

C-, O- Isotope and Whole-rock Geochemistry of Proterozoic Jahazpur Carbonates, NW Indian Craton

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Abstract

The Jahazpur Group (NW Indian craton) meta-pelite – carbonate – quartzite sequence of presumed Palaeoproterozoic age unconformably overlies the volcano-sedimentary rocks of Hindoli Group and a tonalitic gneiss – leucogranite complex (Jahazpur Granite) basement. Leucogranite, the younger component of the Jahazpur Granite Complex, has been considered to be coeval with the ca. 2.5 Ga Berach Granite. The lowermost unit of the Jahazpur Group, the basal conglomerate, which unconformably overlies the Hindoli Group, is conformably overlain by a phyllite – dolomite – phyllite sequence. This sedimentary package is developed in two belts, designated as the Eastern and Western Jahazpur Belts. Preliminary C- and O-isotopic results, and relevant whole-rock geochemical data on representative dolomitic limestone samples are presented and discussed in this paper.

The Lower Dolomite unit shows significantly negative to near zero $\delta^{13}\text{C}$ values (-4.8 to $+0.9\%$ OV-PDB), while the Upper Dolomite (developed in the western belt only) shows near zero values. Various geochemical parameters (Mn/Sr and Ca/Mg ratios) and non-correlative $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values indicate well-preserved isotopic characteristics. The isotopic signatures of Jahazpur Dolomites are significantly different from the highly positive $\delta^{13}\text{C}$ values reported from the Palaeoproterozoic Aravalli Supergroup rocks occurring around Udaipur (Jhamarkotra Formation). The Jahazpur carbonates show some similarity in the C-isotopic characteristics with the Delwara Formation carbonates which underlie the Jhamarkotra Formation. However, the observed negative $\delta^{13}\text{C}$ values in the Delwara Formation carbonates have possibly resulted from effects of metamorphic decarbonation.

Key words: Jahazpur Group, Aravalli Craton, NW India, carbonates, C-isotopes.

Introduction

Sedimentary carbonate rocks provide a well-documented record of palaeoclimatic changes in terms of carbon (also oxygen) isotopic trends and thus serve as significant tools in stratigraphic correlation and modelling major transition events. The C-isotope stratigraphy is based on the primary assumption that the $\delta^{13}\text{C}$ values of the seawater carbonate species fluctuate through time, largely in response to the changes in the net rate of organic burial (Shields, 1999). In the absence of any recognizable body fossils the C-isotopic signatures remain the sole criterion for paleo-environmental reconstruction during the Proterozoic. Glaciation events (resulting in reduced organic activity), with intermittent warmer conditions, are usually preserved as observable secular variations in

the carbon isotopic record. Compared to $\delta^{18}\text{O}$ values, which are susceptible to post-depositional modifications, the $\delta^{13}\text{C}$ values remain largely unaffected during most subsequent crustal processes (Jacobsen and Kaufman, 1999), and thus offer reliable chemostratigraphic constraints even in case of significantly metamorphosed rocks (Melezhik et al., 2001).

Positive $\delta^{13}\text{C}_{\text{carb}}$ excursions, recorded at different times in the geologic past, have most commonly been interpreted to represent large-scale perturbations in the organic matter burial (Melezhik et al., 1999 and references therein) because they reflect increased marine phytoplankton productivity or increased preservation under anoxic waters. Likewise, the negative excursions have been interpreted to reflect the opposite. However, an increase

in the proportion of carbonate weathering, relative to organic carbon and silicate weathering, can also result in positive excursion in the isotopic composition of the sea (Kump and Arthur, 1999). If the burial event is the result of an increase in riverine P supply, the associated pulse of isotopically light carbon would cause a temporary negative shift, similar to the effect of reduction in organic carbon weathering (Kump and Arthur, 1999). There are a number of factors that can cause positive $\delta^{13}\text{C}$ excursion. Preferential removal of ^{12}C during photosynthesis leaves the residual carbon pool enriched in ^{13}C , also, carbon dioxide degassing from spring deposits can result in ^{13}C enrichment (Melezhik et al., 2000; Melezhik and Fallick, 2001). Some of less discussed factors that can also potentially cause $\delta^{13}\text{C}$ variations relate to a stratified ocean and long-term changes in the mantle input carbon isotope ratio (Melezhik and Fallick, 1997). A positive $\delta^{13}\text{C}$ excursion (up to +12‰) of Palaeoproterozoic age was first reported from the Fennoscandian Shield (Galimov et al., 1975; Schidlowski et al., 1975) and Lomagundi Supergroup in Zimbabwe (Schidlowski et al., 1976). Subsequent studies carried out on Palaeoproterozoic successions suggested the 2.33–2.06 Ga $\delta^{13}\text{C}$ positive excursion to be a global phenomenon, based on its ubiquitous occurrence in all the continents (Baker and Fallick, 1989 a, b; Melezhik et al., 1999; McNaughton and Wilson, 1983; Lindsay and Brasier, 2002). This has been attributed to major disturbance in the geochemical cycle affecting the evolution of atmosphere, hydrosphere and biosphere. Melezhik and Fallick (1997) have argued in favour of local factors to cause positive $\delta^{13}\text{C}$ excursions, as different explanations proposed for high $\delta^{13}\text{C}$ do not perfectly agree with existing geological evidence. They have also pointed out inconsistencies in the global background for the Palaeoproterozoic isotopic shift and have emphasized that better palaeoenvironmental analyses can contribute in assessing local versus global contributions to isotopic excursions. Compared with the positive C-isotopic excursions in the Neoproterozoic and Palaeozoic, the Palaeoproterozoic positive $\delta^{13}\text{C}$ excursion has been described to be a unique one both in terms of the duration (~300 million years) and for its extremely high $\delta^{13}\text{C}$ values (up to +18‰_{00V-PDB}; Karelian Complex, see Yudovich et al., 1991). It has been recognized that the previously postulated ~300 Ma single positive C-isotopic excursion during Palaeoproterozoic actually comprises of three shorter duration positive excursions, each followed by a return to ~0‰ level (Melezhik et al., 1999; Buick et al., 1998). The Palaeoproterozoic $\delta^{13}\text{C}$ positive excursions are not followed by negative shifts significantly below 0‰ (Melezhik et al., 1999). Termination of the Paleoproterozoic $\delta^{13}\text{C}$ positive

