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BREAKUP OF GONDWANALAND AND EMPLACEMENT OF OPHIOLITIC COMPLEX IN MUSLIM BAGH AREA OF BALUCHISTAN

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ABSTRACT

Many Lower and Upper Triassic fossils were discovered in the "Alozai Group", "Loralai Limestone" and "Parh Group" in the Axial Zone of the Muslim Bagh area. Accordingly, they were distinguished from those in the Calcareous Zone. The Triassic sequence in the Axial Zone is characterized by pillow lava, hyaloclastites, olistostromes and hemipelagic sediments. Based on lithological characteristics, a narrow sedimentary basin, bounded on the south by the Indian continent and on the north by a mid–oceanic ridge, is reconstructed. These are regarded to suggest the breakup of Gondwanaland along the northern margin of the Indian continent. The volcanic rocks of the Bibai Formation are regarded as the products of the temporal island arc magmatism on the northern margin of the Indian continent in the latest Cretaceous.

The process of the obductional emplacement of the Axial Zone upon the Calcareous Zone is also studied. The direction of the emplacement is estimated to be from NNW to SSE. The time of the emplacement is confirmed to be Paleocene and Early Eocene. The emplacement distances of the major thrust sheets are also estimated. The thin metamorphic layer which is associated with the major thrust beneath the ultramafic bodies is described, and the metamorphism is considered to be due to the baking effect of the oceanic plate which obducted on the Triassic sequence.

INTRODUCTION

The Muslim Bagh area is divided into three geologic terrains from north to south: Flysh Zone (Eocene to Miocene), Axial Zone (Triassic), and Calcareous Zone (late Triassic ? to Neogene) (Fig. 1).

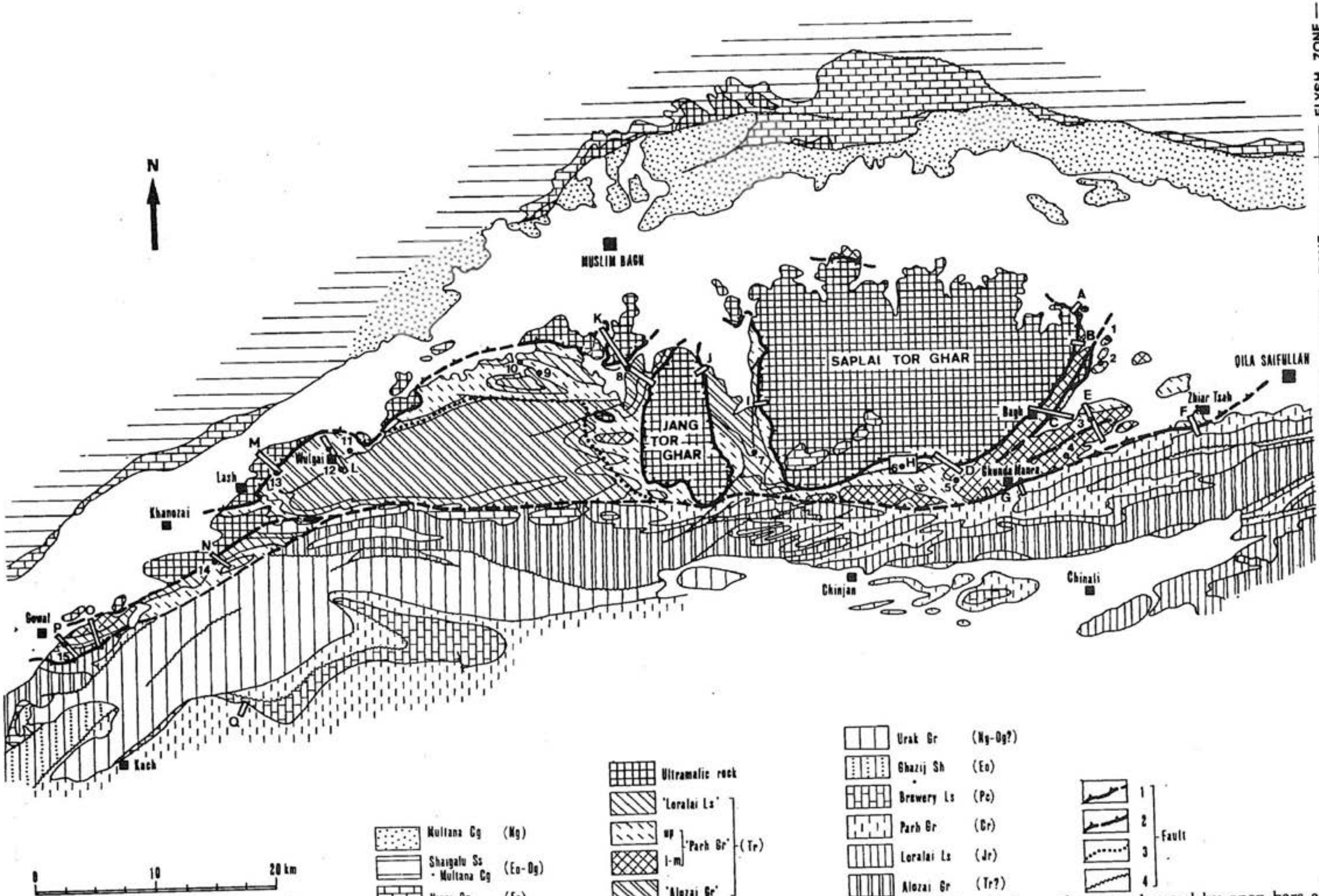

Fig 1. Geological map of Muslim Bagh area, modified from Hunting Survey Corporation Ltd. (1960). The localities of geologic sections are denoted by open bars and a rectangle associated with a capital letter of the alphabet. The fossil localities are shown by solid circles with a numeral. Legend of faults: 1 = thrust beneath the ultramafic rock bodies which are associated with a layer of metamorphic rocks, 2 = thrust between the Calcareous Zone and the Axial Zone, 3 = hypothetical thrust between the "false Alozai Group" and the "false Parh Group", 4 = other faults.

The Axial Zone is characterized by large ultramafic rock bodies, pillow lava–hyaloclastite complex and deep sea sediments. The Calcareous Zone is mainly composed of limestone and marl. They are associated with minor amount of basaltic and andesitic volcanic rocks of latest Cretaceous. The oldest sedimentary rock in the Flysh Zone is Eocene limestone which unconformably overlies the ultramafic rocks of the Axial Zone. Major part of the Flysh Zone is composed of the flysh type alternating beds of sandstone and siltstone. The three zones are divided by the E–W trending and northward dipping major thrusts and collectively form a thrust pile.

Detailed field observation of the Triassic lithofacies suggests that the Axial Zone marks initial stage of the breakup of Gondwanaland. This paper concerns the late Cretaceous island arc volcanism on the Calcareous Zone, and the emplacement of the ultramafic bodies and Triassic formations in the Axial Zone.

RE–DEFINITION OF "ALOZAI GROUP", "LORALAI LIMESTONE" AND "PARH GROUP"

According to the geologic map by Hunting Survey Corporation Ltd. (HSC) (1960), the Triassic (?) to Jurassic Alozai Group, Jurassic Loralai Limestone and the Cretaceous Parh Group are distributed not only in the Calcareous Zone but also in the Axial Zone. However, the differences between these Mesozoic formations in the two zones became clear not only in their lithofacies but also in their geologic ages through our field observation. Accordingly, we tentatively call the Mesozoic formations in the Axial Zone "false Alozai Group", "false Loralai limestone" and the "false Parh Group" differently from those in the Calcareous Zone. Our field survey is not so sufficient to draw regionally a new geologic map. However, the distributions of the "false Alozai Group," "false Loralai Limestone", the lower and middle parts of the "false Parh Group" and the upper part of the "false Parh Group" correspond roughly with those of the "Alozai Group," "Loralai Limestone", "Hindubagh Intrusions + Parh Group" which is denoted by the inclined cross hatch in Fig. 1, and the "Parh Group" identified in the Axial Zone by HSC (1960). The small distributions of "Alozai Group" at the eastern and the northwestern margins of the Jang Tor Ghar ultramafic rock body should be included in the "false Parh Group."

The false Alozai Group, false Loralai Limestone and false Parh Group in the Axial Zone are Upper and Lower Triassic. On the other hand, the major part of the Parh Group and the Loralai Limestone in the Calcareous Zone are Cretaceous and Jurassic in age, respectively, and no Triassic fossil has been found in the Alozai Group in the Calcareous Zone of this area. From the upper part of the Alozai Group at the Mara Kili section to the northeast of Loralai, we discovered a lowest Jurassic ammonite. It is the oldest fossil which has been found in the Alozai Group in this area.

