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Influence of Bela Ophiolite on Trace Element Composition of Jurassic and Cretaceous Carbonate Rocks of Phuari Area Balochistan

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Major and selected trace element analyses of carbonate rocks of Loralai formation and Parh limestone from Phuari area of Balochistan province were carried out. These carbonates are melanged with rocks of Bela Ophiolite. The distribution of various trace elements (Ni, Cr, Cu, Mn, Cd, Pb and Zn) in the carbonate rocks in the light of their plots was discussed with respect to primary dispersion, mobility and physicochemical environment. An attempt has also been made to evaluate the influence of magmatic bodies for impregnating trace elements into limestones. High Ni, Cr, Mn, Cu, Cd, Pb and Zn assemblage show similarity with tholeitic Mid Oceanic Ridge Basalt (MORB). Petrographic studies were also made for description and classification of carbonates. Presence of dark glassy/amorphous igneous material in thin-sections emphasizes the influence of igneous bodies on carbonate rocks.

Key words: Trace element geochemistry, Bela Ophiolite, Jurassic-createaceous carbonates, Phuari, Balochistan.

Introduction

The area under study is a part of a geologically complex region. It is situated in the southern most extension of Bela Ophiolite belt, Pab and More Ranges. The sedimentary rocks exposed in the area include Loralai formation of Jurassic, Parh limestone of Cretaceous and some shales of Khadro formation of Paleocene age (Fig. 1). The Pab and Mor Ranges and Bela Ophiolite Belt are just aposed in a very narrow stripe. In the area Chaotic mixture of sedimentary rock along with rocks of Bela Ophiolite are present as a melange (Kazmi and Jan 1997). Southeast of the area younger rocks of Eocene-Miocene age are present. The tectonic setting is due to the collision of Indian Plate with Eurasian Plate during Paleocene time. As a result Bela Ophiolite was emplaced onto the rocks of Jurassic-Cretaceous age.

The present study deals with the geochemical and petrographic investigation of Loralai Formation and Parh limestone and to correlate the similarities in major and selected trace elements in these rocks of the area under study with the work done by other workers in Pab and Mor Ranges. The paper is also aimed to discuss the impregnation of various mobile and trace elements of Bela Ophiolite into the sedimentary rocks of Loralai formation and Parh limestone over which it was emplaced. Structurally area is quite complicated, small sedimentary isolated outcrops with low relief are present. Rocks are highly disturbed and at places micro folds are noticed. All structural features reveal that the area was subjected to intense tectonic movements in different episodes of time during which there were great contortions, compressions and distortions of the strata.

Stratigraphy. Mostly the outcrops are allocthonous and generally exhibit no stratigraphic relationship. The geological map of the area is given in Fig 1. A summary of the exposed rocks is given below.