excursions is followed by the formation of vast reservoirs of ^{13}C depleted organic matter and extreme depletion (up to -45‰_{00V-PDB} at Shunga; see Melezhik et al., 1999).

In India, parallel studies have been carried out on the Precambrian–Cambrian transition and early Cambrian sequences in the lesser Himalayan region (Aharon et al., 1987; Banerjee et al., 1997; Kumar and Tewary, 1995) and the Central Indian Vindhyan basin (Friedman et al., 1996; Kumar et al., 2002). The Neoproterozoic–Cambrian transition events have also been documented in western Rajasthan (Banerjee and Majumdar, 1999) where significant $\delta^{13}\text{C}$ negative excursions have been correlated by Pandit et al. (2001) with the Neoproterozoic – Cambrian transition. A significant discovery was the identification of $\delta^{13}\text{C}$ positive excursion in Palaeoproterozoic Aravalli Supergroup (Sreenivas et al., 1998, 1999; Maheshwari et al., 1999) from a section north of Udaipur (NW India). This C-isotope excursion has been correlated by Sreenivas et al. (2001) with the Palaeoproterozoic global $\delta^{13}\text{C}$ excursion recorded elsewhere. We have initiated complementary geochemical and isotopic investigation of carbonate rocks from the hitherto unexplored Jahazpur Group, NW India (Fig. 1), which has been considered correlative with the Aravalli Supergroup (Sinha Roy et al., 1998; Malhotra and Pandit, 2000). The low-grade (green-schist facies) metamorphic rocks of the Jahazpur Group, which show well-preserved primary sedimentary features, offer an excellent opportunity to investigate them for geochemical and C-isotopic characteristics. This paper reports the preliminary C- and O-isotopic results from dolomitic limestone of the Jahazpur Group.

Geological Setting

The NE-trending Jahazpur Belt in southeastern Rajasthan (NW India) contains two metasedimentary sequences; the Hindoli and Jahazpur Groups of presumed Archaean and Palaeoproterozoic ages, respectively (Fig. 1). This belt is tectonically bound on the east by the Great Boundary Fault (GBF), which juxtaposes the platform sedimentary sequence of the Vindhyan Supergroup against the Hindoli Group. In the west, another prominent thrust brings rocks of Mangalwar Complex against the Hindoli Group. This thrust has been described as a ductile shear zone (Reddy et al., 1995). The shearing seems to have obliterated the original contact between Hindoli Group and Mangalwar Complex but the two units can be distinguished on the basis of marked differences in litho-assemblages and grade of metamorphism. The amphibolite facies Mangalwar Complex contains an ensemble of migmatized pelitic gneisses and amphibolite