We newly discovered *Halobia* fossils at seven localities (locality 1, 3, 4, 5, 8, 9, 10 in Fig. 1) and a lower Triassic ammonite fossil at one locality (locality 6) of the false Parh Group. A *Halobia* fossil was discovered also at the locality 14 which was included in the Loralai Limestone by HSC. However, the lithofacies at this locality is olistostromic, hence it should be included in the false Parh Group. The fossils of *Halobia* were discovered also in the false Alozai Group (locality 11, 12, 13, 15). From the false Alozai Group along the Gowal and Wulgai sections, the lower Triassic ammonite fossils and *Halobia* and *Daonella* fauna were collected by two of us. (A.N.F. & Y.O) and their colleagues. The details will be reported in near future. A fossil of *Halobia* was found also from the false Loralai Limestone (locality 7).

The lithofacies of the false Alozai Group, false Loralai Limestone and false Parh Group are quite different from the Alozai Group, Loralai Limestone and Parh Group in the Calcareous Zone. The latter are mainly composed of the regularly folded limestone, marl and alternating beds of them, and volcanic rocks are limited in the Bibai Formation of latest Cretaceous. On the other hand, the former are characterized by pillow basalt, basaltic hyaloclastites, olistostromes, chert and deep sea sediments.

The lower part of the false Parh Group is mainly composed of pillow basalt and basaltic hyaloclastites. The middle part is olistostromes with exotic blocks of gabbro, basalt, chert and limestone. The upper part is pale greenish-brown or black coloured papery shale which is intercalated with thin beds of micritic limestone. The false Alozai Group is mainly composed of pale green tuffaceous and siliceous shale with thin interbeds of micritic limestone. Olistostromes are developed also in the lower part of the false Alozai Group but limestone olistoliths are more dominant than in the middle part of the false Parh Group. However, the lithofacies of the upper part of the false Alozai Group resemble that of the upper part of the false Parh Group. The false Loralai Limestone dominantly comprises of limestone and alternating beds of micritic limestone and shale. It is thought to be the youngest among the Triassic formations of the Axial Belt, but its exact stratigraphic position is uncertain.

Based on fossils, the middle part of the false Parh Group ranges in age from Lower to Upper Triassic, whereas the upper part is Upper Triassic. The false Alozai Group ranges in age from Lower and Upper Triassic and a part of the false Loralai limestone is also Upper Triassic. Accordingly, the Mesozoic sequence in the Axial zone is quite different from that of the Calcareous zone both in age and lithofacies.

The Triassic formations of the Axial Zone have been described as "melange" by Gansser (1979), Ahmad and Abbas (1979) and other authors. We regard "olistostrome" a more suitable term than "melange", because, "melange", especially "tectonic melange", means implicitly the rock complex at the subduction zone of plate, whereas the Triassic formations of the Axial zone lack the structural characteristics of a melange. Moreover, they are not the rock complex at subduction zone but at the rift zone, as described in the following section .

DESCRIPTION ALONG SEVERAL GEOLOGIC PROFILES

North of Karimdad (Section A: Fig. 2)

Highly serpentinized ultramafic rocks overlie pillow lavas in thrust contact. The thrust plane dips southwestward. The pillow lava (basalt) is followed by basaltic hyaloclastite, basaltic coarse tuff, thin bedded fine tuff intercalated with thin beds of shale and limestone in ascending order. The beds strike N80°-90°E and dip 45°-90°N, and are in fault contact with gabbro. The serpentinite occurs as a slice in the fault zone. The rocks of footwall are metamorphosed into chlorite-epidote schists. They belong to the lower part of the false Parh Group.

Slightly metamorphosed rocks are found also at the cliff of Karimdad (Section B). They consist of alternating beds of basaltic tuff, thin bedded limestone/shale, shale and tuffaceous chert with radiolarian fossils. At the foot of the cliff, gabbro is exposed as tectonic blocks surrounded by serpentinite films.

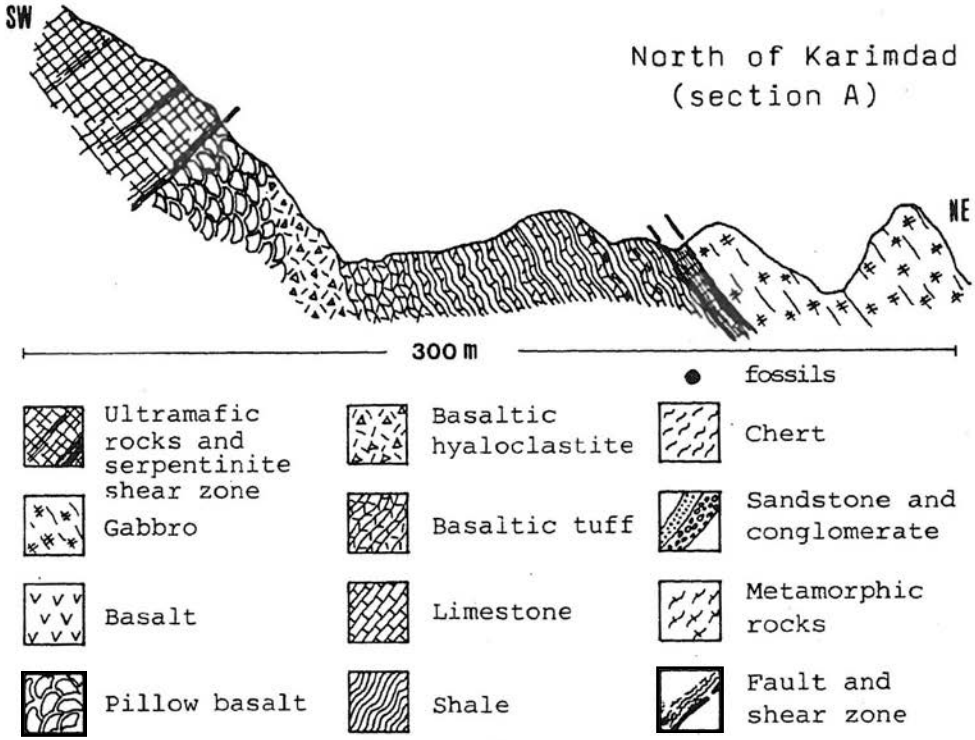

Fig. 2. Schematic geological profile along the north of Karimdad section (Section A).

Bagh (Section C: Fig. 3)

Metamorphic rocks are found also along the Bagh section. They are overthrusted by the Saplai Tor Ghar ultramafic rock body. Several slices of serpentinite and gabbro are present along the contact between ultramafic and metamorphic rocks, and within the metamorphic rocks. The metamorphic rocks are composed of basaltic tuff, alternating thin beds of tuff and limestone, and minor amount of pillow basalt, red chert and limestone. Both the serpentinite slices and schistosity of the metamorphic rocks dip northwest.

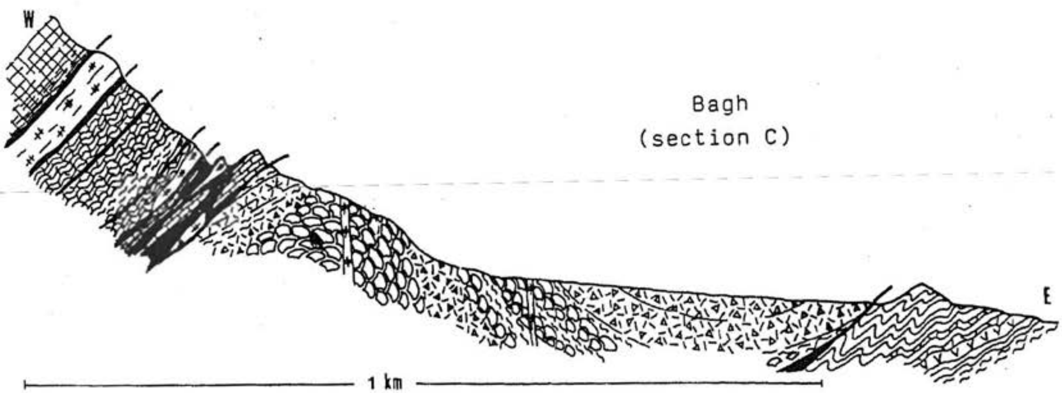

Fig. 3. Schematic geological profile along the Bagh Section (Section C). Legend as in Fig. 2.

The metamorphic rocks are thrust upon the un-metamorphosed pillow basalt with an intercalation of serpentinite slice between them. Pillows, several tens of centimeter to one meter in diameter, are closely packed and intruded by dikes of micro-gabbro. The pillow basalt dips southwest and is overlain by hyaloclastites with basalt breccia and fragments of pillow. Red tuffaceous chert is intercalated in the hyaloclastites. These basalt and hyaloclastites belong to the lower part of the false Parh Group.