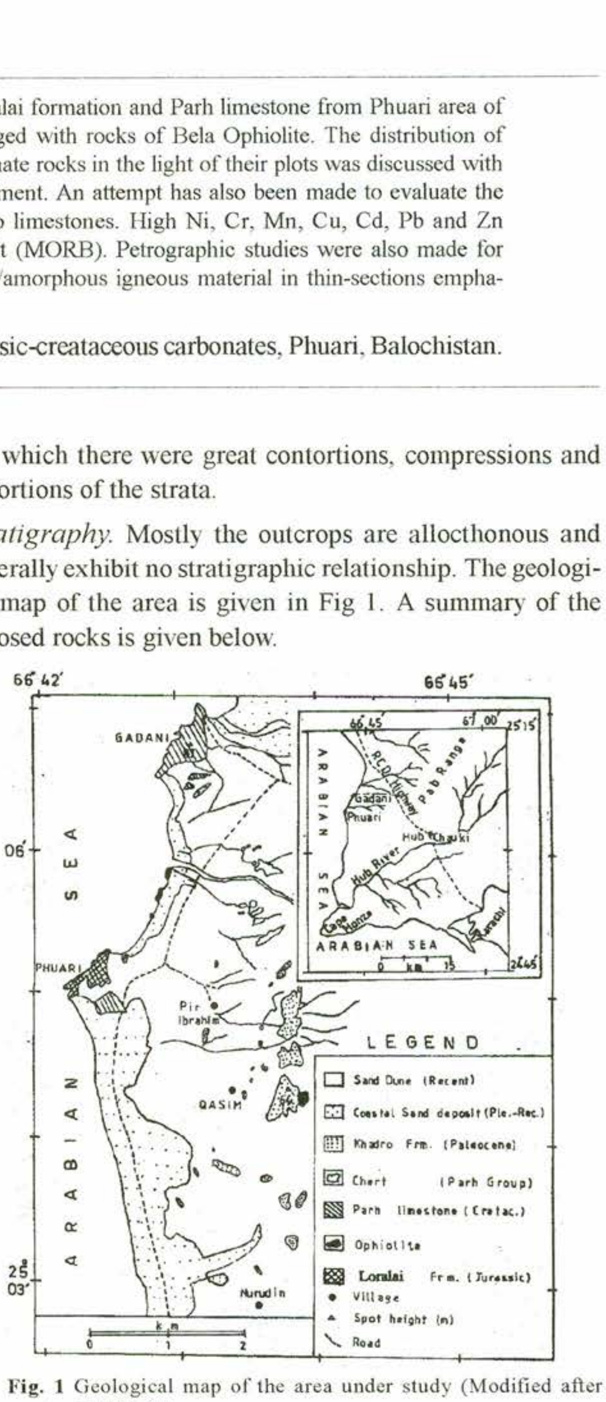

Fig. 1 Geological map of the area under study (Modified after Naseem *et al* 1996-97).

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a) Ferozabad Group (Early to Middle Jurassic: In the lower Indus Basin Ferozabad group comprises of Spingwar, Loralai formation and the Angira formations (Ahsan and Mallick 1996). The basal Spingwar formation includes a sequence of interbedded grey to black crystalline limestone about 600 to 1800m thick, which is oolitic and shelly at places and contains calcareous shale with sandstone interbeds in lower part. The type section is at Spingwar, 35 km west of Loralai town. The contact with the overlying formation is transitional. The Loralai formation overlies the Spingwar formation conformably and is dominantly thin to the medium bedded dark grey to black, hard, crystalline limestone. The type section is at Zamarai Tangi. The Anjira formation overlies the Loralai formation conformably. Anjira formation consists of dark grey thin, hard, porcelaneous to sublithographic limestone and interbedded softer argillaceous limestone and splintery mudstone. Its thickness ranges from about 100 to 400 m. The type section is located about 12 km. East of Anjira town.

b) Parh Limestone (Cenomanian to Santonian): Limestone, light grey, white, cream, olive green, hard, thin to medium bedded, lithographic to porcelaneous, argillaceous platy to slabby (occasional) and fossiliferous with subordinate calcareous shale and marl intercalations. In the study area, the beds of this formation retain the original characteristics and become maroon to red in color and loose all resemblance of sedimentary structures. Secondary manganese veins and dendrites are common. The loss of bedding, veins of calcite and manganese is possibly due to induration effects of Bela Ophiolite. At Gadani, the Parh limestone is riddled with calcite veins and is closely folded. Near Phuari, penecontemporaneous folds have been observed.

c) Khadro Formation (Danian): The Khadro formation comprises of sandstone and subordinate shale with minor limestone and basaltic flows (Deccan Trap). Sandstone is olive, yellowish, brown grey and green, soft, medium grained, ferruginous and calcareous. Shale is olive, bluish grey, chocolate and reddish brown, gypsiferous with minor interbeds of limestone. Thickness 67 m in type section. Khadro Nala, Laki Range Sindh is the type section.

2. Analytical methods. Insoluble Residue (IR), combined oxides (R_2O_3) and Loss on Ignition (LOI) were determined by gravimetry, and CaO and MgO were estimated by EDTA compleximetric titration.Trace element analyses of the selected samples were made by Atomic Absorption Spectrophotometer (Perkin Elmer model 31100) at Environmental Science Laboratory, Hamdard University, Madinatul-Hikmat, Band Murad Khan, Karachi.