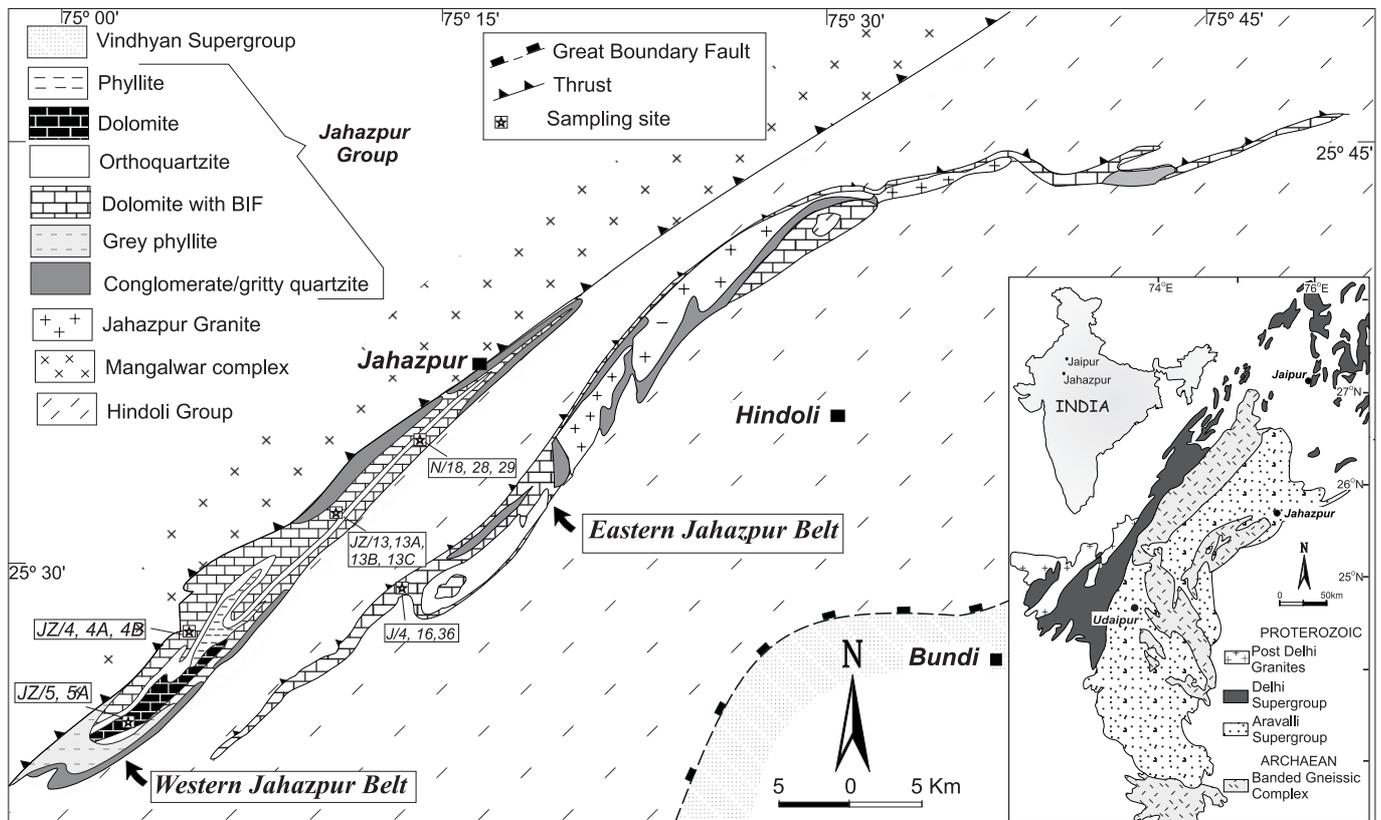


Fig. 1. Geological map of the Jahazpur Belt in NW India showing the lithostratigraphy of Jahazpur Group in the eastern and western Belts (adapted from Malhotra and Pandit, 2000). Inset map (compiled from published literature and those published by Geological Survey of India) shows the distribution of major Precambrian rocks in the Aravalli Craton, NW India.

gneisses. In contrast, the Hindoli Group comprises a greenschist facies assemblage (Sinha Roy et al., 1995; Mohanty and Guha, 1995) which includes predominantly bimodal volcanics and metapelites in the lower part (Bose and Sharma, 1992) and a turbidite sequence of meta-greywacke - metapelites in the upper (Malhotra and Pandit, 2000).

In the Eastern Jahazpur Belt, the Hindoli metasediments are intruded by a composite granitoid pluton, known as the Jahazpur Granite, which includes an older tonalitic gneiss and a younger and undeformed alkali-granite components. The alkali-granite has been correlated (without any definite geochronologic constraints) with the 2.5 Ga old Berach Granite (Anon, 1981). This association (Hindoli Group + Jahazpur Granite) forms the basement for the Jahazpur sequence which contains pebbly quartzite and grit at the base, representing an erosional unconformity. The unconformity between Jahazpur rocks and the basement is also marked both by a structural and stratigraphic hiatus. In the type area (Western Jahazpur Belt), the Jahazpur conglomerate, with maximum thickness of about 100 m near Jawal and Amalda, shows thinning along the strike towards the northeast where a facies variation has led to the

development of gritty quartzite. The conglomerate, having fanglomerate characters, is polymictic in nature and contains clasts of rounded to sub-rounded quartzite, quartz schist, variegated phyllite and vein quartz, set in an arenaceous matrix. It shows upward fining clast size, indicating an upright sequence. In Amalda, the upward fining conglomerate unit contains ironstone intercalated grit quartzite at the top. The upper grit quartzite is conformably overlain by grey phyllite, dolomitic limestone with BIF, orthoquartzite, dolomite, variegated phyllite and carbonaceous phyllite (Fig. 1). Palaeosol pockets are developed between Jahazpur Granite and gritty quartzite/carbonate units in the eastern belt. However, any direct contact relation between palaeosol and the basal conglomerate has not been observed in the eastern belt. Primary sedimentary structures in the orthoquartzite suggest the sequence to be normal with its top towards carbonaceous phyllite unit. Both the dolomite units are separated by a thin intervening ortho-quartzite band.

Sampling and Analytical Procedure

The dolomite units from the Western Jahazpur Belt and Eastern Jahazpur Belt have been sampled across the

strike; sampling locations are shown in figure 1. The C- and O-isotopic ratios (as ‰ deviation with reference to V-PDB) and partial whole-rock geochemical data for the dolomite samples are presented in tables 1 and 2. Major and trace elements were analyzed on an RIX-3000 (RIGAKU) X-Ray Fluorescence spectrometer using fused beads. Fused beads were prepared using lithium fluoride and lithium tetraborate. For C- and O-isotopic determinations, powdered samples were treated with H_3PO_4 at 25°C for 3 days to release CO_2 (McCrea, 1950). More than 72 hours (usually four days) was allowed to ensure complete reaction of slow reacting dolomite and to eliminate any laboratory isotopic fractionation effects. The $\delta^{13}C$ and $\delta^{18}O$ values were measured on cryogenically cleaned CO_2 (Craig, 1957) in a dual-inlet triple collector SIRA II mass spectrometer. Borborema Skarn Calcite (BSC), calibrated against international standards, was used as the reference standard and reproducibility of measurements was better than $\pm 0.1\text{‰}$, in general.

