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PETROGRAPHY, TRACE ELEMENT GEOCHEMISTRY, AND DOLOMITIZATION MODEL - JHIMPIR DOLOMITE, SINDH, PAKISTAN

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Dolomites of Jhimpir area have been examined petrographically and geochemically to observe and characterize the process and extent of dolomitization. These are petrographically classified as calcitic dolomite and dolomitic limestones. The texture of dolomite is idiotopic. Most of the dolomite rhombohedrons are fine to medium grained and zoned. The replacement of biomicritic carbonate rocks (Laki Limestone of Early Eocene age) by Mg and Fe-rich solutions is observed in thin section. Major and trace elements have been analyzed in order to assess the compatibility of these elements with dolomite. The average MgO content in the samples close to small fault is between 16 and 17 % and decreases from the fault outwards, down to 5 to 4 %. The Fe, Mn, Na and K contents exhibit a positive correlation with increasing dolomitization, whereas, it correlates inversely with Sr. This paper provides evidence that the dolomites of the Jhimpir area are derived from epigenetic replacement.

Key words: Dolomite, Petrography, Geochemistry, Dolomitization model.

Introduction

Extensive deposits of dolomite are found in the Upper Indus Basin of Pakistan (Kazmi and Abbas 2001). In the Lower Indus Basin, deposits of dolomite are limited to Jhimpir and the adjoining areas. Dolomite mineralization is confined to the lower beds of Laki Limestone Unit, the uppermost member of Laki Formation of Ypresian age, in the eastern foothills of southern Kirthar Range.

The process of dolomitization creates the scenario for possible hydrocarbon reservoirs with high porosity and improved capillary properties. Dolomite can also serve as host for Mississippi Valley-Type sulphide ores (Beales and Hardy 1980; Buelter and Guillmette 1988). Dolomite itself serves as an excellent commodity in various applications in metallurgy, refractory material, agriculture and building material.

The origin of dolomite has been a matter of discussion for a long time in sedimentary geology. It is a complex mineral and difficult to be synthesized in the laboratory. Purser *et al* (1994), Mresah (1998), Burns *et al* (2000), Cioppa *et al* (2000), Teal *et al* (2000), Yoo and Shelton (2000), Railsback and Hood (2001) are few examples of recent work on the origins of dolomites. The present study is focused on the study the trace element geochemistry and petrography of the Jhimpir dolomite deposit. Based on these studies and field relationships a genetic model for dolomitization is suggested.

Materials and Methods

Three sections namely Quarry, Road and North were sampled to evaluate the extent of dolomitization (Table 1). Samples were crushed to 10 mm size using Jaw crusher and pulverized (-200 mesh) in a Tema mill for chemical analysis. One-gram air free sample was treated with hot concentrated hydrochloric acid. The solutions were analyzed for Mn, Fe, Sr, Na, K and Zn using a Hitachi Atomic Absorption Spectrophotometer, model Z-8000, at the Pakistan Council of Scientific and Industrial Research Laboratories, Karachi. Insoluble residue (IR), combined oxides (R_2O_3) and loss on ignition (LOI) were determined gravimetrically. Calcium and Mg were measured by EDTA titration.

Thin sections of dolomite were studied with the help of a photographic microscope (Laborlux POLS). Photomicrographs of the selected samples were done with the help of Photoautomat Wild Leitz (MPS46).

Location and accessibility. The study area is situated at 2 km west of Jhimpir railway station in the district of Thatta. The area is accessible from Karachi both by Super Highway and National Highway. On Super Highway a link road turns towards Jhimpir at 94 km from Karachi.

General geology. The study area lies in the southern extension of the eastern foothills of the Kirthar Range. The area has a low relief, of ~30 m above the local ground. Numerous small ridges are scattered in the area. Tertiary sedimentary

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rocks are exposed in the study area (Table 2). The Ranikot Group of Paleocene age is the oldest rock formation of the area and occupies the southern part of the study area. The Laki formation of Ypresian age outcrops mainly in the southern part of the Kirthar Province of the Lower Indus Basin. It is confined to a strip that extends from the Laki and Bhadra Ranges in the north to the hills near Thatta in the south. The Nari Formation (Oligocene) is also exposed as small outcrops.

The Laki Formation consists mainly of limestone, but marl, calcareous shale, sandstone and lateritic clay are locally significant constituents of the formation. At the type locality of this formation, consists predominantly of white argillaceous and nodular limestones. The basal sequence of the Laki Formation, named Sohnari Member is a ferruginous assemblage. The main components of this member are lateritic clays and variegated shales, colored in yellow, white, orange, red and brown. Variegated sandstones are also common as lenticular beds. The sandstones are soft, sugary, friable and generally ferruginous. Some of the clays, lignite, white sandstones and ochre of this formation have some commercial value. The Laki Formation is 250 m thick in the type locality (Mari Stream) and attains more than 600 m in thickness near Thatta. The formation contains rich fossil assemblages including foraminifers, gastropods, bivalves, echinoids and algae (Shah 1987).

The upper part (Chat Member) constitutes the major portion of the formation. It consists of hard limestones with soft shales and marls. The limestones are thickly bedded, massive and rich in large foraminifers. The Chat Member is divided into three units (Table 3) and the dolomite beds are found in the basal part of the uppermost Laki Limestone Unit.

Structurally, the area consists of several small asymmetrical, gently-dipping plunging folds, which are displaced by faults running NE-SW. Regionally, this region is the part of the Sonda-Jhimpir monoclinal structure, dipping westward. The dolomite-bearing structure is an asymmetrical anticline. The western limb dips 10°-12° whereas, the eastern limb dips 12°-22°. The axis plunges 3° towards south. The western limb is affected by a NE-SW running fault with a maximum displacement of 7 m (Hussain 1976).