The hyaloclastites are in fault contact with papery shale interbedded with thin limestone beds. The fault plane strikes N3°E and dips 60°E. The shear zone is very thin, but a thick slice of ultramafic rock is associated within the northeastern extension of this fault zone. The olistostromes of the middle part of the false Parh Group are devoid of this fault, and the shale of the upper part contacts directly with the hyaloclastites of the lower part. The papery shale of upper part of the false Parh Group is underlain by shale intercalated with thin basalt layers and red chert. This may be a transitional horizon from the olistostromes of the middle part of the false Parh Group to the upper part.

The upper part of the false Parh Group is typically exposed at the low hills on the southwestern side of the main road from Muslim Bagh to Qila Saifullah. It is characterized by dark grey or pale greenish-brown papery shale which is interbedded with thin beds of limestone turbidite. They are irregularly folded with a wave length of a few hundred meter. Fossils of *Halobia* (locality 1) and ammonite (locality 2) were collected from this shale.

Southeast of Bagh (Section E: Fig. 4)

From the structural relationship, the stratigraphic horizon of the northwestern end of this section is assumed to be just below that of the eastern end of the Bagh section. There are two wide exposures of the complex of microgabbro and basalt. They are quite heterogeneous and the boundary between gabbro and basalt is essentially gradual. Structurally and stratigraphically, this complex occupies the lowest position in this section. Judging from the normal ophiolitic sequence, it may be correlated with the horizon just below the pillow basalt of the false Parh Group.

Both the northern and southern sides of the two exposures of the complex are covered by basaltic flows and hyaloclastites. These are thicker in the southern part than the northern part of this section. They are overlain by alternating thin beds of shale and micritic limestone, chert, hyaloclastite, basalt and bedded purple limestone. Major part of them appears to be olistostromic. Accordingly, they are regarded as a middle part of the false Parh Group.

There are two sheets of microgabbro at the southern part of this secton. A nearly horizontal slice of serpentinite is observed within the complex of basalt and gabbro. *Halobia* fossils were collected from the alternation of shale and limestone.

Zhiar Tsah (Section F: Fig. 5)

The true boundary between Parh Group and the false Parh Group is found at this section. Along the southern part of this section, a typical sequence of the Sembar and Goru Formations and the Parh Limestone is observed. They dip steeply northward. The contact of the Parh Limestone with purple tuff of the false Parh Group is a shear zone several tens of meters in width. The fault plane strikes N65°E and dips 70°N.

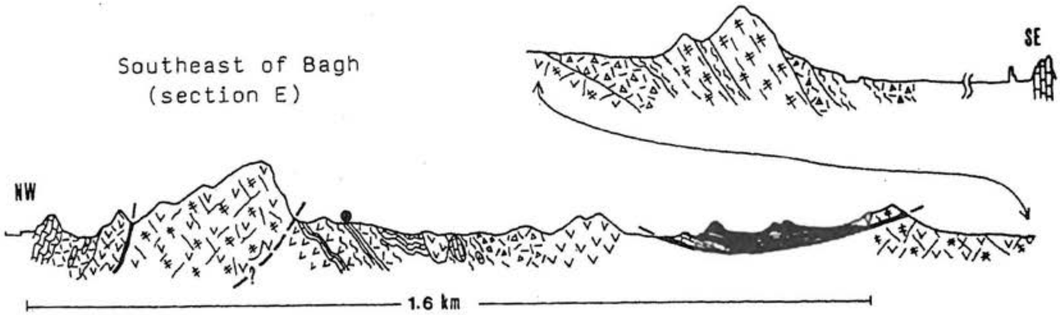

Fig. 4. Schematic geological profile along the southeast of Bagh section (Section E). Legend as in Fig. 2.

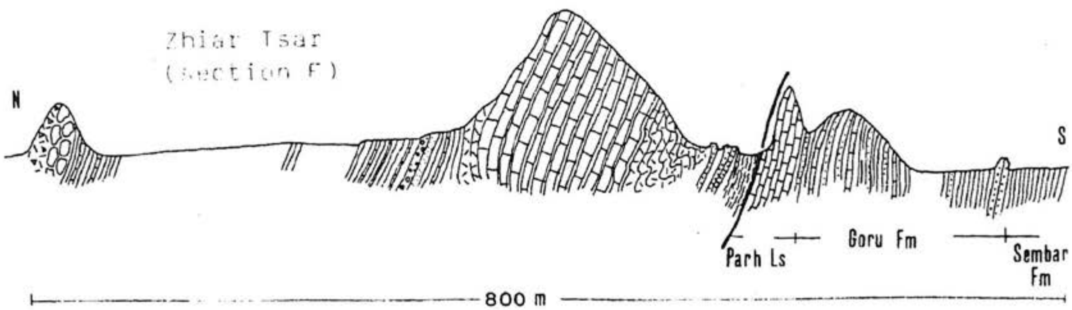

Fig. 5. Schematic geological profile along the Zhiar Tsar section (Section F). Legend as in Fig. 2.

The purple tuff is intercalated with two thin beds of green and very hard quartzose sandstone. They are highly folded. On the north side of them, thick alternating beds of siliceous limestone a few tens to several tens of centimeter in thickness and thin beds of marl are exposed. On the northern side of the bedded limestone, another purple siliceous tuff and shale with thin beds of micritic limestone are exposed. The thick bedded limestone resembles the Loralai Limestone. However, the latter is never associated with purple tuff. In addition, the shale on the north side of the bedded limestone is quite similar to the upper part of the false Parh Group. Accordingly, the sequence on the north side of the fault is regarded to be the upper part of the false Parh Group and false Loralai Limestone. The pillow basalt at the northern end of this section suggests that the north side is upward. However, the structural relationship between the pillow basalt and the sequence on the south side is uncertain.

Ghunda Manra (Section G: Fig. 6)

Olistostromes are widely distributed around Ghunda Manra. Most of the olistoliths are of basalt and red tuffaceous chert, but minor amount of limestone and sandstone olistoliths are also present. The matrix is black or pale green papery shale with intercalation of micritic limestone. Fossils of *Halobia* and solitary coral were collected from the matrix (locality 4). It is certain that these olistostromes belong to the middle part of the false Parh Group.

There is an E-W trending limestone ridge at Ghunda Manra. Paleocene larger foraminiferas were discovered in this limestone. Accordingly, this is correlated with the Brewery Limestone in the Axial Zone. The limestone dips 60° to 70°N. Accordingly, a high angle reverse fault is assumed between the Triassic olistostromes and the Paleocene limestone.

Along the southern half of the section, the Loralai Limestone, Sembar Formation, Goru Formation and Parh Limestone are typically exposed. The Parh Limestone is directly overlain by pillow basalt. It is followed by andesitic hyaloclastites and volcanic sandstone in ascending order. Large phenocrysts of hornblende are contained in the andesitic breccia in the hyaloclastites. The stratigraphic horizon between the volcaniclastics and the Paleocene limestone is marked by black or dark green marly shale which contains well rounded solitary pebbles of volcanics. A similar sequence is found also to the east of Kach (Section Q). However, the volcanic Group changes there into volcanic conglomerates which contain not only basaltic and andesitic cobbles but also dacitic and granitic cobbles. These volcanics and shale just above it belong to the Bibai Formation of Kazmi (1979).

Northwest of Ghunda Manra (Section D: Fig. 7)

This section is located at the southeastern corner of the Saplai Tor Ghar Ultramafic rock body. The ultramafic rocks are thrust upon pillow basalt. Serpentinite shear zone at the western end of this section is associated with low grade metamorphosed basaltic and calcareous tuffs. This thrust extends nearly horizontally eastward to the mountainside of the 2699 m peak. A thin slice of serpentinite is observed there, and basaltic rocks and gabbro which are metamorphosed into amphibolite facies rest upon it. The metamorphic minerals appear to increase in size upward. A thin layer of chlorite schist of basaltic tuff is associated just below the serpentinite slice.

Below the low angle thrust mentioned above, pillow basalt is widely distributed. It is composed of closely packed pillows about one meter in diameter. In the northwestern part of the section, pillow lava dips moderately southeast. It is overlain by basaltic hyaloclastite which is intercalated with thin and purple limestone with cobble size breccias of basalt. Pillow basalt is widely distributed also around the base of the 2699 m peak. It appears to form a broad anticline east of the peak. Pillow basalt is intercalated by red chert, and intruded by micro-gabbro and dolerite dikes. These pillow basalt and hyaloclastites belong to the lower part of the false Parh Group.