Table 1. C- and O-isotopic ratios (as standard ‰ deviation with reference to V-PDB) of carbonate rocks from Jahazpur Group (NW India).

S. No.	Sample	$\delta^{13}C_{V-PDB}$	$\delta^{18}O_{V-PDB}$
1	JZ/5	0.2	-5.0
2	JZ/5 A	0.0	-7.8
3	JZ/4B	0.9	-6.6
4	JZ/4	0.6	-7.2
5	JZ/4 A	0.9	-6.7
6	JZ/13C	-1.2	-14.3
7	JZ/13	-3.0	-15.4
8	JZ/13A	-1.9	-4.5
9	JZ/13B	-2.9	-9.5
10	N/18 W	-1.3	-4.9
11	N/28 W	-1.5	-3.8
12	N/29 W	-4.8	-5.9
13	J/4	-0.6	-5.7
14	J/16	-2.2	-4.4
15	J/36	-3.8	-15.4

1, 2 – Upper Dolomite, Western Jahazpur Belt, 3 to 12 – Lower Dolomite, Western Jahazpur Belt, 13 to 15 – Lower Dolomite, Eastern Jahazpur Belt

Table 2. Partial major and trace element concentrations (Sr in ppm and major oxides as wt.%) and some significant elemental ratios for Western Jahazpur Belt carbonate rocks.

Sample	SiO ₂	MgO	CaO	MnO	Fe ₂ O ₃	Al ₂ O ₃	Sr	Mn/Sr	Mg/Ca
JZ/5	2.78	20.11	31.56	0.02	0.22	0.12	55	1.45	0.54
JZ/5 A	0.39	21.07	32.85	0.04	0.69	0.32	63	5.08	0.55
JZ/4	1.61	20.21	31.47	0.02	0.45	0.24	41	3.17	0.55
JZ/4A	18.92	16.02	23.32	0.04	0.88	1.77	62	5.02	0.58
JZ/4B	5.35	19.07	29.47	0.04	0.77	0.46	36	8.39	0.55
JZ/9	1.45	19.59	30.79	0.08	1.10	0.99	62	10.48	0.54
JZ/13	24.17	11.63	20.68	0.64	4.63	3.06	154	35.48	0.46
JZ/13A	12.40	0.67	42.79	0.05	0.82	2.93	54	7.00	0.01
JZ/13C	8.50	15.83	27.28	0.36	4.36	1.88	85	35.95	0.49

The values obtained for NBS-20 (as an unknown) in a separate run against BSC yielded $\delta^{13}C = -1.05\text{‰}_{V-PDB}$, and $\delta^{18}O = -4.22\text{‰}_{V-PDB}$. These are in close agreement with the values reported by the U. S. National Bureau of Standards (-1.06‰_{V-PDB} , and -4.14‰_{V-PDB} , respectively).

Results

C- and O-isotope compositions

The carbon isotopic compositions for the Lower and Upper Dolomite units from the western belt (type section) and Lower Dolomite unit from eastern belt are given in table 1 and also presented graphically as a $\delta^{13}C$ - $\delta^{18}O$ cross-plot (Fig. 2). The Lower Dolomites in both the belts show $\delta^{13}C$ values ranging from -4.8 to $+0.9\text{‰}$, most of them being within the prescribed range for marine carbonates ($0 \pm 2\text{‰}$ see Burdett et al., 1990). Most of the Lower Dolomite samples show negative $\delta^{13}C$ values (-4.8 to -0.6‰) while three samples have marginally positive values (between $+0.6$ and $+0.9\text{‰}$). The Lower Dolomites thus define a significant C-isotopic variation of the order of $\sim 5.4\text{‰}$. However, other critical parameters need to be evaluated before implicating the significance of such C-isotopic variation. Two Upper Dolomite samples (Western Belt) show near zero values (0 and $+0.2\text{‰}$).

Majority of Lower Dolomite samples have $\delta^{18}O$ values between -9.5 and -3.8‰_{V-PDB} , except three samples which are significantly lower ($< -14\text{‰}$). Two samples of Upper Dolomite show similar $\delta^{18}O$ values of -6.6 and -5.0‰_{V-PDB} . Carbonates with a $\delta^{18}O$ range of -10 to -5‰ can be considered to retain primary O-isotopic signatures, being comparable with the 'best-preserved' $\delta^{18}O$ values of $\sim 7.5 \pm 2\text{‰}$ reported for most of the Proterozoic-early

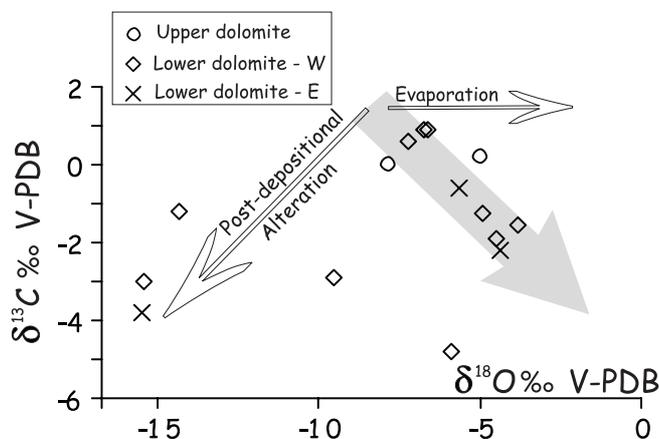


Fig. 2. $\delta^{13}C$ - $\delta^{18}O$ cross-plot for Jahazpur Group dolomitic limestone. The data shows a general inverse correlation between them. Trends of post-depositional alteration and evaporative effects have also been superimposed onto the figure.