Results and Discussion

Classification of dolomites. Dolomite is a mineral that belongs to the mineralogical class of carbonates. Chemically, it contains 45.65 weight % $MgCO_3$ and 54.35 weight % $CaCO_3$. Structurally dolomite is a rhombohedral carbonate consisting of alternating layers of carbonate anionic group and the equivalent number of cations of Ca and Mg. Stoichiometrically, dolomite has an ideal $CaCO_3/MgCO_3$ molar ratio of 50:50 (Tucker 1990). Dolomite can be classified on the basis of its MgO content in the calcite-dolomite system, being a rock-forming mineral of magnesian limestones, dolomitic limestones, calcitic dolomites and dolomites with increased Mg content. There are certain drawbacks in this sketch. First, the carbonate may not form a 100 % of the rock composition. Second the percentage of dolomite is not the reciprocal of the calcite content. Fairbridge (1970) presented a schematic classification for the Ca-Mg carbonate rock system (Fig 1). In this scheme the terms are directly applied to the carbonate fraction only and the analysis are plotted in that diagram, in order to illustrate the possible classification of the studied samples.

Table 1
Location, section, and sample numbers of the study area

Section	Sample No.	Location
Quarry Section	Q1 to Q10 (Bottom to top) Q11 to Q16 (West to east)	N 25° 00’ 36” E 67° 59’ 53”
Road Section	R1 to R9 (Bottom to top)	N 25° 01’ 87” E 68° 00’ 01”
North Section	N1 to N5 (Bottom to top)	N 25° 02’ 68” E 68° 00’ 05”

The plots of all samples, collected close to fault plane fall into the “Calcitic dolomite” field on the Fairbridge (1970) diagram, while the samples from the fold limb fall into the “Dolomitic limestone” field (samples R4, N1, Q11, Q14, Q15 and Q16) except for the sample Q2. Two samples (R1 and N3) are ploted into the “Limestone” field of the diagram. The latter were included to study the process and extent of dolomitization towards the basal part of the Laki Limestone Unit of the Laki Formation.

Iron can substitute Mg in dolomite to give ferroan dolomite (<2 mole % $FeCO_3$), and the mineralogical term ankerite is used for Fe-rich compositions about $CaMg_{0.5}Fe_{0.5}(CO_3)_2$.

Petrography. Twenty selected samples were analyzed petrographically. The rocks are composed of zoned crystals of dolomite and ferroan dolomite (Fig 2a-d) with a 30 % of the area of the thin section composed by dolomicrite. A few allochem ghosts (forams) are also seen bounded in dolomicrite (Fig. 2b) indicating an epigenetic replacement. The size of dolomite rhombohedrons has a bimodal distribution and is classified as fine-grained (0.125- 0.05 mm) and medium grained (0.3-0.25 mm). The cores of crystal have higher concentrations of cations with higher atomic number (Fe) and are cloudy, whereas, the rims have higher concentrations of cations with lower atomic number (Mg) and are relatively clear. About 80 to 90 % of the dolomite crystals are zoned. The variable con-

Table 2
Lithostratigraphy of the study area (after Shah 1987)

Era	Cenozoic					
Period	Tertiary					
Epoch	Paleocene			Eocene		Oligocene
Group	Ranikot Group					
Formation	Khadro	Bara	Lakhra	Laki	Kirthar	Nari
Description	Sandstone with shale, minor limestone and basaltic flows (Deccan Trap). Sandstone olive, yellowish brown, gray and green, soft, medium grained, ferruginous and calcareous.	Sandstone with minor shale and volcanic debris. Sandstone multicolored, fine to coarse-grained, soft and crumbly, massive, ferruginous, ripple marked and cross stratification.	Limestone and subordinate sandstone and shale interbeds. Limestone gray and yellowish stains. Thin to thick bedded, nodular, brecciated textured, sandy, in places argillaceous and fossiliferous.	Mainly limestone subordinate marl, calcareous shale, sandstone and laterite. Divided into Basal (Sohnari) and Upper (Meeting Limestone and Shale) members.	Limestone and shale with minor marl. Limestone light gray, cream, chalky-white, thick bedded to massive. Nodular contains algal and coraline structures.	Sandstone and shale with subordinate limestone and minor conglomerates. Sandstone greenish gray, gray, brown or white, fine to coarse grained, often gritty and calcareous.

centration of Mg and Fe due to different phases of dolomitization will cause cloudy appearance in the zoned rhombs (Blatt 1982; Sibley 1982). Cioppa *et al* (2000) also observed recrystallization events that caused zoning and a gradual increase in size of the dolomite crystals in the Turner Valley Formation, Alberta Canada.

The texture of dolomites in majority samples is idiotopic (Fig 2c). The dolomite crystals are euhedral to subhedral with planer boundaries. Above a critical roughening temperature (CRT) a rough surface of crystal is favored; leading to a mosaic of anhedral crystals and a xenotropic texture is formed. Gregg and Sibley (1984) suggested that CRT for dolomite occurs between 50° and 100° C. The idiotopic textures can be expected to form at a higher temperature range in a porous environment close to the surface (low pressure).The crystals grew in micro-cavities (intergranular and intragranular both in case of Laki limestone) and contain impurities such as clays and organic matter. Secondary irregular cavities and fossil moulds are lined by clear sparry calcite merging into or etching planar boundaries of dolomite rhombohedrons (Fig 2c). The latter is due to later processes of dedolomitization under a meteoric (near surface) environment. Specks and stains of black and brown iron oxides are also present. A few cavities are also lined by magnetite. Post and pre-dolomitization (encroached by dolomite rhombohedrons) tectonic fractures are also present, and are lined by clear sparry calcite though a few of them are lined by ferruginous material.

The rocks (dolomite) seem to be the result of replacement of biomicrite (Laki Limestone) by Mg and Fe-rich solutions under uniformly fluctuating conditions of the replacement environment suggesting a fracture controlled dolomitization model. Later, the conditions changed and under the influence of a meteoric environment partial dedolomitization (replacement by sparry calcite) of dolomite rhombohedrons occurred and dolomicrite formed (Fig 2d). Such process occurs at low temperatures, low pressures and close the surface, under the influence of surface water. On the contrary burial-related dedolomitization has low Fe (200 ppm) and Mn (30 ppm) and moderate Sr (350 ppm) content (Budai and Lohmann 1984).

