), Babarmal area (■).

4. Interpretation of isotopic data

The carbon and oxygen isotopic composition of carbonates from the Iswal, Bari and Babarmal regions have been provided (Table 1; see Fig. 2). Although Aravalli Supergroup carbonates are dolomitic in composition, dolomite is generally considered as a diagenetic mineral. Nonetheless, there is growing evidence that precipitation of dolomite in the Precambrian was either coeval with calcite or that dolomitisation was an early diagenetic phenomenon caused by waters isotopically comparable to that of seawater (Veizer and Hoefs, 1976; Veizer et al., 1992; Kah, 2000).

Many workers (Schidlowski et al., 1976; Veizer et al., 1999; Frank and Lyons, 2000; Kah, 2000) have provided average $\delta^{18}O$ compositions of Precambrian carbonates from different parts of world and considered values between ~ -5 and -8‰ to be fairly normal for Precambrian carbonates. The $\delta^{18}O$ of the studied carbonates except from Bari Talab, are very similar to these $\delta^{18}O$ values, suggesting only a minor role of diagenesis in the studied carbonates. Comparatively low $\delta^{18}O$ values in Bari Talab carbonates may be attributed perhaps, to the associated Delwara volcanic rocks. Most of the studied carbonate samples with heavy carbon also preserve oxygen isotope compositions similar to presumed pre-metamorphic values. This is good evidence for a pre-metamorphic origin of the heavy carbon isotope signature, as any process involving a carbonate during metamorphism is likely to decrease its $\delta^{18}O$ values significantly. Exchange with other silicates, exchange with an infiltrating fluid and devolatisation reactions are all likely to cause a decrease in $\delta^{18}O$. Hence, high $\delta^{18}O$ carbonates must have been little affected by metamorphic processes and should therefore preserve pre-metamorphic $\delta^{13}C$ (Valley, 1986). It may therefore be suggested that carbonates from the Jhamarkotra Formation of the Aravalli Supergroup had high positive $\delta^{13}C$ values over a large area and this feature may be attributed to some synsedimentary process.