Cambrian rocks (Burdett et al., 1990; Hall and Veizer, 1996). The $\delta^{13}\text{C}$ - $\delta^{18}\text{O}$ cross-plot shows a wide scatter of data and non-linear relationship between the two (Fig. 2). A corresponding lowering of both $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values would result during late diagenesis and low-grade metamorphism and deformation due to devolatilization reactions, whereas the evaporative processes should result in variable enrichment in ^{18}O (Guerrera et al., 1997). The absence of any apparent correlation between $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values in the Jahazpur carbonates suggests that there has been little post-depositional modification in isotope characteristics (Guerrera et al., 1997). It is interesting to note that the most ^{13}C -depleted sample (N/29) does not show any depletion in $\delta^{18}\text{O}$ ($-5.9\text{‰}_{\text{OV-PDB}}$). The $\delta^{18}\text{O}$ values are normally considered prone to post-depositional modifications by exchange with meteoric water or interstitial fluids at elevated temperatures (Fairchild et al., 1990). Diagenetic dolomitization of calcite-rich carbonates would require a large volume of water, in order to supply the required Mg (Land, 1992). As a result, the $\delta^{18}\text{O}$ values of the dolomite product should mostly reflect the isotopic composition of the dolomitizing water (Land, 1992). The O-isotopic ratios are susceptible to modifications during later processes. In contrast, $\delta^{13}\text{C}$ values most likely, reflect the C-isotopic composition of precursor carbonate due to the relatively low CO_2 content of diagenetic water (Burdett et al., 1990). The preservation of the isotopic signals depends upon the water/rock ratio for a given element at the time of diagenetic recrystallization (Banner and Hanson, 1990). The usual sequence of water/rock interaction is $\text{O} > \text{Sr} > \text{C}$ (cf. Jacobsen and Kaufman, 1999) indicating that the C-isotopic compositions are least likely to be modified. $\delta^{13}\text{C}$ values, therefore, have the best potential for preservation of near original signatures while the $\delta^{18}\text{O}$ values are most susceptible to resetting. Dolomitization has been recognized as an early diagenetic phenomenon during the Proterozoic (Schidlowski et al., 1976; Kaufman et al., 1990; Burdett et al., 1990) that involved direct transformation of still-preserved metastable aragonite and/or Mg-calcite into dolomite. Therefore, the isotopic signatures can be taken as representative of the seawater. This is further corroborated by excellent preservation of sedimentary textures, which would otherwise have become obliterated during multiple transformations of the metastable precursor, first into calcite and subsequently into dolomite. The best-preserved C- and O-isotopic compositions of early Archaean carbonates also suggest that the dolomitization was an early diagenetic phenomenon, caused by waters isotopically similar to that of Archaean seawater (Veizer et al., 1989, 1990, 1992).

Elemental concentrations

Whole-rock geochemical data for carbonates from the western sub-belt are provided in table 1. The major and trace-element compositions reflect the mineral assemblage of the rock and offer significant clues regarding diagenetic history. All the samples are predominantly dolomitic with subordinate calcite except JZ/13A, which is predominantly calcitic. The carbonate rocks show a range of SiO_2 content, varying from 0.39 to 24.17%; the higher values indicate a significant clastic input. Likewise, Al_2O_3 also shows a wide variation (0.12 to 3.06%). A positive correlation between SiO_2 and Al_2O_3 indicates that the non-carbonate minerals are mainly aluminosilicates, most likely clay minerals (Fig. 3A). A non-linear relationship between Sr and Al_2O_3 precludes the possibility of plagioclase to be a significant phase (Fig. 3B). The MgO - SiO_2 cross-plot (Fig. 3C) shows a negative correlation between the two, suggesting that most of the MgO might be locked in the carbonate phase and not in the silicate phase. Relatively higher abundances of Fe and Mn in two samples (JZ/13 and JZ 13C) are probably the reflection of detrital and organic effects relative to the inorganic chemical carbonate precipitate (Tucker, 1983). Further discussion on geochemical parameters has been provided in the subsequent section while evaluating the degree of preservation of the samples.

Discussion

Sample evaluation

In order to have some chronostratigraphic significance, the isotopic data should first be evaluated for retention of primary signatures. A number of geochemical parameters have been proposed to test the degree of preservation of primary isotopic signatures (Veizer, 1983; Kaufman et al., 1993; Narbonne et al., 1994). Although none of them is independently conclusive, they yield unequivocal results if applied in combination. The abundance of certain trace elements such as Fe, Mn and Sr has been recognized as a powerful tool to evaluate the diagenetic history of carbonates, especially the enrichment in Fe and Mn and depletion in Sr in successor phases (Brand and Veizer, 1980). The Mn/Sr ratio has, thus, been regarded as a definitive indicator for the degree of preservation and/or post-depositional alteration (Brand and Veizer, 1980; Veizer et al., 1989, 1992; Derry et al., 1992). Although samples with $\text{Mn/Sr} < 3$ have been considered to be well-preserved and unaffected by post-sedimentation alterations (Derry et al., 1992; Kaufman et al., 1992, 1993; Kaufman and Knoll, 1995), those with an Mn/Sr ratio as high as 10 still appear to be little reset during post-