Geochemistry. The degree of correspondence and mutual relationship between CaO versus different trace element and scatter grams among various trace elements are also presented in Fig. 2. Concentration of trace elements in the rocks of study area are compared (Table 1) with the average abundance of trace elements in carbonates (Krauskopf 1983), the rocks of Bela Ophiolite (Naseem *et al* 1996-97) and the rocks of Duddar area (Ahsan and Mallick 1996). These reference helped to unjderstand and evaluate the influence of Bela Ophiolite and degree of impregnation in carbonate rocks.

Calcium shows nearly similar pattern of distribution (Fig. 2) No sympathic and antipathic relations were observed which probably indicate that the trace elements were enriched at different degree in the carbonates rocks of the study area having nearly 50 % CaO. It is inferred that the enrichment process was active in later stage (epigenetic). Carbonates of Ni and Cr and not common in nature and their abundance is very low in carbonates (Table 1). The rocks of study area having high amount of these elements indicate some addition from external source. The possible source is tholeitic Bela Ophiolite that generally contains high amount of Ni and Cr (Sarwar 1992).

Iron and Mn exhibit different patterns (Fig. 2) a few samples show linear positive relation probably indicating incorporation of Fe into calcite forming ferruginous calcite. Thick sideritic veins at Ratti Hills in the south further support the hypothesis. Manganese is the most abundant trace element found in limestone (av. 1100 ppm). The samples of study area have high concentration and show vertical trend i.e. for 50% CaO, Mn have variable enrichment (1110-7225 ppm) possibly as foreign element and not as Mn-carbonate (rhodochrosite).

Table 1

Comparison of selected trace elements composition (ppm) a, in limestone (Krauskopf 1983); b, present study, Phuari Area; c, Loralai formation, Mor Range (Ahsan and Mallick 1996); d, Parh limestone of Pab Range (Naseem *et al* 2000) and; e, Bela Ophiolite, Phuari Area (Naseem *et al.*, personal communication).

Element	(a)	(b) av. of 14 samples	(c) av. of 13 samples	(d) av. of 30 samples	(e) av. of 9 samples
Mn	1100	3360	800	380	1160
Ni	20	290	-	12	85
Cr	11	30	-	9	115
Cu	4	40	7	15	80
Cd	0.1	10	-	-	-
Pb	9	150	6	35	-
Zn	20	1510	25	40	140