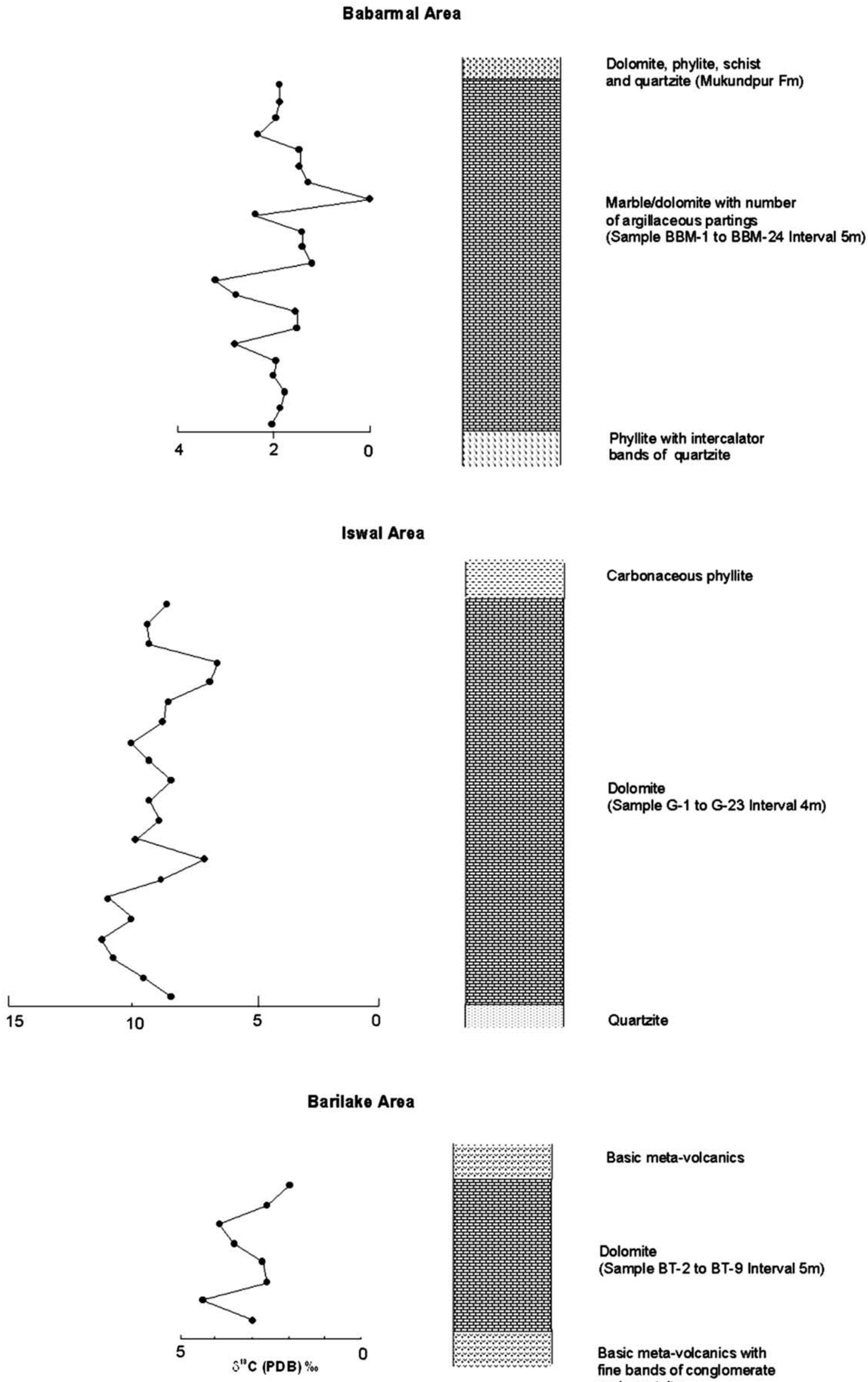

Fig. 3. C-isotopic profile along the Paleoproterozoic carbonates, Aravalli Supergroup, India.

The Aravalli rocks of the study areas have suffered low to very low-grade regional metamorphism up to Greenschist facies (Sharma, 1988). In regional metamorphic terrains, $\delta^{18}O$ and $\delta^{13}C$ depletions are generally less pronounced (Rye et al., 1976; Valley, 1986) and the cause and timings of the isotopic depletions are less clear. In the Adirondacks, granulite facies marble has oxygen and carbon isotopic compositions that are similar to those of unmetamorphosed Grenville-age limestones (Valley and O'Neil, 1984). In contrast, metamorphosed carbonates in other regional metamorphic terranes are variably depleted in $\delta^{18}O$ as a result of synmetamorphic fluid infiltration (Wickham and Taylor, 1987; Cartwright et al., 1995); pre-metamorphic magmatism (Buick and Cartwright, 1996), pre-metamorphic diagenesis (Rumble et al., 1991), or a combination of these processes. $\delta^{13}C$ is much more difficult to change than $\delta^{18}O$ in a rock system, because the relative masses of C in rock versus diagenetic fluids are typically such that $\delta^{13}C$ compositions will be buffered to rock values (Banner and Hanson, 1990). As such, oxygen isotopic compositions of the carbonate will be altered upon diagenesis at a much quicker rate than carbon isotopic compositions. Oxygen isotopic compositions preserved in Aravalli Group carbonates are fairly consistent with 'least altered' isotopic compositions from many other Precambrian carbonate successions and suggest that the rocks have undergone relatively little post-depositional exchange. Therefore, it is unlikely that the carbon isotopic compositions are much changed from their primary depositional compositions.

Carbonate rocks from Bari Talab are characterised by $\delta^{13}C$ values up to 4.36‰ PDB. Although $\delta^{18}O$ values of Bari Talab carbonates are quite low (−12.56 to −16.39‰ PDB), these values may be attributed to their intimate association with Delwara volcanics as contact-metamorphosed carbonate rocks commonly exhibit large depletions in $\delta^{18}O$ (Valley, 1986). Iswal dolomites show $\delta^{13}C$ values up to 11.2‰ PDB with an average $\delta^{13}C$ of 9.09‰. However, most of the samples are represented by $\delta^{13}C$ values between 8 and 10‰ PDB. $\delta^{18}O$ in Iswal dolomites ranges from −12.43 to −8.06‰ PDB. The carbonates from Babarmal are represented by relatively high $\delta^{18}O$ values (−7.02 to −12.11‰, averaging −8.00‰ PDB) and $\delta^{13}C$ values between 0.05 and 3.19‰ PDB.