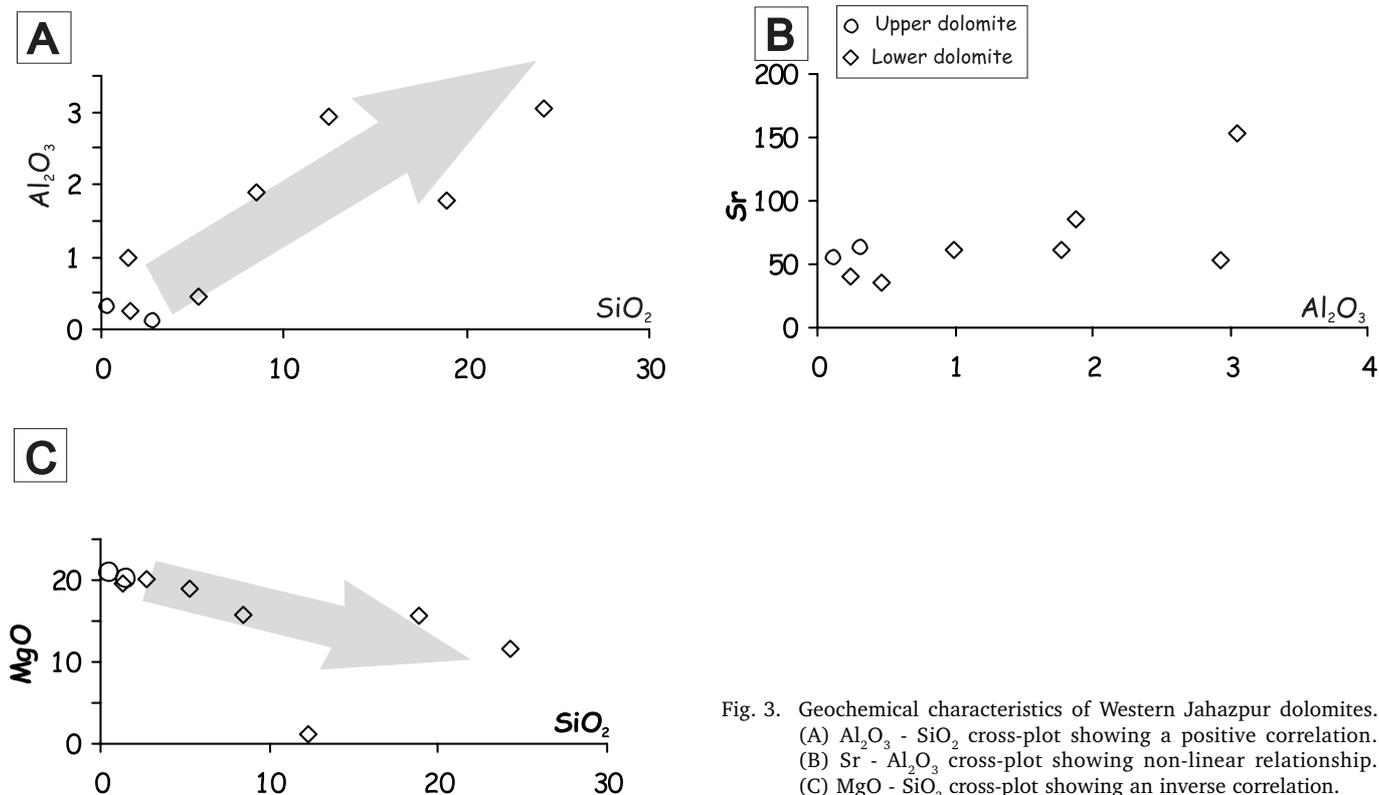


Fig. 3. Geochemical characteristics of Western Jahazpur dolomites. (A) Al₂O₃ - SiO₂ cross-plot showing a positive correlation. (B) Sr - Al₂O₃ cross-plot showing non-linear relationship. (C) MgO - SiO₂ cross-plot showing an inverse correlation.

depositional processes (Narbonne et al., 1994). The MnO concentration in most of the western Jahazpur carbonates varies within a narrow range between 0.02 to 0.05%, with the exception of two samples that are extremely enriched (0.36 and 0.64%). The Mn/Sr ratio for the carbonates varies from 2.82 to 8.61 except for two anomalous samples with extremely high Mn/Sr ratios (32.19 and 32.81). Discarding the two anomalous samples, the Mn/Sr ratios suggest that C-isotopic signatures should be well preserved in most of the samples. A non-linear relationship in the $\delta^{13}\text{C}$ - Mn/Sr cross-plot (Fig. 4A) indicates that the samples are generally unaffected by post-depositional alterations, as that would have resulted in a depletion in $\delta^{13}\text{C}$ and corresponding increase in the Mn/Sr ratio (Melezhik et al., 2001). A non-linear correlation between Mn/Sr and Mg/Ca (Fig. 4B) also rules out any metamorphic dolomitization (closed-system metamorphic devolatilization) as that would usually result in a correlative increase in both the parameters (Melezhik et al., 2001). A positive correlation of Mg/Ca with both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ (Fig. 4C, 4D) is also consistent with well-preserved geochemical signatures, unaffected by later metamorphic process (Azmy et al., 2001).