To the south of this section, papery shale and black shale are exposed. They are intercalated with thin beds of micritic limestone, and have fossils of *Halobia* (locality 5). These shales contain olistoliths of basalt, and may belong to the middle part of the false Parh Group. However, their contact relation with the pillow basalt is uncertain.

Southern Margin of Saplai Tor Ghar Ultramafic Rock Body (Section H: Fig. 8)

Highly serpentinized ultramafic rocks overlie the Triassic olistostromes of the middle part of the false Parh Group. They are in fault contact, and the fault plane dips northwest in a high angle. The matrix of the olistostromes is pale green and purple colored papery shale with intercalated thin beds of micritic and siliceous limestone. The bedding planes of these lime-

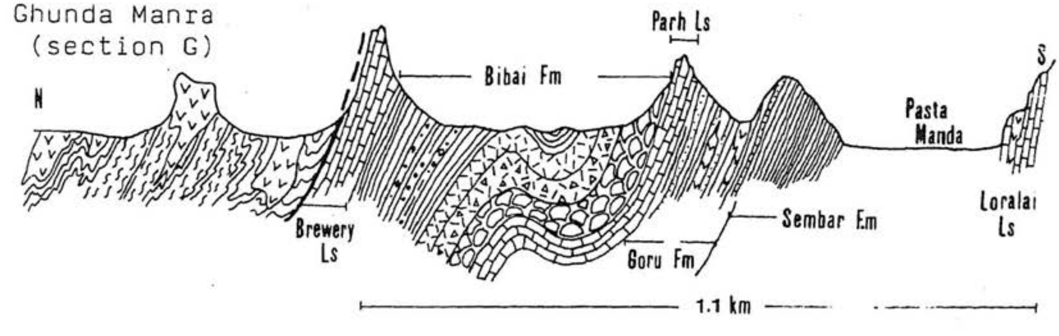

Fig. 6. Schematic geological profile along the Ghunda Manra section (Section G). Legend as in Fig. 2.

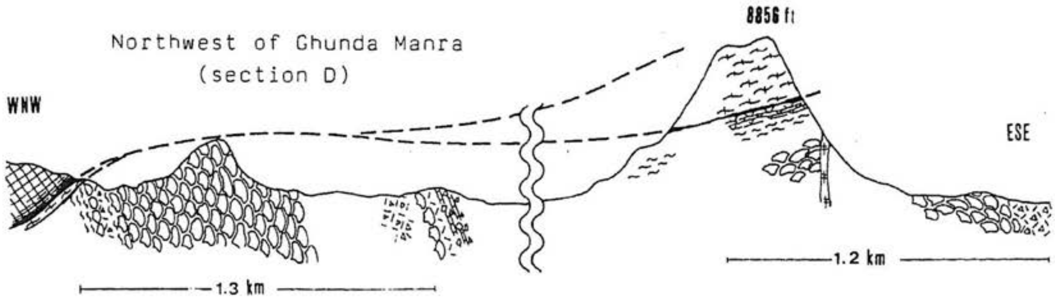

Fig. 7. Schematic geological profile along the northwest of Ghunda Manra section (Section D). Legend as in Fig. 2.

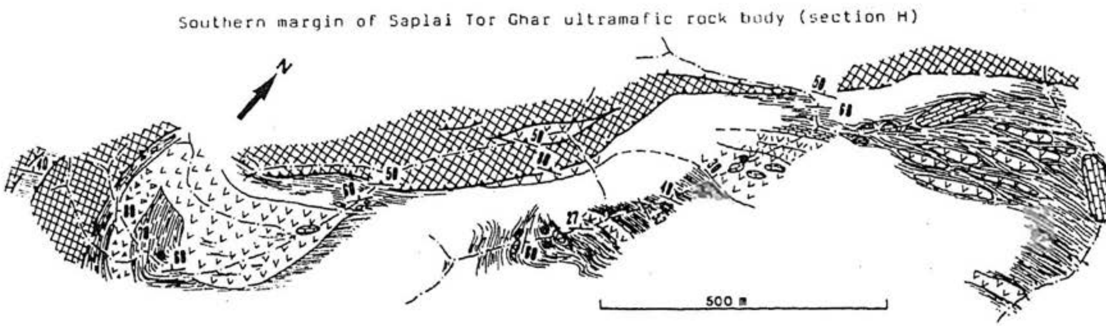

Fig. 8. Geological sketch map of the southern margin of the Saplai Tor Ghar ultramafic rock body (Section H). Legend as in Fig. 2.

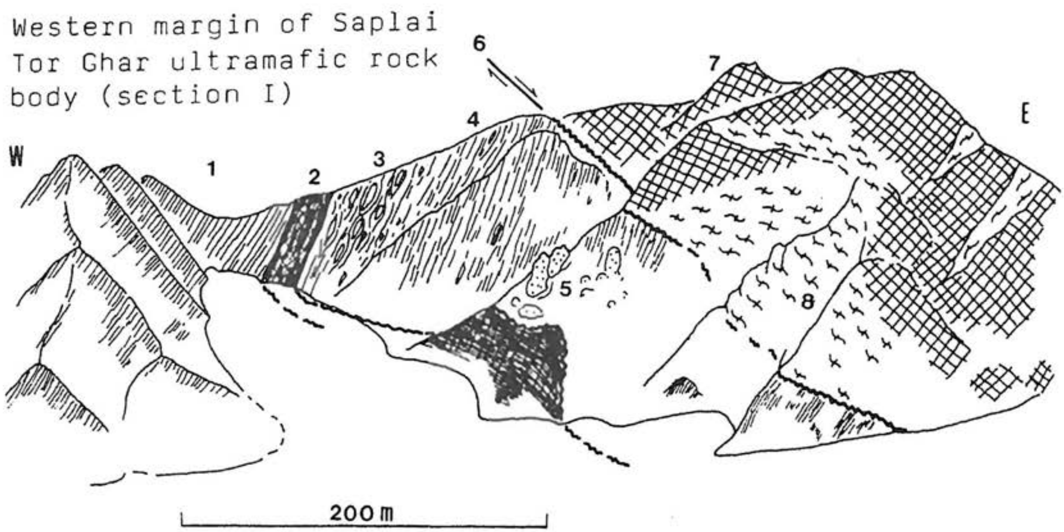

Fig. 9. Geological sketch of the western margin of the Saplai Tor Ghar ultramafic rock body (Section I). Legend as in Fig. 2.

stone are complexly disturbed. Lower Triassic ammonite fossils were collected from the shale. Siliceous shale and siliceous limestone contain radiolarian fossils.

Most of the olistoliths are pillow basalt and limestone. The largest olistolith is a slab-like pillow lava several hundred meters across. Some of the olistoliths have interesting successions from pillow basalt to reefoid limestone through limestone with basalt breccias, or from pillow basalt to alternating beds of siliceous limestone and micritic limestone through alternating beds of basaltic tuff and siliceous limestone. Some coral fossils were collected from the reefoid limestone which caps the olistolith of pillow basalt.

The area between Jang Tor Ghar and Saplai Tor Ghar Ultramafic Rock Bodies (Section I: Fig. 9)

Thin bedded pale green and purple colored shales intercalated with thin beds of micritic limestone are dominant in this area (Gansser, 1979). Bedded and micritic limestone become dominant at some places. Shale and limestone beds are complexly folded. These formations were denoted as "Alozai Group", "Loralai Limestone" and "Parth Group" by HSC (1960). However, according to our field observation, they are regarded as the upper part of the false Parh Group and the false Loralai Limestone. A *Halobia* fossil was collected from the limestone-dominant sequence of the false Loralai Limestone at locality 7. This fact supports our interpretation.

Geologic sketch of the western margin of the Saplai Tor Ghar body is shown in Fig. 9. The light brown and purple colored thin bedded shale on the west is in fault contact with chlorite schists on the east. The fault is associated with a highly sheared serpentinite slice dipping 70°W. The chlorite schists are derived from tuffaceous shale, red tuff, chert, and olistoliths of chert and sandstone. The chlorite schists are in fault contact with serpentinite of the Saplai Tor Ghar body on the east. The fault plane strikes N10°W and is vertical. The drag folds and striate suggest a right-lateral motion along the fault. The serpentinite includes blocks of chlorite schist and garnet-amphibolite schist with no reaction rim.

Gansser (1979) showed contorted flyshoid shales with blocks of diabase and marble overlain in fault contact by ultramafic mass at the northeastern side of Jang Tor Ghar body. Just south of this locality (Section J), we found thick basaltic hyaloclastites with pillow basalt and red chert overlain in thrust contact by the ultramafic mass. The lithological characteristics mentioned above suggest that they should be included in the lower and middle parts of the false Parh Group.