The C-isotopic values from Babarmal (up to 3.19‰ PDB) and Bari Talab (up to 4.36‰ PDB), although similar to each other, are significantly lighter than values recorded in the Iswal strata (+11.20‰ PDB). The difference in C-isotopic values of carbonates from different study areas are most likely attributed to their different stratigraphic position within the Jhamarkotra Formation of the Aravalli Supergroup. Carbonate strata from the study areas do not occur as a continuous sequence. In the absence of age constraints, the stratigraphic position of these carbonates has been deciphered mainly from field observations. The Iswal dolostones, however, have been assigned an age of 2.1 Ga (Sreenivas et al., 1999). On the basis of lithological position, the Bari Talab carbonates are interpreted as stratigraphically lower than the Iswal carbonates, and the Babarmal carbonates are interpreted to be the youngest strata within the study areas. This stratigraphic observation also get support from the fact that the carbon isotopic compositions of Bari Talab carbonates are clearly enriched with respect to the Babarmal region. The fine-scale stratigraphic Carbon isotopic data for individual sampling sections have been plotted in Fig. 2. The overall trend of the C-isotopic profile along three studied stratigraphic sections in Fig. 2 indicates that the carbon isotopic compositions in the Jhamarkotra Formation of the Aravalli Supergroup varies from ~3‰ to >9‰ within a short stratigraphic interval.

Instead of being a primary depositional feature, elevated $\delta^{13}C$ values could be due to diagenesis. However, burial and meteoric diagenesis typically results in shifts toward lower $\delta^{13}C$ values (Marshall, 1992; Saltzman et al., 1998). Moreover, studies of Paleoproterozoic carbonates suggest that diagenetic shifts in $\delta^{13}C$ are typically much smaller (<1‰) than in Phanerozoic equivalents (Strauss et al., 1992). Similarly, dolomitisation of ~2 Ga Proterozoic mixed dolomite–calcite carbonates elsewhere appears to be associated with a very slight lowering of $\delta^{13}C$ values (~1‰; Schidlowski et al., 1976) and therefore are unlikely to have resulted in the elevated $\delta^{13}C$ values observed in this study.

Diagenetic methanogenic reactions can produce both high-$\delta^{13}C$ CO_2 and low-$\delta^{13}C$ CH_4, and may therefore produce elevated $\delta^{13}C$ values (Dix et al., 1995). However, mixing of early formed high-$\delta^{13}C$ CO_2 with CO_2 derived from the subsequent oxidation of low-$\delta^{13}C$ CH_4 commonly leads to the precipitation of carbonates with a wide range of both large positive and negative $\delta^{13}C$ values. This results in significant carbon isotope heterogeneity and subvertical trends on $\delta^{13}C$ versus $\delta^{18}O$ diagrams (De Giovani et al., 1974). In contrast, high $\delta^{13}C$ carbonates in the study areas do not show significant scatter (Fig. 3), and do not show the range of highly negative $\delta^{13}C$ values that might be expected from diagenetic reactions with methane. Combined, these observations suggest that elevated $\delta^{13}C$ values from dolostones in this study probably reflect their protolith compositions, rather than subsequent diagenetic processes. Dolostones with lower, yet still significantly elevated $\delta^{13}C$ values, likely reflect superimposed metamorphic fluid-driven devolatilisation.

5. Discussion

Stromatolitic carbonate strata belonging to the Jhamarkotra Formation, Paleoproterozoic Aravalli Supergroup, are characterised by $\delta^{13}C$ enrichment in their organic carbon (Banerjee et al., 1986). The carbon isotopic compositions of marine limestones are generally controlled by the proportion of sea-water carbon that passes into carbonates and the proportion that passes into organic carbon. Increases in the