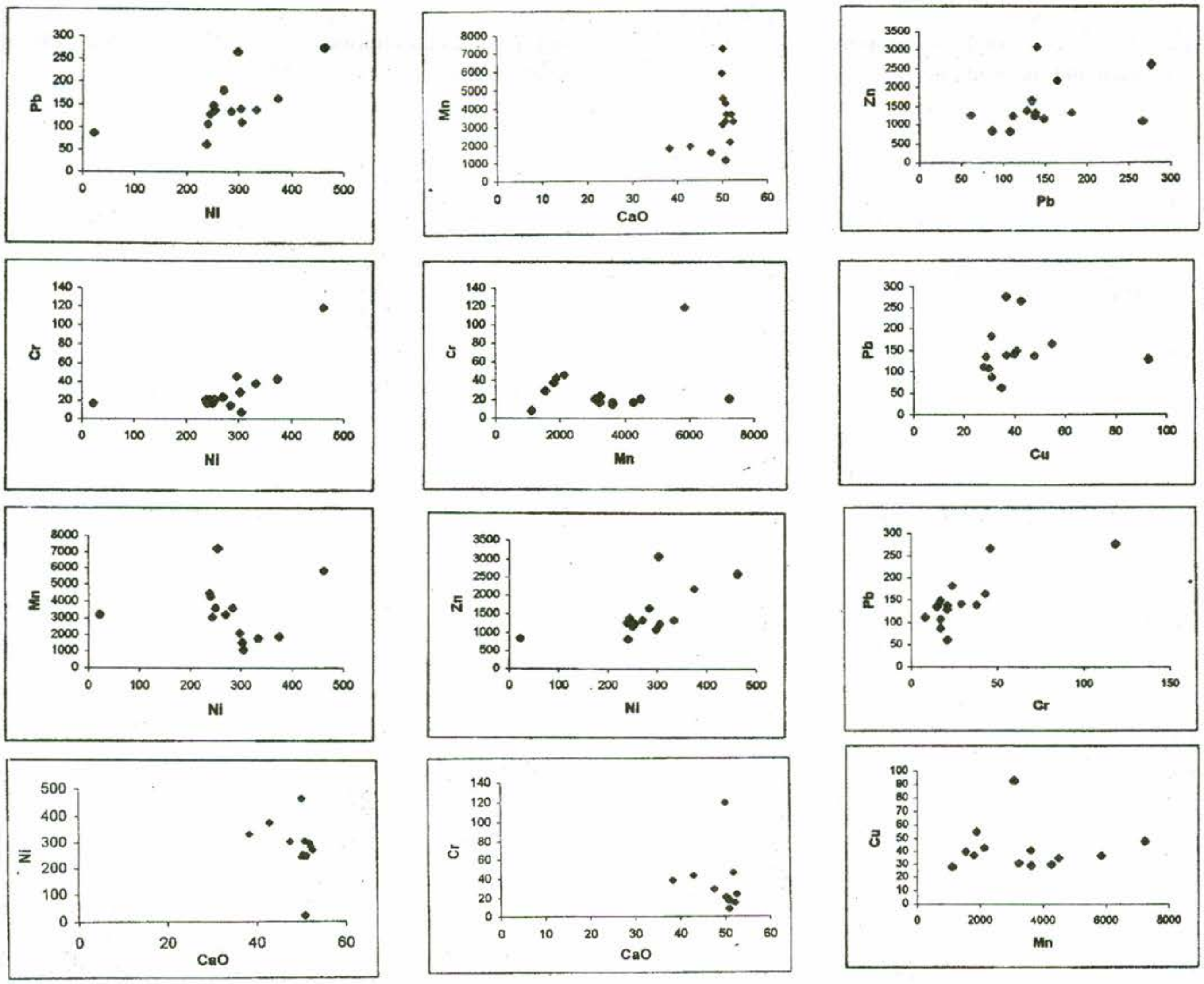

Fig. 2 Plots showing degree of correspondence between CaO with trace elements and degree of correspondence among different trace elements.

It is important to note that Mn ions is compatible with calcite and has high coefficient D but Mn was not properly incorporated in the calcite lattice of Loralai formation of Parh limestone, although Bela Ophiolite is rich in Mn and Lasbela Mn deposits of Pakistan are associated with it (Naseem *et al* 1997). About 1 km south from the study area Mn showing is present in the pillow basalt. The only possible explanation of above situation is the low mobility of Mn especially in the tetra ionic states. Thin section study also advocates the presence of Mn dendrites in the samples. The average abundance of Pb, Zn and Cu are much lower then the samples of study area (Table 1). These elements are possibly substantially enriched from ophiolitic rocks. The Loralai formation has good potential for Pb-Zn and barite mineralization in Mor Range (Ahsan and Mallick 1999). The anomalous high concentration of Pb, Zn and Cu is probably from the two different sources, from syngenetic mineralization and secondly from igneous bodies. In contrast to Pb and Cu, Zn has good mobility so that it is highly enriched even as compared to the Zn mineralized area (Duddar).

The graph plots among different trace elements (Fig. 2) do not reflect any systematic relationship. However some poor sympathic relation can be observed in a few samples. Probably this indicates differential enrichment at different phases of tectonic activity, geochemical characteristics of individual element, degree of mobility, physicochemical conditions such as pH and Eh and composition of magmatic bodies etc. This clearly indicates that primary concentrations of trace element were disturbed due to the influence of magmatic rocks in the area especially due to the Bela Ophiolite. The Bela Ophiolite was itself influenced and added trace elements to carbonate

Table 2
Summary of petrographic characters of the rocks of Phuari area.