Northwestern side of Jang Tor Ghar Ultramafic Rock Body (Section K: Fig. 10)

A southeastward dipping fault plane is found along the base of the ultramafic body at the northeastern side of the Jang Tor Ghar rock body. A thrust is found also at the base of the small body of ultramafic rocks to the northwest. The fault plane dips gently northwest. Accordingly, these thrust planes are regarded to be folded and forming an antiformal structure.

The Jang Tor Ghar body is underlain by metamorphic rocks showing an upward increase in metamorphic grade from chlorite schist to garnet-amphibolite schist. Their original rock types are basalt, basaltic tuff and gabbro. The metamorphic rocks are not found under the small ultramafic rock body. However, amphibolite schist appears again in the low and small hill further northwest.

Various rocks are exposed between the two bodies of ultramafic rocks, that is, under the thrust plane and the layer of metamorphic rocks. Along the northwestern part of this section occurs a sequence of pillow basalt, hyaloclastites, tuffaceous papery shale with olistoliths of basalt, and siliceous shale in ascending order. They dip 20°-40° NW. A *Halobia* fossil was collected from black shale just below the pillow basalt.

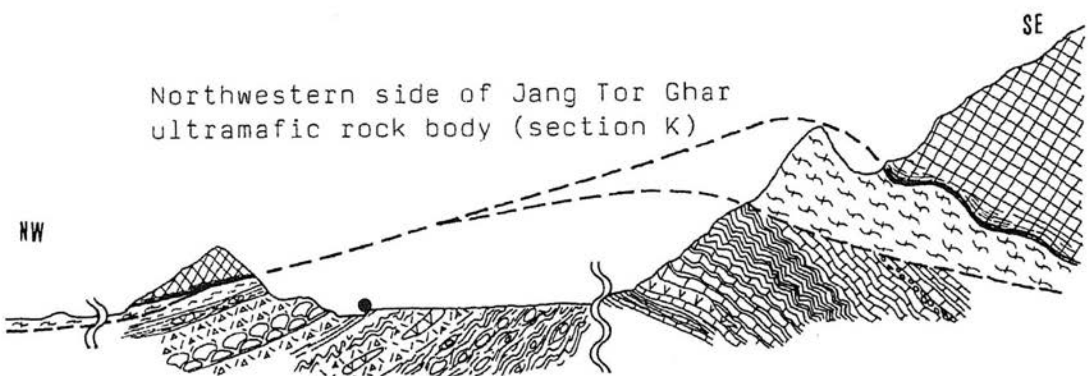

Fig. 10. Schematic geologicl profile along the section across the northwestern side of the Jang Tor Ghar ultramafic rock body (Section K). Legend as in Fig. 2.

The middle part of this section is dominant in olistostromes with matrix of papery shale. Basaltic hyaloclastites are partly dominant in these olistostromes. Judging from the lithofacies, the formations of northwestern and middle parts of this section are included in the lower and middle parts of the false Parh Group.

The southeastern part of this section is dominated by limestone. The lowest part is siliceous shale intercalated with micritic limestone and basaltic sheets. The intercalation of limestone beds increase upward, and changes into alternation of shale and limestone. The middle part is characterized by alternation of thin beds of limestone and shale (thickness of one unit is several centimeter). Minor kink and chevron folds are well developed in it. At one place, this alternation is in fault contact with chlorite schist, and at another it is followed by irregularly folded alternation of micritic limestone and shale (thickness of one unit is several tens of centimetres), a conglomerate bed of debris flow and alternating beds of dominant black shale and subordinate limestone in ascending order. This calcareous sequence is included in the false Loralai Limestone, and dips southeastwards. Accordingly, this and the NW-dipping sequence to the northwest appear to form a broad anticlinal structure, but details are uncertain.

In the area to the east of this section, HSC (1960) denoted the distributions of the Parh Group and Loralai Limestone. Pale green shale interbedded with thin limestone beds and olistostromes are exposed there. *Halobia* fossils were collected from the shale (locality 9 and 10). Accordingly, these are neither the Parh Group nor Loralai Limestone, but the middle and lower parts of the false Parh Group. There is a possibility that these beds belong to the false Alozai Group. Detailed field investigation is needed to confirm this interpretation.

Wulgai (Section L)

The locality of the Wulgai formation of Williams (1959) is briefly described here. HSC (1960) included it in the Alozai Group. Vredenburg (1904) reported Permian fusulinids from limestone at the upper stream of this section. However, present studies show that the limestones are olistoliths, with an Upper Triassic ammonite in the matrix. Williams (1959) reported Lower Triassic ammonite, Upper Triassic ammonite and *Halobia* from this section. Our investigations confirm these observations.

The stratigraphic sequence along the down stream side (from the entrance to Wulgai village) is largely divided into two. The upper half of the entrance side characterized by thin bedded shale is interbedded with thin beds of limestone turbidite. A bed of debris flow-type conglomerate with basalt and limestone cobbles is interbedded in the upper part. The lower half of the village side is mainly composed of olistostromes. Olistoliths are of basalt, hyaloclastites, chert laminite, limestone and quartzose sandstone, whereas the matrix is contorted siliceous shale and black shale. At the river on the east *Halobia* fossils were collected from shale intercalated with thin limestone beds (locality 11).

A NE-treding major fault is assumed at the upstream side of the Wulgai village from the characteristic topography. The formations become older toward upper stream. Just usptream side of the fault, a Hexacoral fossil was discovered from shale interbedded with thin limestone beds. The Triassic sequence of further upstream side is mainly composed of olistostromes. The olistoliths of basalt and gabbro are dominant on the downstream side, and limestone olistoliths

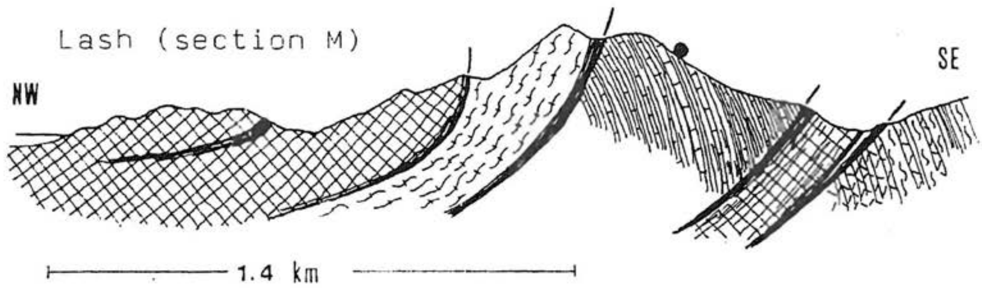

Fig. 11. Schematic geological profile along the Lash section (Section M). Legend as in Fig. 2.

increase upstream. Some of these limestone olistoliths contain coral and Permian fusulinids. However, an Upper Triassic ammonite was collected from the matrix consisting of tuffaceous papery shale interbedded with thin beds of limsone and coarse sandstone of smoky quartz grains. The shale become pale-green and slaty cleavage becomes marked towards upstream.

All of the formations along the Wulgai section are regarded as false Alozai Group.

Lash (Section M: Fig. 11)

Serpentinized ultramafic rocks on the northwestern side are in fault contact with metamorphic rocks on the southeastern side. The fault plane is nearly vertical. The metamorphic grade increases rapidly toward the ultramafic rock body from chlorite schist to garnet-amphibolite schist. The metamorphic rocks are also in fault contact with the Upper Triassic formation on the southwest. The fault plane dips northwest steeply and the shear zone contains a serpentinite slice.

The Triassic sequence is divided into two zones by a major fault which is associated with serpentinite. The northwestern zone is composed of alternating thin beds of light brown papery shale and micritic limestone. Coral and *Halobia* fossils were collected from this zone (locality 13). The southeastern zone is composed of thinly bedded pale-green and purple colored siliceous tuff and thin beds of siliceous micritic limestone. The strata of both zones dip steeply to the southeast and belong to the false Alozai Group.

Khanozai (Section N: Fig. 12)

Ultramafic rocks occupy the western part of the section. The lower part consists of dunite with compositional banding of cumulate origin. The dunite is in fault contact with olistostromes. The fault plane is nearly vertical. The olistoliths are of basalt, limestone and sandstone. The matrix is formed by alternating beds of tuffaceous shale and limestone turbidite, containing *Halobia* fossils (locality 14).