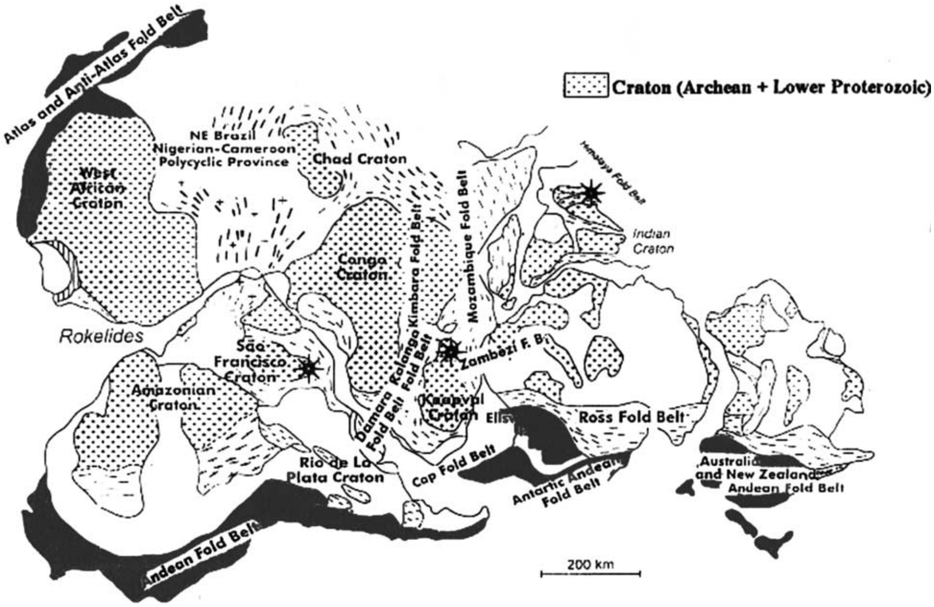

Fig. 4. Schematic structural map of Gondwana (modified from Trompette, 1994) showing the geographic distribution of cratons and foldbelts. ★—Paleoproterozoic Formations, where the anomalous $^{13}C/^{12}C$ rich carbonates have been recorded (Fecho do Funil Fm., Minas Gerais, Brazil; Lomagundi Fm., Zimbabwe, Africa, and the Aravalli Craton, India).

amount of organic carbon deposited can lead to positive $\delta^{13}C$ excursions and these excursions may cause significant increase in atmospheric oxygen contents (Knoll et al., 1986). An increase in atmospheric and oceanic oxygen during the Paleoproterozoic is likely to have been accompanied by major changes in the carbon cycle (Karhu and Holland, 1996; Des Marais et al., 1992). It is suggested that increased oxygen contents of the oceans were produced and accompanied by an increase in organic production (Baker and Fallick, 1989b). The increased oxygen contents of the atmosphere may have been the direct result of an increase in the population of photosynthesising bacteria (Holland, 1984). Increasing oceanic oxygen contents may also have enabled the further exploitation of certain oceanic environments and enlargement of the biomass. This increased organic productivity, in the absence of a compensating increase in the rate of organic carbon recycling, would have increased the rate of organic carbon deposition and resulted in the deposition of high $\delta^{13}C$ carbonates (Baker and Fallick, 1989a,b). This increase in organic carbon burial rates may also be associated with tectonic changes that facilitated organic carbon burial in rapidly filling and subsiding marine basins (Des Marais et al., 1992).

Several Paleoproterozoic provinces with widespread development of carbonates significantly enriched in ^{13}C have been identified from Gondwanaland (Schidlowski et al., 1976; Maheshwari et al., 1999; Sial et al., 2000). Carbonates with isotopically heavy carbon are increasingly reported from the various parts of Gondwanaland after the discovery of the Lomagundi Event in Zimbabwe, Africa. Recently, $\delta^{13}C$ rich carbonates have been reported from the Fecho do Funil Formation, Brazil (Sial et al., 2000). The $\delta^{13}C$ rich Palaeoproterozoic carbonate occurrences reported from different parts of Gondwanaland are shown in Fig. 4. The global presence of $\delta^{13}C$ rich carbonates within Paleoproterozoic Gondwanaland points to a global event and suggest that the Lomagundi Formation in Zimbabwe (Schidlowski et al., 1976), Kapvaal Craton; Fecho do Funil Formation, Brazil and the Aravalli Craton basin in India are marine in origin and were deposited under almost similar depositional conditions.

6. Conclusions

A Palaeoproterozoic province with a widespread positive $\delta^{13}C$ anomaly has been discovered from the Aravalli Supergroup, Western India. The widespread positive $\delta^{13}C$ anomaly, being reported from this subcontinent with sufficient isotopic data, coincides with the emergence of stromatolites and development of red beds. Widespread positive $\delta^{13}C$ anomalies in Palaeoproterozoic carbonates of the Fennoscandian Shield (Melezhik and Fallick, 1996) also coincides with the abundance of stromatolites and with widespread development of red beds. In addition to the Lomagundi Formation, Kapvaal Craton, Zimbabwe, carbonates with elevated $\delta^{13}C$ values have also been reported from the Fecho do Funil Formation, Sao Francisco Craton, Brazil (Sial et al., 2000) for Gondwanaland. Similarities between Paleoproterozoic carbonates of the Aravalli Craton and similar strata from other continents strongly support the current hypotheses suggesting a significant global paleoenvironmental change during the Paleoproterozoic.

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