Era	Period	Formation	Sample no.	Class (Folk 1959)	Characteristic features
Mesozoic	Cretaceous	Parhist	P3	Biomicrite	Formineral, Limestone, with thick vein of ferruginous material
			P2	Biomicrite	Rich in Globogerina, stylolitic sutures, some igneous material
			P1	Biomicrite	Several sets of calcite veins with some igneous material
	Jurassic	Loralai formation	L11	Micrite	Sparite veins and styolitic sutures
			L10	Pelmicrite	Filamental shell fragments with few sparite veins
			L9	Biomicrite	Abundant shell fragments
			L8	Biomicrite	Grain of calcispheres and less bioclasts
			L7	Biomicrite	Thick veins of sparite
			L6	Micrite	Veins of sparite with impregnated igneous material
			L5	Micrite	With ferruginous material
			L4	Biomicrite	Veins of sparite with impreganted
			L3	Micrite	Net of ferruginous material
			L2	Biomicrite	Rich in forams, ferruginous and contains sparite veins
			L1	Biomictite	Ferruginous, with altered igneous material as veins and patches, few oolites

rocks while the heat generated due to obduction of these ophiolitic rocks onto carbonates is responsible for redistribution of trace elements.

High concentration of Ni and Cr signature for pillow tholeiitic Mid Oceanic Ridge Basalt (MORB) is identical to Bela Ophiolite. The high enrichment (Ni 290 and Cr 30 ppm) in the carbonates was probably due to impregnation from Bela Ophiolite during obduction over these rocks.

4. Petrography. The petrographic investigations of the carbonate rocks were carried out to elaborate the mineralogical composition, texture, diagenetic changes and the effect of different tectonic forces. One of the objectives of this study was to recognize the stratigraphic names of the rocks exposed in the area. The rocks are also classified according to Folk (1959). The thin sections of the rocks are of great assistance to study the influence of different igneous bodies in the Loralai formation and Parh limestone. Photomicrographs (Fig. 3) of selected samples are also presented to illustrate this phenomenon.

The petrographic study reveals biomicritic to purely micritic (lithographic) classes of limestone (Folk 1959). The summary of the petrographic studies of the samples is presented in Table 2. Majority of the samples are rich in species of forminifera with few fragments of Brachiopods. The thin sections also exhibit several sets of cris cross joints filled by calcite spar indicating intense deformation due to complex teconics in the area. Another important feature is the presence of stylolitic structure, which is possibly developed due to high pressure during diagenesis (Fig 3). Quartz is 2 to 3%; relatively ferruginous material is high in many samples and appears as vein filling or patches. In sample L1 few ferruginous concretions are present whose internal structure is not preserved. All samples are low magnesium calcite (LMC). In many samples altered igneous material (Fig. 3) is disseminated in veins or present as patches (samples L1, L4, L6, P1 and P2). Identification of this material is questionable. According to Naseem *et al* (1996-97) identification is difficult which is due to intense alteration even in the igneous rocks associated with these carbonates. It appears logical to interpret that the igneous material entered in the limestones through fractures and joints at late stage when igneous activities were intense. The percolating waters (sea or connate) through fracture and joints deposited calcite spar and chalcedonic silica, altered igneous material and oxidized Iron present at different exposure conditions and phases of diagenesis.

Conclusions

1. The study area is highly complex and has different sized rock fragments juxtaposed with each other to form mixed igneous and sedimentary melange. The exposed sedimentary rocks include Loralai formation (Jurassic), Parh Limestone (Cretaceous) and Khadro formation (Paleocene), which are associated with Bela Ophiolite.
2. The poor relation of CaO versus different trace elements suggests that the distribution function was not controlled by the coefficient D instead it was due to late stage magmatic activity responsible for the dispersion of trace elements of carbonates.