Post-depositional alteration and evaporative effects can potentially alter the C- and O-isotopic compositions. The likely alteration trends (Burdett et al., 1990; Gurrera et al., 1997; Melezhik et al., 2001) have been

superimposed onto the $\delta^{13}\text{C}$ - $\delta^{18}\text{O}$ cross-plot (Fig. 2). The post-depositional alterations lead to simultaneous depletion in both the parameters while evaporative process would result in variable and unrelated enrichment in $\delta^{18}\text{O}$. Most of the Jahazpur carbonate samples show an inverse correlation between C- and O-isotopic ratios, arguing against any post-depositional modifications. The present dataset is non-conclusive in evaluating the stratigraphic significance of the low $\delta^{13}\text{C}$ samples. Nevertheless, the near sedimentary textures, critical geochemical parameters and C- and O-isotopic characteristics in most of the samples underline the isotopic signatures to be primary and only little affected by any post-depositional modifications.

Comparison with Aravalli Supergroup carbonates

The Jahazpur Group has been described by previous workers as a Palaeoproterozoic sequence that overlies the Hindoli Group (Sinha Roy et al., 1998). Malhotra and Pandit (2000) have also recognized an unconformable relationship between Hindoli and Jahazpur Groups. However, the stratigraphic status of the Hindoli Group remains to be equivocal as Bose and Sharma (1992) consider both Hindoli and Jahazpur Groups to be Proterozoic in age. Recently Deb et al. (2002) have dated zircons (U-Pb method) from felsic volcanics intercalated with Hindoli sediments (and hence

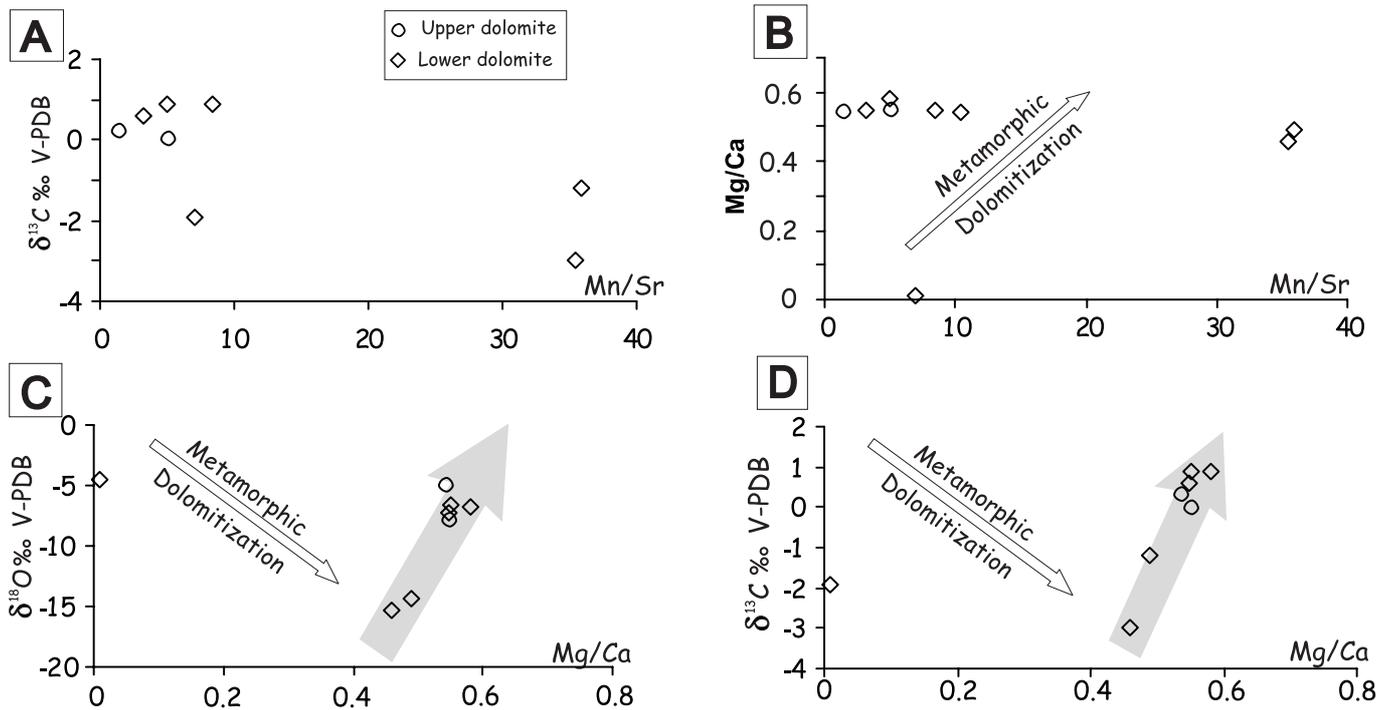


Fig. 4 (A) Cross-plot of Mn/Sr against $\delta^{13}\text{C}$ for carbonates from the Western Jahazpur Belt. Note that most of the analyzed samples show Mn/Sr < 10 except for two samples that show diagenetic trends. (B) Mg/Ca - Mn/Sr cross plot showing the analyzed samples to be unaffected by any metamorphic dolomitization effect. (see Azmy et al., 2001, for details on metamorphic dolomitization). (C) and (D) Mg/Ca cross-plots against $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$, respectively. A positive correlation argues against any metamorphic dolomitization effect.