Crystal chemistry. Sedimentary minerals are generally formed as metastable phases, time and changing environmental conditions lead them to change and to recrystallize into more stable phases. The actual pathway of stabilization is governed by kinetic factors (Tribble *et al* 1995). Calcite and dolomite are chemically an integral part of the $CaCO_3^-$ $MgCO_3$ solid solution series but, despite their strong similarities, they are structurally different. In the structure of dolomite one emphasizes the alternate layers of Ca-Mg atoms and CO_3^- groups. The crystals of dolomite consist of an equal number of Ca^{++} and Mg^{++} ions arranged into separate sheets with planes of CO_3^- ions between them (Tucker 2001), since Mg substitutes alternate layers of Ca of the calcite structure. The Mg ion is smaller (0.78Å) than that of Ca (0.99Å), so the CaO_6 octahedra in dolomite are smaller and less distorted than in calcite. Dolomite has higher bond strength and a lower degree of symmetry than calcite (Tucker 1990). Another important dissimilarity is the rotation of the C-O bond with reference to a-axes. In calcite, the C-O bonds are coincident with

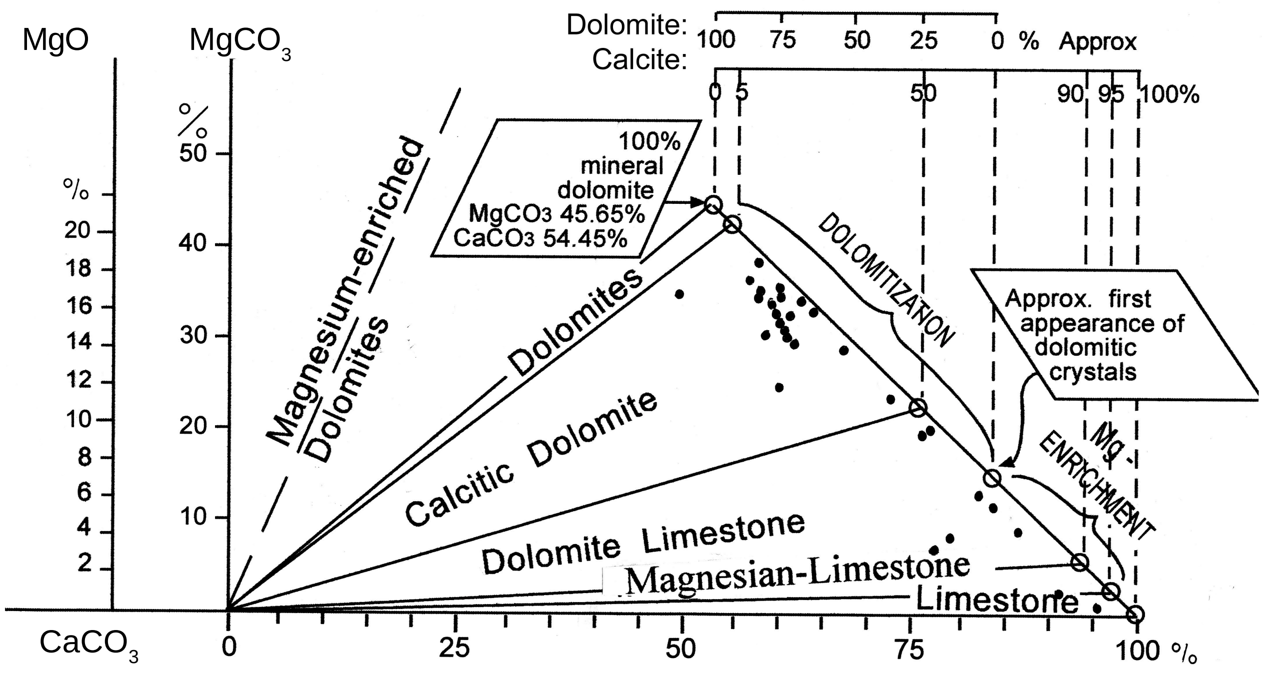

Fig 1. Classification of dolomite deposits of study area (after Frirbridge 1970).

the three a-axes but in dolomite they are rotated 6.5° from the a-axis.

During replacement, the substitution of Ca in the calcite lattice is a function of the ionic size of the substituting element. In general, Mg, Fe and Mn can substitute Ca forming dolomite, ankerite and kutnohorite at different physicochemical conditions. The ionic diameter and the mutual relations in terms of miscibility and stability of Ca-Mg-Fe-Mn are illustrated in Fig 3. The less ionic size differences among these elements lead to complete miscibilities between them. However, incomplete miscibility occurs between Ca-Mg, Ca-Fe and Ca-Mn (Fig 3). Inspite of the large ionic size difference (0.27 Å) between Ca and Mg, their association is stable. In dolomite, Fe substitutes Mg forming ferroan dolomite, which is stable and common; on the other hand, Mn may replace Ca forming kutnohorite, a stable but rare double carbonate mineral (Fig 3). Wu and Wu (1998) have also suggested diagenetic modifications in middle Ordovician carbonates, Taiyuan City area, China, based on Sr, Fe and Mn concentration difference between the dolomite and coexisting limestone.