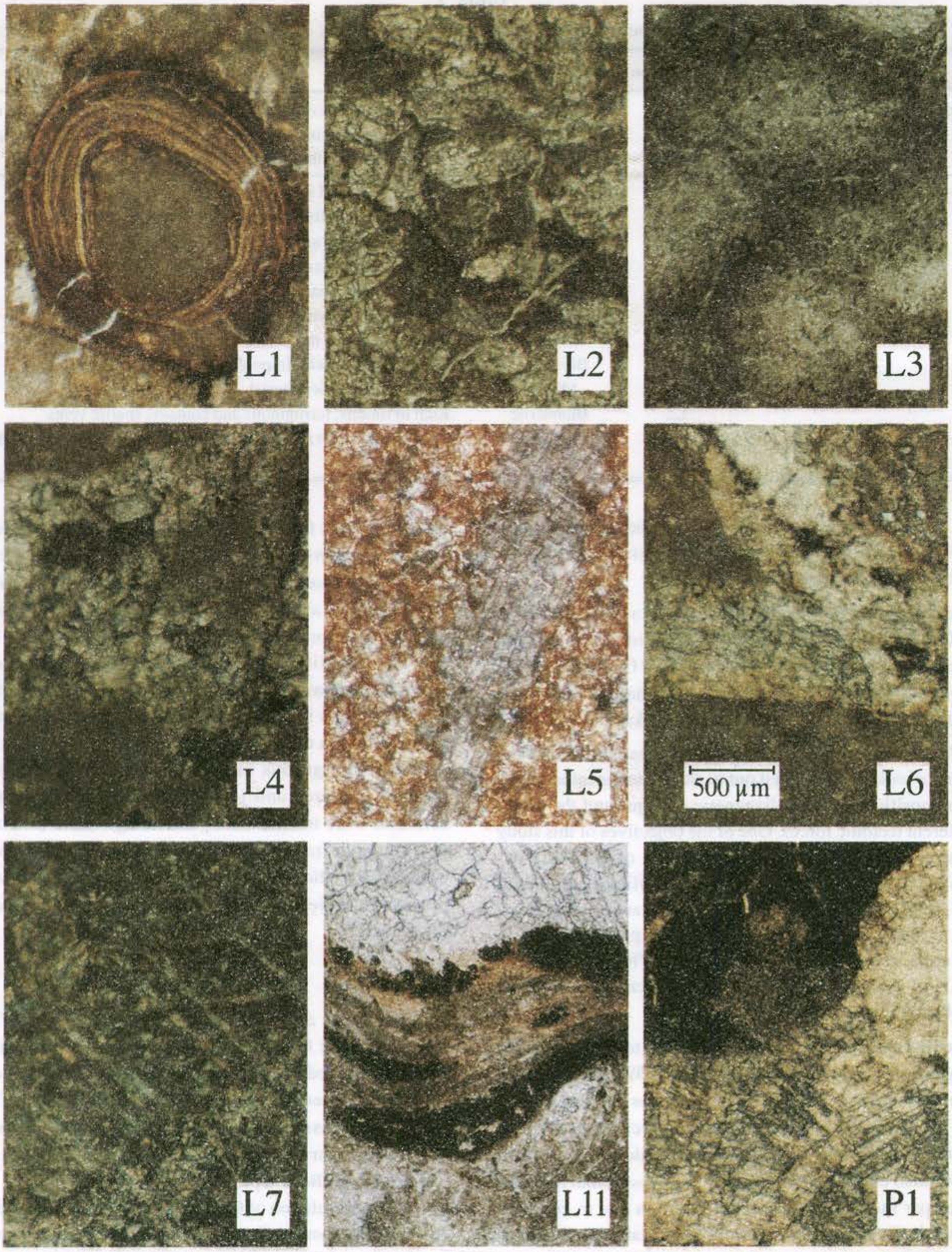

Fig. 3 Photomicrographs of Loralai formation and Parh limestone.

3. Generally the graph plots between different trace elements do not reflect any established standard relationship. It is therefore inferred that the obduction of Bela Ophiolite may surely has contributed trace elements but simultaneously redistributed primarily dispersed trace elements due to different mobilities of elements disturbing normal distribution.
4. The trace element content of these rocks is much higher than in the type areas and also from the mean abundance generally found in the limestone. The very high enrichment of Ni, and Cr showed similarities with tholeiitic pillow basalt. It is inferred that Ni and other trace elements are impregnated from Bela Ophiolite during obduction. No other sedimentary process is responsible for such a high enrichment because many of them (Ni, Cr, Pb, Mn) are immobile and have no relation with calcium carbonate precipitation except Mn and Pb.
5. The thin section studies show the biomicritic to pure micritic class of carbonate, Manganese dendrites, igneous impregnations, forams and fragments of brachiopod shells. This referred to the pelagic nature of the rock, which might have close association with mid-oceanic ridge activities.
6. Presence of several sets of microfractures filled with sparry calcite (sparite) and stylolitic sutures reveal more than one phases of intense tectonic activity in the area.

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