contemporaneous with the latter). Although the zircons from a felsic tuff gave a wide range of ages between 3259 and 1877 Ma, based on the concordia age of 1854 Ma for a massive rhyodacite sample, these authors have correlated Hindoli felsic volcanics with Aravalli Supergroup. The geochronologic data and other geological evidence support a late Palaeoproterozoic age for Jahazpur Group, and thus, it would be apt to compare the isotopic composition of Jahazpur carbonates with the better-studied Aravalli Supergroup. Published C-isotopic data on Aravalli carbonates are compared with the Jahazpur carbonates in figure 5. The age of Aravalli sedimentation is also not properly constrained and some of the stratigraphic relationships continue to be debated (Roy and Kataria, 1999; Sinha Roy et al., 1998; Shekhawat et al., 2000, 2001). The Aravalli sedimentation cycle was tentatively postulated between 2500 Ma (Berach Granite) and 2000 Ma by Gupta et al. (1992). However, some indirect evidences, such as the model Pb-Pb age of galena from barite intercalated with basal Aravalli volcanics, reported by Deb (1999), have been cited to indicate ca. 2150 Ma as the maximum age of the Aravalli Supergroup (see also Roy and Jakhar, 2002). The Rb-Sr age of ~1900 Ma for post-Aravalli granitoids (Choudhary et al., 1984) suggests a possible time span

between 2150 and 1900 for the Aravalli rocks. Significantly positive $\delta^{13}\text{C}$ values (up to +12‰; see Fig. 5) recorded from the Aravalli carbonates are consistent with the globally reported positive $\delta^{13}\text{C}$ excursion for this period (Melezhik et al., 1999). The Jahazpur carbonate rocks with near zero to moderately negative $\delta^{13}\text{C}$ values are, thus significantly different from the $\delta^{13}\text{C}$ -enriched massive dolomite of the Aravalli Supergroup (Fig. 5). However, the phosphorite-rich carbonate rocks, immediately overlying the $\delta^{13}\text{C}$ -enriched dolomites and belonging to the same stratigraphic unit (Jhamarkotra Formation) show near zero to slightly negative $\delta^{13}\text{C}$ values (Banerjee et al., 1986, Sreenivas et al., 2001), typical of marine carbonates. Sreenivas et al. (2001) have also analyzed three carbonate samples from the Delwara Formation (basal unit of Aravalli Supergroup) that yielded moderate to significantly negative $\delta^{13}\text{C}$ values (-6.7, -2.2 and -1.9‰) as well as low $\delta^{18}\text{O}$ values. A correlation between the Jahazpur Dolomites and Delwara Formation carbonates cannot be attempted despite a close agreement in the $\delta^{13}\text{C}$ values because the isotopic ratios in the latter appear to have been modified by decarbonation process (Shieh and Taylor, 1969) during amphibolite facies metamorphism. A corresponding depletion in $\delta^{18}\text{O}$ values also supports such a contention.

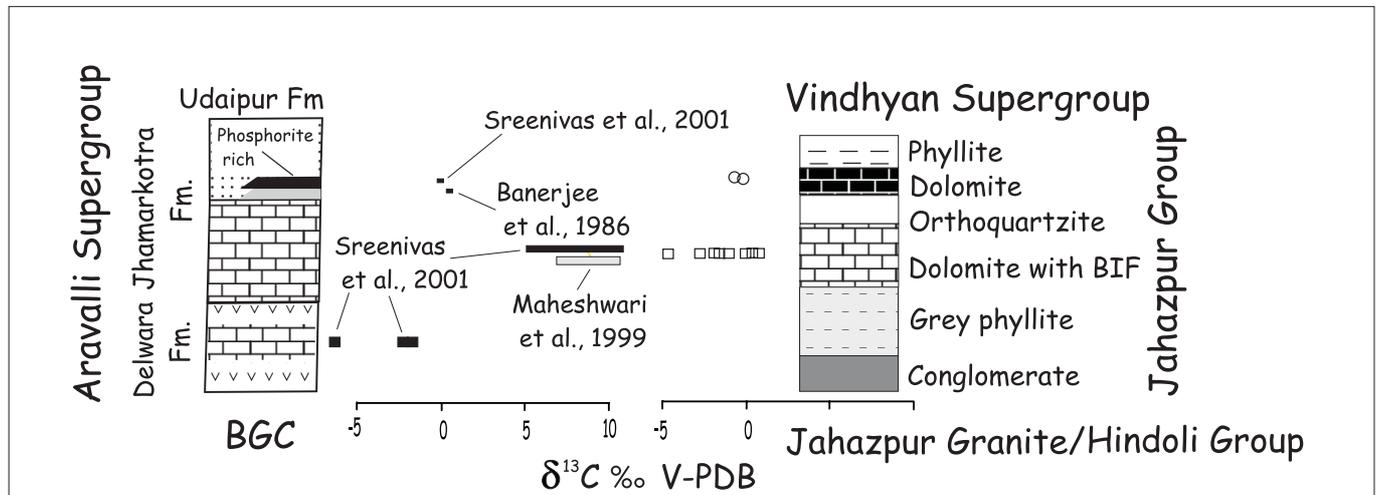


Fig. 5. Comparison of the $\delta^{13}\text{C}$ values of Aravalli Supergroup carbonate rocks with those from the Jahazpur Group. The massive dolomites of the Jhamarkotra Formation show extremely positive $\delta^{13}\text{C}$ values. Note a close resemblance of the Jahazpur Group carbonate rocks with the Delwara Formation carbonates, the basal unit of Aravalli Supergroup.

Each of the Palaeoproterozoic $\delta^{13}\text{C}$ positive excursions has been followed by a negative shift (Melezhik et al., 1999) and the negative $\delta^{13}\text{C}$ values (-4.8 to $+0.9\text{‰}$) in Jahazpur carbonates would potentially be attributed to one such shift. Such an assumption needs to be substantiated by more evidence such as Sr-isotopic data, which would also provide precise chronostratigraphic constraints.

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