Trace element geochemistry. The composition in terms of major and trace elements of Jhimpir dolomites is given in Tables 4 and 5. Dolomitization is stronger close to the fault and decreases away from either side of the fault plane. In the quarry section, samples Q11, 14, 15, and 16 have low MgO contents (Table 4). Sample R1 (non-dolomitized sample of the Laki Formation) has a very low MgO (1.33 %) content. It is important to note that samples Q1-10 collected vertically (Table 1) from the quarry, parallel to the fault plane, have nearly the same MgO content. It is inferred that Mg bearing solution came through the fault, since the extent of dolomitization is uniformly distributed parallel to the fault plane. The correlation between CaO and MgO exhibits an inverse correlation indicating a progressive dolomitization (Fig 4). A close linear association is observed between the Ca/Mg ratio and CaO plot, except in sample R1 and N3, which have high Ca/Mg ratio (45 and 127, respectively). The K versus CaO plot (Fig 4) displays a linear relationship in the dolomitized samples, but, partially dolomitized and non-dolomitized samples do not show a clear correlation. Scattered association is observed between K and MgO (Fig 4). This implies a close association between K and Ca in the dolomite, but no significant relation is observed between K and Mg, probably due to the similar ionic size of K and Ca. Sodium behaves similar to K, except for its close association with Na (Fig 4). The distribution of Na is nearly uniform with an increasing dolomitization (4060-6875 ppm). High Na contents reflect the salinity of the water from which the dolomite crystals formed. Furthermore, the fossils (skeletal ghosts) replaced by dolomite also have high Na values (Sibley 1980). A high Na content in dolomites is possibly a function of their poor ordering and nonstoichiometrical character, which is due to lattice distortion (Burns *et al* 1988).

The Fe concentration in samples of the study area varies between 50 and 1000 ppm. In general the average content of Fe

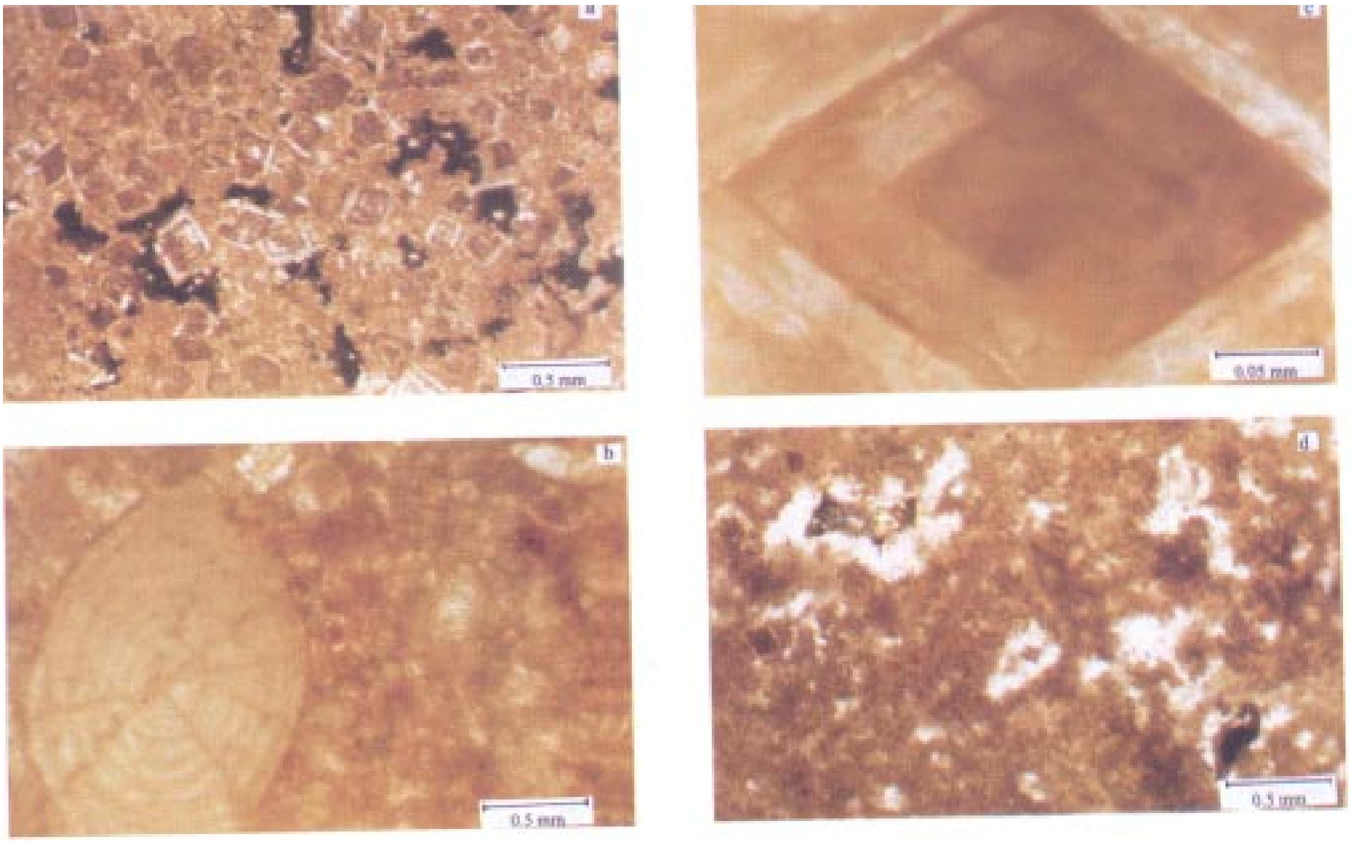

Fig 2. Photomicro graphs of dolomites of study area.

is about 200 ppm, but higher (2000 ppm) in diagenetic dolomites (Mattes and Mountjoy 1980). Iron is easily incorporated into the dolomite forming a ferroan variety, exhibiting good agreement between Fe and CaO (Fig 5). Relatively pure dolomite also presents a sympathetic relationship between Mn and CaO, but poorly and partially dolomitized samples show an inverse relationship. Both Fe and Mn show variable concentrations related to MgO content around 15 % (Fig 5). This situation probably indicates favourable conditions for the incorporation of Fe and Mn in the dolomite lattice because the coefficient of distribution is high for both Fe and Mn. (Fig 5). The high concentration of Fe and Mn is probably due to the interaction of the carbonate rocks with reducing pore-water that has high Fe and Mn contents (Fathy *et al* 1997). Possible Fe and Mn rich dolomitizating fluids came from basinal mud rock dewatering, because these elements could have been released during the conversion of smectite to illite at elevated temperatures during burial (Tucker 1990). From the above discussion it is clear that the dolomites of Jhimpir were not originated during earlier diagenesis in a marine environment, since Fe and Mn contents are very low in seawater. The distribution and size of epigenetic dolomite is not very common in the world. Geodic dolomite, Sardinia, Italy is one of the most extensive dolomites of epigenetic type (Boni *et al* 2000).