On the southeast of olistostromes, thin bedded pale-green and purple colored marly shale is exposed. It is overlain by cliff forming bedded limestone. These shale and limestone resemble the Sembar Formation and the Loralai Limestone, respectively. However, huge blocks

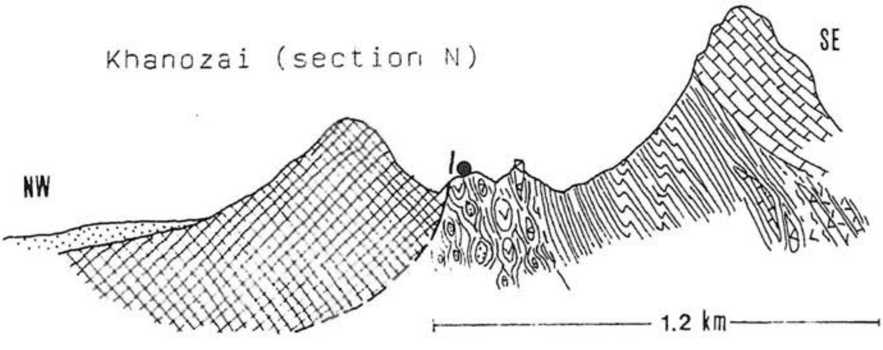

Fig. 12. Schematic geological profile along the Khanozai section (Section N). Legend as in Fig. 2.

of limestone and basalt are contained in the shale just below the bedded limestone. In addition, the cliff forming bedded limestone pinches out southwestward, and it too may be a huge olistolith. Accordingly, these may be included in the false Parh Group.

Gowal (Section 0 and P)

There is a small outcrop of basaltic hyaloclastite at the entrance of the river. It appears to be thrust upon the bedded limestone on the south. This limestone is overlain by irregularly folded sequence of dark limestone, marl and shale. This sequence is bound on the southern side by a fault with a tectonic slice of ultramafic rocks. The bedded limestone and the sequence of limestone, marl and shale are intruded by basalt and andesite sheets. This andesite contains large phenocrysts of hornblende, and the lithofacies is quite similar to that of the latest Cretaceous Bibai Formation. As it will be mentioned in the later section, the formations in the Axial Belt were emplaced from north during the Paleocene and Early Eocene. Accordingly, it is probable that these sequences are autochtonous and exposed as a window.

Southward dipping Triassic strata are exposed upstream. The lower half is composed of grey, green and purple coloured shale with grey micritic limestone interbeds which contain Scythian ammonite fossils. The upper half is thin bedded calcareous shale, argillaceous limestone, fine grained calcareous sandstone with *Daonella and Halobia.* A limestone conglomeratic bed of debris flow type is present at the boundary between the upper and lower parts of the Triassic strata. These Triassic strata are included in the false Alozai Group.

South of Triassic sequence the southward dipping Sembar and Goru Formations are exposed, and the latter is followed again by the southward dipping Sembar Formation and Loralai Limestone which show an overturned sequence. Accordingly, a southward dipping axial plane of a syncline is assumed at the midst of the exposure of the Goru Formation. The sequence from the Goru Formation to the Loralai limestone belongs to the Calcareous Zone. There is a southward dipping major fault between the Sembar Formation and the Triassic false Alozai Group. At the southern side of section 0, bedded limestone (probably the Loralai Limestone) is observed to be thrust upon the ophiolitic rocks on the north. Accordingly, around these places the Calcareous Zone is thrust upon the Axial Zone.

TECTONIC AND SEDIMENTARY ENVIRONMENTS IN TRIASSIC

As mentioned above, the lithofacies of the Triassic sequence in the Axial Zone are quite different from those of the Mesozoic sequence in the Calcareous Zone. The former are characterized by submarine volcanic rocks, olistostromes and hemipelagic sediments. In contrast with this, the Alozai Group and Loralai Limestone in the Calcareous Zone suggest sedimentation on the non-volcanic continental shelf and upper part of continental slope. In addition, a major thrust between the two zones was confirmed at some places. Accordingly, these two zones are considered to have been originally away from each other.

Both the false Parh Group and the false Alozai Group contain Upper and Lower Triassic fauna. However, the stratigraphic and structural relationships between the two groups are uncertain. The differences between these are as follows:

a) Thick pillow basalt and basaltic hyaloclastites are well developed in the lower part of the false Parh Group. However, they are not found in the false Alozai Group.

b) The middle part of the false Parh Group which contains both the Lower and Upper Triassic fauna is represented by huge amount of ophiolitic olistostromes. In contrast with this, olistostromes are minor in the false Alozai Group. In addition, the dominant rock types of olistoliths in the false Alozai Group are not only ophiolitic but also shallow marine limestone and quartzose sandstone.

c) The false Alozai Group is more dominant in greenish and purple tuffaceous and siliceous shale than the false Parh Group. HSC (1960) denoted a wide distribution of the "Alozai Group" to the west of the Jang Tor Ghar ultramafic rock body, distinguishing it from the "Parh Group" and "Loralai Limestone". This was based on the lithologic differences among them. We have also confirmed preliminarily these differences along the long river to the west of the Jang Tor Ghar rock body.

d) Slaty cleavage is well developed in the false Alozai Group, especially in its lower part where chlorite and sericite developed during low grade metamorphism. On the other hand, the false Parh Group is not metamorphosed and no slaty cleavage is developed. These reflect the difference in their burial depth.

The fore-mentioned differences between the false Parh Group and the false Alozai Group suggest differences in their tectonic and sedimentary environments. Thus they may have been brought in contact with each other by later tectonic transport. Accordingly, we assume a major thrust between the false Alozai Group and the false Parh Group (shown by a dotted line in Fig. 1). This thrust is expected to start from the north of Wulgai village, and extends eastward along the boundary between the distributions of the "Alozai Group" and that of the "Parh Group" or "Loralai Limestone", denoted by HSC (1960). It turns southeastward along the bourdary to the west of the Jang Tor Ghar rock body and coverges on the fault between the Axial Zone and the Calcareous Zone.

A narrow sedimentary basin whose northern and southern sides were bounded by a mid-oceanic ridge and a continent, respectively, similar to the present Red Sea, is reconstructed as a tectono-sedimentary environment of the false Parh Group and the false Alozai Group ("a" in Fig. 13). The thick pillow basalt, the complex of gabbro and basalt, hyaloclastites and radiolarian chert of the lower part of the false Parh Group suggest mid-oceanic ridge environments.