Strontium is largely substituted for Ca rather than Mg ions in dolomite lattice (Tucker 1990). The inverse correlation between Sr and CaO with increasing dolomitization in the samples of the study area is reflected in Fig 5. The limestone facies have high amounts of Sr, except in sample Q 11 (600 ppm). The high contents in Sr (~3000 ppm) probably reflect an inheritance from the precursor calcite. Strontium can be used to assess the timing of dolomitization. Its low content is the indication of ancient dolomitization, whose trace is lost during recrystallization (Tucker 1990). The correlation between Sr and Fe reflects roughly inverse affinity (Fig 5), except in samples N2, Q16 and R1 that are limestone. The inverse role of Sr can be easily understood by its large ionic size (1.32Å) which is incompatible in the dolomite lattice. The concentration of Sr decreases this way in carbonate minerals: aragonite > calcite > dolomite.

The concentrations of Zn in the samples of the study area are nearly uniform (15 to 25 ppm). Dolomitized, partially dolomitized and non-dolomitized samples have concentrations about 25, 20 and 15 ppm, respectively (Table 5). Dolomitization does not seem to have large affect on Zn concentrations. This probably indicates that Zn was introduced by dilute water in the Laki limestone because of its high distribution coefficient. The ionic size of Zn is compatible with the dolomite lattice and thus dolomite is a good host for Zn-mineralization in

Table 3

Members and units of Laki formation and respective thicknesses, measured in the querry section (after Hussain 1976)

Formation	Member	Units	Thickness
		Laki limestone *(Dolomite at base)*	40 m
Laki (Y presian)	Chat	Meeting shale Meeting limestone	30 m 42 m
	Sonhari	Sonhari	35 m

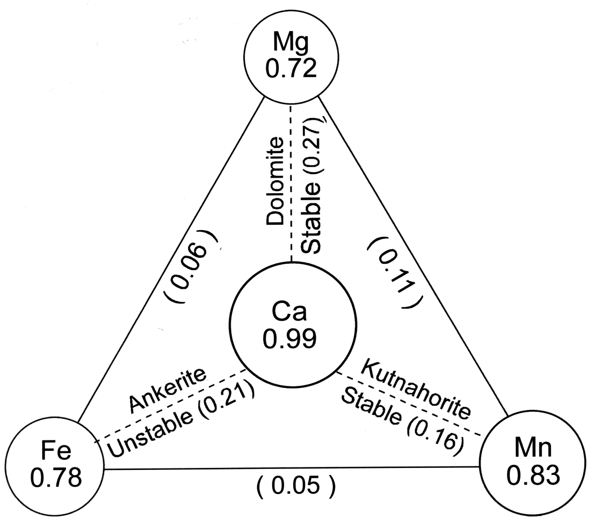

Fig 3. Coordination of Ca with Mg, Fe and Mn showing ionic size and stability (after Tucker 1990).

Table 4

Concentrations of elements in the samples of study area

S. No	I.R %	R_2O_3%	CaO %	MgO %	LOI %	Na (ppm)	K(ppm)
Q1	10.51	4.32	28.35	16.10	40.57	5500	425
Q2	2.93	2.05	46.55	5.75	42.47	5000	250
Q3	4.39	2.71	32.20	16.51	43.94	4625	255
Q4	1.60	1.92	34.49	16.38	45.03	5250	170
Q5	2.30	1.85	34.31	16.38	44.92	5250	195
Q6	2.21	1.47	32.84	17.89	45.01	5250	185
Q7	2.07	1.39	34.39	16.81	45.14	5625	210
Q8	2.06	2.22	32.34	17.64	44.81	5500	235
Q9	2.90	1.91	34.15	16.63	44.30	5560	295
Q10	0.59	1.21	36.18	16.52	45.16	5250	140
Q11	1.50	0.42	46.96	6.38	43.81	4560	195
Q12	2.25	1.77	33.29	17.38	45.06	5500	245
Q13	7.10	0.47	36.95	12.60	42.94	5250	370
Q14	7.23	2.52	44.51	4.28	41.11	5000	250
Q15	4.18	0.55	48.23	4.78	41.89	4375	165
Q16	5.78	5.34	44.16	4.03	40.33	4685	200
R1	3.95	2.39	50.83	1.33	41.40	5935	325
R2	1.86	4.97	32.86	15.12	44.52	4725	210
R3	1.22	1.79	40.78	11.05	44.82	4550	165
R4	1.35	1.24	42.57	9.57	44.87	5000	165
R5	3.61	2.37	35.05	13.86	44.83	5000	295
R6	2.04	4.73	34.64	14.62	43.48	4060	145
R7	4.00	4.21	33.27	15.37	43.05	5250	360
R8	3.70	2.18	34.29	14.74	44.79	4550	230
R9	0.48	1.15	35.16	16.63	46.32	5250	120
N1	0.97	1.29	43.91	9.20	43.91	6875	145
N2	1.76	2.67	33.56	16.63	44.51	5000	290
N3	0.85	2.72	53.62	0.51	41.77	4560	120
N4	2.95	2.32	33.64	15.86	44.74	5625	255
N5	0.89	1.17	37.85	14.11	45.77	5500	165

Table 5
Concentrations of trace elements (ppm) in selected samples

S. No.	Fe	Mn	Sr	Zn
Q1	1000	160	500	25
Q2	360	95	1000	15
Q4	440	325	300	15
Q8	500	510	400	15
Q10	330	365	800	15
Q11	250	165	600	15
Q12	370	285	400	20
Q13	680	380	750	20
Q16	400	100	2900	20
R1	450	130	2800	15
R2	160	230	800	15
R7	250	110	400	15
R9	550	230	300	25
N2	500	95	3000	20
N3	50	55	1200	15
N4	1000	110	310	20

Mississippi Valley-Type hydrothermal deposits (Buelter and Guillmette 1988). This type of mineralization is common in the Mor Range, Pakistan (Naseem *et al* 2002). The low concentration of Zn in the samples of study area indicates that these rocks are not related to a hydrothermal origin.

Conclusion

In the Lower Indus Basin, deposits of dolomite are reported from the town of Jhimpir and adjacent areas. These deposits are confined within the lower beds of the Laki Limestone Unit, the uppermost member of Laki Formation, of Ypresian age in the eastern foothills of southern Kirthar Range. The rock formations are folded and dissected by faults of various dimensions. The dolomite deposits are associated with local faults. The field and analytical data suggest that the intensity of dolomitization decreases away from the fault planes. Close to the fault, calcitic dolomite grades outwards to dolomitic limestone. The lateral extent of dolomitization is about 50 m on either side of the fault.

The majority of samples have idiotopic textures developed due to low to moderate temperatures (50 - 100˚C) by a near surface replacement. The dolomite crystals are euhedral to subhedral with planar boundaries. The rock is composed of zoned crystals of dolomite, dolomicrite and ferroan dolomite. The size of dolomite rhombohedrons displays a bimodal distribution, both fine-grained (0.125 - 0.05 mm) and medium grained (0.3 - 0.25 mm crystals). Nearly 80 - 90 % of the crystals are zoned. The majority of crystals have denser centres and lighter rims. This possibly indicates various pulses of dolomitization by Mg and Fe-rich solutions in variable concentrations for each element. Presence of iron minerals as specks and streaks in the samples of dolomite further endorses the above findings. Sparry calcite crystals are also present, filling cavities and tectonic micro-fractures, formed due to partial dedolomi-tization during a late-stage mineralization which took place under dominant meteoric influence.

The crystal chemistry of the calcite-dolomite system also justifies the current results. The ionic size, charge, coordination number and stability of calcite and dolomite lattices are mainly responsible for the distribution of major and trace elements in the samples of Jhimpir dolomites. Large ions (Sr and K) were depleted during dolomitization because these two elements are not compatible with the dolomite lattice. On the contrary, Na, Fe and Zn have strong affinities with dolomite crystals, so that their concentration is relatively high in the dolomite in contrast to the Laki limestone.

The correlations among major and trace elements also support on epigenetic replacement process of dolomitization. Calcium exhibits inverse relation suggesting progressive dolomitization. The content in both alkalis (K and Na) do not correlate with that of Mg of the dolomite. However, they show some correlation with Ca. High contents of Na in the dolomite samples reflect that the salinity of replacing water was high. Furthermore, a high Na content implies a poor ordering and lattice distortion in dolomite. Strontium shows an antipathetic relation with Mg because it is leached during the process of dolomitization. The high Sr content (~3000 ppm) in the samples of the Laki Limestone probably reflects inheritance from a calcite precursor. In contrast, Fe and Mn are concentrated in dolomite because both elements are easily incorporated in the dolomite structure due to their high distribution coefficient. This is possibly because of the interaction of Fe-Mn-rich reducing pore water that was released by dewatering of basinal muds. Small-scale faults were generated due to overburden pressure and the dolomitizing water oozed out from these faults to cause dolomitization. It is observed that the dolomites of Jhimpir were not originated during early diagenesis in a marine environment, because Fe and Mn contents are very low in seawater. Thus we consider that these deposits are epigenetic and due to replacement during later stages of diagenesis/dolomitization. Zinc contents (15 - 25 ppm) in the samples of the study area support a non-hydrothermal origin.

References

Beales F W, Hardy J W 1980 Criteria for the recognition of diverse dolomite types with an emphasis on studies on host rocks for Mississippi Valley-type ore deposits, In:

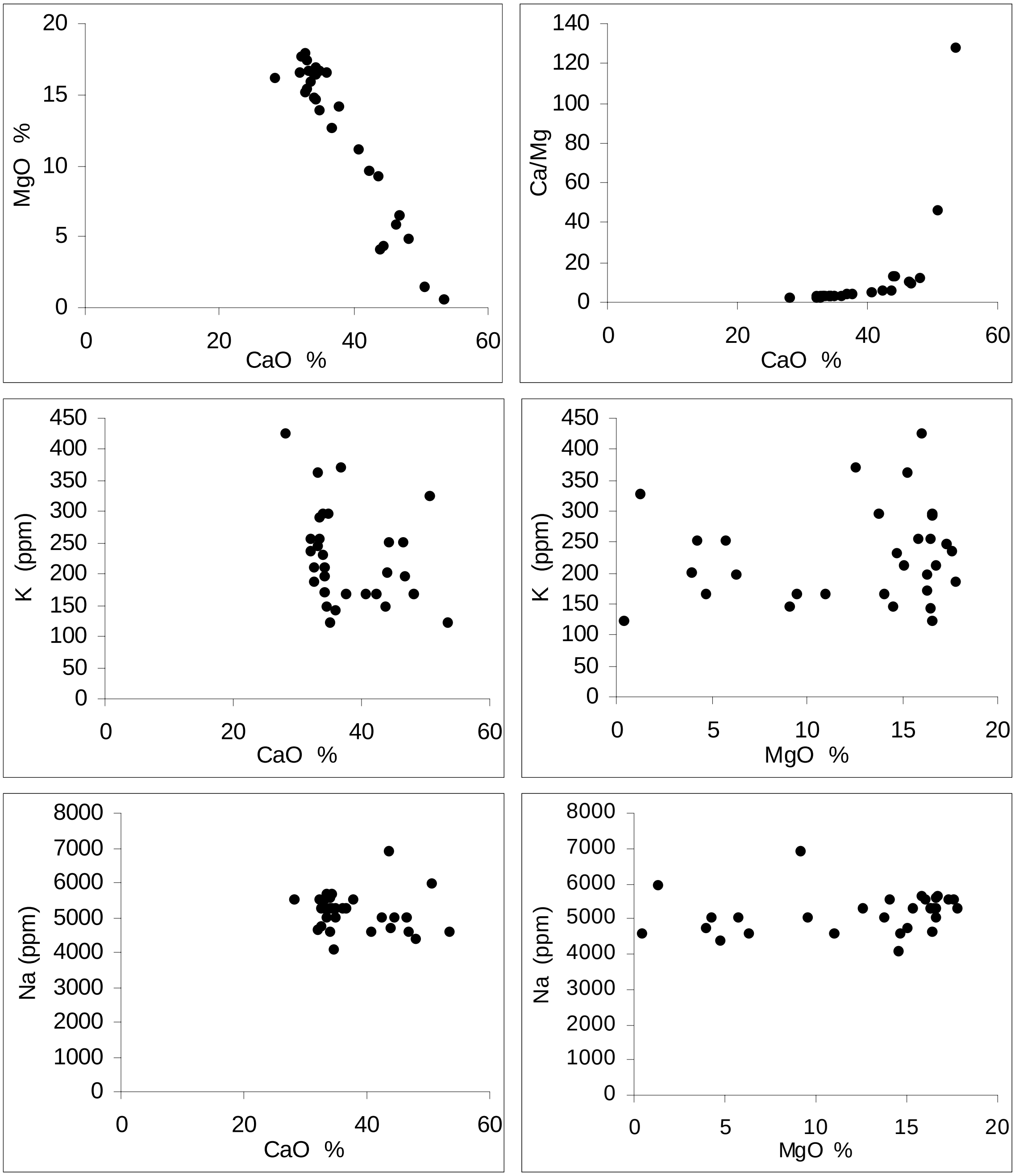

Fig 4. Degree of correspondence among various elements in the samples of the study area.

Concepts and Models of Dolomitization, eds Zenger D H, Dunham J B, Ethington R L, Soc. of Economic Paleontologists and Mineralogists **28** 197 - 213.

Blatt H 1982 *Sedimentary Petrology.* Freeman WH and Co. New York, USA, p 564.

Boni M, Parente G, Bechstädt T, De Vivo B, Iannace A 2000 Hydrothermal dolomites in SW Sardinia (Italy): evidence for a widespread late-Variscan fluid flow event. *Sedimentary Geology* **131** 181 - 200.

Budai J M, Lohmann K C 1984 Burial de-dolomitization in the Mississippian Madisan Limestone, Wyoming and Utah Trust Belt. *Jour Sedi Petrology* **54** 276 - 288.

Buelter D P, Guillmette R N 1988 Geochemistry of epigenetic dolomite associated with lead-zinc mineralization of the Viburnum Trend, southeast Missouri: A reconnaissance study, In: *Sedimentology and Geochemistry of Dolostones*, eds. Shukla V, Baker P A, *Soc Econ Pal and Min Sp Pub* **43** pp 85 - 95.