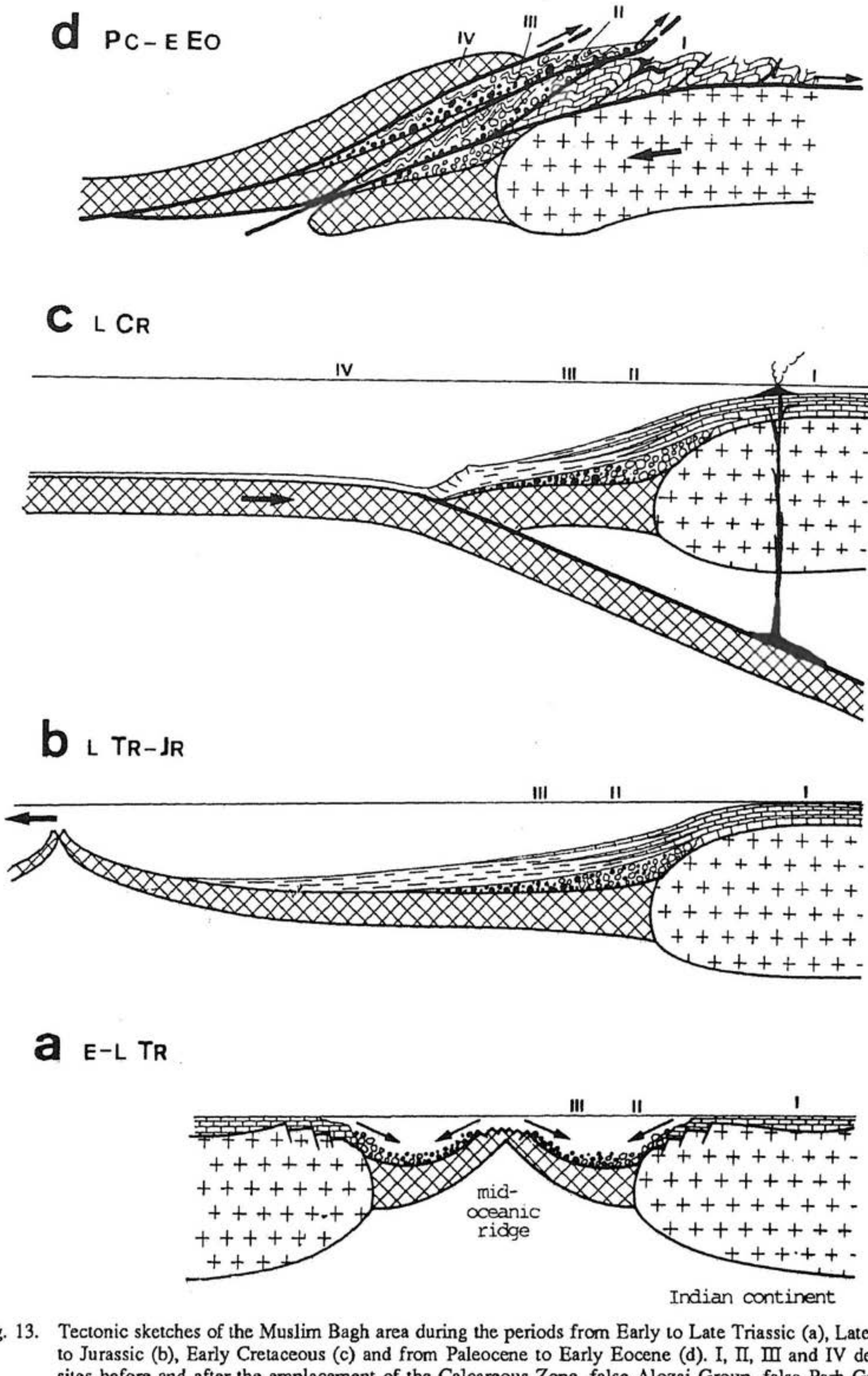

Fig. 13. Tectonic sketches of the Muslim Bagh area during the periods from Early to Late Triassic (a), Late Triassic to Jurassic (b), Early Cretaceous (c) and from Paleocene to Early Eocene (d). I, II, III and IV denote the sites before and after the emplacement of the Calcareous Zone, false Alozai Group, false Parh Group and the ultramafic rocks, respectively.

The ophiolitic olistostromes of the middle part of the false Parh Group are due to the collapse of the mid-oceanic ridge.

As mentioned already, some olistoliths of pillow basalt of the false Parh Group are capped by reefoid limestone with coral fossils. This suggests that the top of the mid-oceanic ridge was high enough to be in the photic zone. The shaly matrix of the olistostromes is hemipelagic, and intercalated by thin beds of micritic limestone with radiolarian fossils. These facts suggest that the sea bottom was surely deep but shallower than CCD. Flute casts are found sometimes on the base of thin limestone beds which are intercalated in the shaly matrix of the olistostromes. This suggests that the shelf area was near enough for the limestone clastics to be transported to the basin floor by turbidity current. All of the facts mentioned above suggest that the mid-oceanic ridge was very young and it was not very distant from the continent, and that not only the ridge but also the basin floor were shallower than the normal mid-oceanic ridge and abyssal plain.

Ophiolitic olistoliths are more abundant in the false Parh Group than the false Alozai Group. In contrast with this, olistoliths of shallow marine limestone with coral and fusulinid fossils are dominant in the false Alozai Group. In addition, thin beds of coarse sandstone of smoky quartz grains are intercalated in the false Alozai Group. These suggest that the false Parh Group and the false Alozai Group were deposited on the basin floor of the mid-oceanic ridge side and on that of the continent side, respectively. The lower part of the false Alozai Group which is dominant in tuffaceous materials, may have been deposited on the basin floor of continental side when the pillow basalt and hyaloclastites of the lower part of the false Parh Group were being erupted from the mid-oceanic ridge. Anyway, the olistoliths of shallow marine limestone in the false Alozai Group are mixed with ophiolitic olistoliths. This also suggests that the sedimentary basin was very narrow.

It is a matter of fact that the "continent" mentioned above is the Indian continent, and that the development of the narrow sedimentary basin, related with ocean floor spreading, is a result of the breakup of Gondwanaland. When we assume the width of the basin to be 200 km which may be a maximum distance for the olistostromes from both the contient and mid-oceanic ridge to reach, and the time range of the false Alozai Group and the lower and middle parts of the false Parh Group is estimated to be 20 Ma, we get a spreading rate on the mid-oceanic ridge to be 1 cm/y. This value is very small but is nearly the same as that of Red Sea at present.

As the mid-oceanic ridge moved away from the Indian continent (Fig. 13b) the tectonics of the sedimentary basin changed into a new stage. The basin may have become free of olistostromes from the mid-oceanic ridge side. The continental margin may have been liberated from the tectonics of the continental rifting and the ocean floor spreading. Cooling rate not only of the oceanic lithosphere but also of the adjacent continental lithosphere may have been relaxed. The slow subsidence and the process of the filling up of the basin may have prevailed. The olistostromes decrease upward both in the false Alozai Group and in the sequence from the middle to the upper parts of the false Parh Group. Whereas the intercalations of limestone beds increase in the upper part of these two groups. They are followed by limestone dominant sequences of the false Loralai Limestone. These facts support the above mentioned assumptions on the tectono-sedimentary environments during the later tectonic stage.

It is natural to expect the existence of the counterpart of the Indian continent to the north of the Triassic mid-oceanic ridge. Considering the distributions of the paleo-geosutures and the continental blocks between them and their tectonic process of subduction and continental collisions in Tibet (Liu et al., 1980; Otsuki, 1985), the hypothetical continental block to the north of the Triassic mid-oceanic ridge is thought to correspond to the Gangdise-Nyainqentanglha block which is situated between the Bangong Lake-Nujiang Fault and the Yalucangpujiang-Indus Suture.

LATE CRETACEOUS ISLAND ARC ON THE NORTHERN MARGIN OF INDIAN CONTINENT

The basaltic and andesitic lavas and their pyroclastics of the Late Cretaceous Bibai Formation in the Calcareous Zone were regarded by Kazmi (1979) and DeJong and Subhani (1979) to be of Late Cretaceous island arc origin. The arc was brought about by the subduction of the oceanic plate of the Tethys Sea under the western margin of the Indian continent (Fig. 13c).

We found pillow basalt which directly overlies the Parh Limestone at Ghunda Manra (Section G: Fig. 6). It is followed by andesitic hyaloclastites and volcanic sandstone. Volcanic conglomerate of the Bibai Formation to the east of Kach (Section Q) is an equivalent to the volcanic rocks at Ghunda Manra. It contains cobbles not only of basalt and andesite but also of dacite. Andesite contains large phenocrysts of hornblende. Sheets and dikes of basalt, dolerite and andesite are found in the northern margin of the Calcareous Zone. The texture of the andesitic intrusive rock resembles that of the andesitic effusive rocks of the Biabi Formation. Accordingly, they are probably co-magmatic. Chemical data of these volcanic rocks are not available, but the rock association appears to support the assumption of DeJong and Subhani (1979).

The problem is why the island arc magmatism was temporal? A remarkable tectonic movement is recognized as a clino-uncomformity between the marine Shexing Formation (Apt-Cenomanian?) and the terrestrial Lizizong Formation (latest Cretaceous) in Lhasa region of Tibet. Igneous activity in the "Gandise-Nyainqentanglha Volcano-Magmatic Arc" was most intense during the period from 50 to 90 Ma (Geol. Bureau of Xizang and Geol. Soc. Xizang, China, 1982; Inst. Geol. Academia Sinica. Group of K-Ar Geochronology, 1979). Otsuki (1985) assumed that the intense magmatism may have been due to the subduction of a mid-oceanic ridge in the Tethys Sea from the Yalucangpujiang-Indus paleo-trench. However, the subduction of mid-oceanic ridge is thought to be difficult, therefore another subduction zone may have been initiated. This is a possible cause of the origination of the temporal subduction zone along the northern margin of the Indian continent.

Another plausible cause may be related with the "India's northwards flight". According to Johnson et al. (1976), the Indian continent moved rapidly northward at the rate of 15 to 17.5 cm/y, relative to Antarctica and Australia. A high convergence rate of plates on the Yalucangpujiang-Indus paleo-trench, and hence the strong compression, are naturally expected on the island arc behind it. However, the Lizizong Formation which is a younger member of the "Gandise-Nyainqentanglha Volcano-Magmatic Arc" is deformed only gently. Accordintly, we must assume a complementary subduction zone by which a part of the high subduction rate of the oceanic plate of the Tethys Sea was shared. This is another plausible cause of the origin of the Late Cretaceous island arc on the northern margin of the Indian continent.

Anyway, the development of the Late Cretaceous sedimentary basin in Baluchistan should be re-examined in the framework of the island arc tectonics.

EMPLACEMENT OF THE TRIASSIC FORMATIONS AND ULTRAMAFIC ROCKS

The Axial Zone froms a major thrust pile trending ENE-WSW and dipping NNW. The main thrust sheets are the false Alozai Group, false Parh Group and the ultramafic rock bodies in the structurally ascending order. They are thrust upon the Calcarious Zone (Fig. 13d).