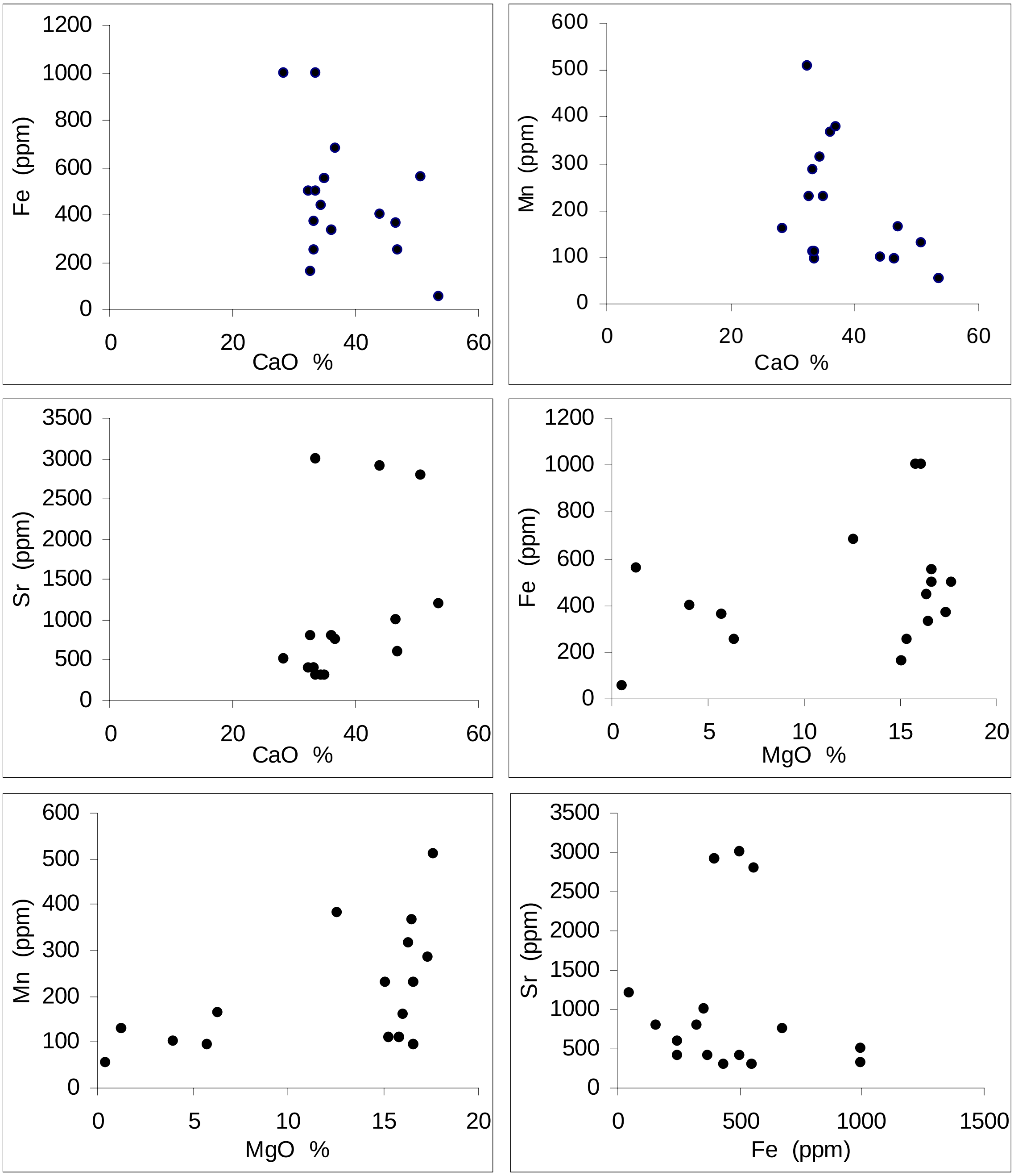

Fig 5. Degree of correspondence among various elements in the selected samples of study area.

Burns S J, Baker P A, Showers W J 1988 The factors controlling the formation and chemistry of dolomite in organic-rich sediments: Miocene Drakes Bay Formation, California, In: *Sedimentology and Geochemistry of Dolostones*, eds. Shukla V, Baker P A, *Soc Eco Pal and Mine Sp Pub* **43** pp 41 - 52.

Burns S J, Mc Kenzie J A, Vasconcelos C 2000 Dolomite formation and biogeochemical cycle in the Phanerozoic. *Sedimentology* **47** 49 - 61.

Cioppa M T, Al-Aasm I S, Symons D T A, Lewchuk M T, Gillen K P 2000 Correlating paleomagnetic, geochemical and petrographic evidence to date diagenetic and fluid flow events in the Mississippian Turner Valley Formation, Moose Field, Alberta, Canada. *Sedimentary Geology* **131** 109 - 129

Fairbridge R W 1970 The dolomite question, In: *Regional Aspect of Carbonate Deposition* eds. Lei Blank R J, Breeding J G., *Soc Eco Pal and Min Sp Pub* **5** pp 125 - 178.

Fathy I, Hertelendi E, Haas J 1997 Geochemistry and dolomitization of Pleistocene coral reefs, in the Gulf of Aqaba Region, South Sinai, Egypt. *Acta Mineralogical-Petrographica, Hungaria*, **38** 73 - 94.

Gregg J M, Sibley D F 1984 Epigenetic dolomitization and the origin of xenotopic dolomite texture. *Jour Sedi Petrology* **54** pp 908 - 931.

Hussain S 1976 A study of Jhimpir dolomite deposit; *The Geologist*, Dept. of Geology, Uni. of Karachi, 22 - 26.

Kazmi A H, Abbas S G 2001 *Metallogeny and Mineral Deposits of Pakistan*. Graphic Publishers, Karachi, p 264.

Mattes B W, Mountjoy E W 1980 Burial dolomitization of the Upper Devonian Miette buildup, Jasper National Park, Alberta. In: *Concepts and Models of Dolomitization*, eds Zenger D H, Dunham J B, Ethington R L, *Soc Eco Pal and Min* **28** pp 259 - 297.

Mresah M H 1998 The massive dolomitization of platformal and basinal sequences: proposed models from the Paleocene, Northeast Sirte Basin, Libya. *Sedimentary Geology* **116** 199 - 226

Naseem S, Sheikh S A, Qadeeruddin M, Shirin K 2002 Geochemical stream sediment survey in Winder Valley, Balochistan, Pakistan. *Jour Geochemical Exploration, Elsevier*, **76** 1 - 12.

Purser B H, Tucker M E, Zenger D H 1994 Dolomites: A volume in honour of Dolomite Sp. Pub. 21. Int Asso Sedi Black Well Sci, Oxford, USA, p 451.

Railsback L B, Hood E C 2001 A survey of multi-stage diagenesis and dolomitization of Jurassic limestones along a regional shelf-to-basin transect in the Ziz Valley, Central High Atlas Mountains, Morocco. *Sedimentary Geology* **139** 285 - 317.

Shah S M I 1987 *Lithostratigraphic Units of the Sulaiman and Kirthar Provinces Lower Indus Basin, Pakistan*. Memoir of the Geological Survey of Pakistan, Quetta, Pakistan, **17** 106.

Sibley D F 1980 Climatic control of dolomitization, Seroe Domi Formation (Pliocene), Bonaire, N.A., In: *Concepts and Models of Dolomitization*. eds Zenger D H, Dunham J B, Ethington R L, *Soc Eco Pal and Min* **28** 247 - 258.

Sibley D F 1982 The origin of common dolomite fabrics. *Jour Sedi Petrology* **52** 1987 - 1100.

Teal C S, Mazzullo S J, Bischoff W D 2000 Dolomitization of shallow marine deposits mediated by sulphate reduction and methanogenesis in normal-salinity sea water, northern Belize. *Jour Sedi Research* **70** 649 - 663.

Tribble J S, Arvidson R S, Lane M, Mackenzie F T 1995 Crystal chemistry, and thermodynamic and kinetic properties of calcite, dolomite, apatite, and biogenic silica: applications to petrologic problems. *Sedimentary Geology* **95** 11 - 37.

Tucker M E 1990 Dolomites and dolomitization models, In: *Carbonate Sedimentology*. eds. Tucker M E, Wright V P, Blackwell Science Pub., London, UK, pp 365 - 400.

Tucker M E, 2001 *Sedimentary Petrology*. Blackwell Science, Pub., London, UK, p 262.

Wu Y, Wu Z 1998 Diagenetic modification of dolomite in middle Ordovician carbonates, Taiyuan City area, China. *Sedimentary Geology* **1161** pp 43 - 156.

Yoo C M, Shelton K L 2000 Dolomitization and dolomite neomorphism Trenton and Black River Limestone (Middle Ordovician) Northern Indiana. *Jour Sedi Rearch* **70** 265 - 274.