A NNW-dipping high angle reverse fault along the boundary between the false Parh Group and the Calcareous Zone was found at Zhiar Tsar (Section F; Fig. 5), and it was estimated at Ghunda Manra (Section G; Fig. 6). It was hypothetically extended westward along the boundary between the dark colored exposures of ophiolitic olistoliths and regularly folded Mesozoic formations (Fig. 1) based on the air-photographic observation.

The boundary fault between the false Alozai Group and the Calcareous Zone was hypothetically drawn along the northern margin of the Eocene limestone exposures which are distributed along the E-W trending boundary. This fault appears to branch into two in the area, to the southeast of Khanozai. The southern branch is covered by the south-dipping thrust sheet in the Calcareous Zone to the south of Gowal.

We have no data on the boundary fault between the false Alozai Group and the false Parh Group. It was tentatively assumed along the northern and eastern margins of the false Alozai Group which is widely distributed in the area between the Jang Tor Ghar and Lash ultramafic rock bodies. Here, we emphasise that this fault was assumed only from the analysis of the tectono-sedimentary environments of the false Alozai and false Parh groups. The structural relationships between the two should be investigated through field observations in future.

The Triassic sequence of the Axial zone is overlain by the ultramafic rock bodies in fault contact. The fault zone is usually associated with the slices of highly serpentinized ultramafic rocks and a layer of metamorphic rocks. The dip angle of the fault plane changes from place to place; for example, north of Bagh it is 40°-60°SW, at Bagh at 65° NW, northwest of Ghunda Manra 70°N, southern margin of Saplai Tor Ghar body 50°-80° NNW, eastern margin of Saplai Tor Ghar body 90°, NE margin of Jang Tor Ghar body 60°S, NW margin of Jang Tor Ghar body highly undulated but moderately dipping SE, southern margin of a small body to the north of Jang Tor Ghar body 25°NW and SE margin of Lash body 90°. However, the distribution patterns of the ultramafic bodies suggest that their basal planes are regionally of quite low angle. It can be concluded that the thrust plane is undulated with short wave lengths, but its envelope surface is nearly horizontal. The undulation may be due to folding after the emplacement of the ultramafic bodies. According to the observation at the northwestern margin of the Jang Tor Ghar body, the undulation is partly due to the mega-grooves by the tectonic erosion through the emplacement.

A layer of metamorphic rocks is found beneath the Saplai Tor Ghar, Jang Tor Ghar and some other small ultramafic bodies. The thickness of the layer does not exceed 200 m. Usually, it is disrupted by the highly sheared serpentinite slices parallel to the boundary fault between the metamorphic layer and the ultramafic mass on it. In spite of the disruption, the metamorphic grade becomes higher upward from chlorite-sericite schist to garnet-amphibolite schist toward the ultramafic mass, as mentioned previously by Gansser (1979) and Ahmad and Abbas (1979).

The original rock is gabbro, pillow basalt, basaltic tuff and thin alternation of basaltic tuff and limestone or chert. These rock associations are quite similar to those of the lower part of the false Parh Group.

Only the rocks of green schist facies are found in the north of Karimdad (Section A; Fig. 2), Karimdad (Section B) and Bagh (Section C; Fig.3). Both greenschist and amphibolite schist are found at the northwest of Ghunda Manra (Section D; Fig. 7), western margin of the Saplai Tor Ghar body (section I; Fig. 9)., northwestern margin of the Jang Tor Ghar body (section K; Fig. 10) and southern margin of the Lash body (Section M; Fig. 11). Garnet is usually found in calcareous tuff of amphibolite facies.

The vertical change of metamorphic facies is typically observed at the northwestern margin of the Jang Tor Ghar body (Section K; Fig. 10) and the small mountain (2699 m peak) to the northwest of Ghunda Manra (Section D; Fig. 7). There is no major fault between the non-metamorphic false Parh Group and the chlorite-sericite schists on it. The facies change upward from greenschists to amphibolite schists of basalt and basaltic tuff is gradual at section K. A thin slice of serpentinite is intercalated between the greenschists of basaltic tuff and the amphibolite schists of basalt and basaltic tuff at Section D. At both these sections, the grains of metamorphic minerals in amphibolite schists increase in size upward, and the upper part of it appears to be meta-gabbro.

The metamorphosed zone is very thin, with metamorphic grade increasing towards the overthrust ultramafic mass. Therefore the metamorphism may be due to shear heating through the emplacement of the ultramafic slab or baking by heat conducted from a hot ultramafic slab. At the western margin of the Saplai Tor Ghar body (Section I; Fig. 9), the xenolith-like blocks of both the high and low grade metamorphic rocks are included in serpentinized ultramafic mass. They have no reaction rim, hence they are thought to have been taken into the ultramafic mass already cooled through the emplacement. On the other hand, at the northwest of Ghunda Manra (Section D; Fig. 7), a fragment of amphibolite schist within the serpentinite slice has a dark coloured reaction rim. This suggests that the ultramafic rock was sufficiently hot to react with amphibolite schist when the latter was taken into the former.

Accordingly, it is concluded that the metamorphism is due to the baking effect by the hot slab of ultramafic rocks, and that the metamorphosed rocks were disrupted and incorporated into the ultramafic mass through the obductional emplacement. The development of the reaction rim depended on whether the ultramafic rocks were still hot or already cooled when the blocks of metamorphic rocks were taken into them. However, the effect of the shear heating is not completely excluded, because it is a common phenomenon in faulting.

The metamorphic layer is associated with the basal plane of ultramafic bodies from the Saplai Tor Ghar to Lash bodies, but other thrusts do not have associated metamorphic layers. Such a difference reflects differences in the emplacement process of the thrust sheets.

From the foraminiferal biostratigraphic study on the Gowal section and the sections to the north and the southwest of Muslim Bagh, Allemann (1979) concluded that the ophiolitic rocks were emplaced after the Late Maastrichtian and before Middle Eocene. He regarded the Cenomanian to Upper Maastrichtian sequence of the Gowal section as a part of the "melange". However, the lithologic and structural characteristics of this suggest strongly that the sequence consists of the Parh limestone and Goru Formation. Accordingly, Allemann's data cannot be considered as an indicator of the oldest time when the Triassic formations and the ultramafic rocks in the Axial Zone were emplaced.

On the other hand, we found that the false Parh Group is thrust upon the Paleocene limestone at Ghunda Manra (Section G; Fig. 6). This indicates that the emplacement continued after the Paleocene time. The Mesozoic sequence in both the Calcareous and Axial Zones are intruded by doleritic, basaltic and andesitic dikes and sheets. It is difficult to distinguish the doleritic and basaltic intrusive rocks in the Calcareous Zone from those in the Axial Zone with the unaided eye. However, the andesite is characterized by large phenocrysts of hornblende, and the lithofacies resemble that of the andesitic effusive rocks of the Bibai Formation. The distribution of these andesites is restricted to the Calcareous Zone. These observations suggest that the thrust pile of the Axial zone was transported to reach the present position after the island arc volcanism on the Calcareous Zone.

Since the age of "Late Maastrichtian" by Allemann (1979) is interpreted to be that of the Parh Limestone which is conformably overlain by the Bibai Formation, the age of the andesitic intrusive rocks is considered to be Late Maastrichtian or slightly younger. Accordingly, the time of the emplacement of the thrust pile is estimated to be after the Late Maastrichtian. As a result, our conclusion regarding the time of the emplacement is the same as that suggested by Allemann (1979).

Some structural features suggest the direction of the emplacement of the Triassic sequence and the ultramafic bodies. We found a boundary fault between the western margin of the Saplai Tor Ghar ultramafic body and the chlorite schist which probably belongs to the false Parh Group at Section I (Fig. 9). The shear zone is very thin but extends continuously. The fault plane trends N27°W 90°. The striates on the fault plane are nearly horizontal. The minor folds in the pale green tuff on the west suggest a right-lateral drag. This indicates that the Sapali Tor Ghar body was emplaced from NNW to SSE.

The mineral lineation on the schistosity of the metamorphic rocks just beneath the ultramafic bodies is constantly within the range from NE-SW to E-W. This appears to be nearly parallel to the axis of minor folds in the metamorphic rocks. If these were formed as drag folds through the emplacement of the ultramafic bodies, the direction of the emplacement is estimated to be NNW-SSE.

The features of EW-trending large folds in the Calcareous Zone also offer some informations for the emplacement of the Axial Zone. It is quite clear that the intensity of folding is high in the northern part and becomes lower southward. The feature of the folds on the vertical cross section is commonly asymmetric, that is, most of the axial planes dip north. Such a structural feature suggests the NS-trending compressional stress which becomes strong northward. This may be related with the southward emplacement of the thrust pile in the Axial Zone.

In addition, the folds in the Axial Zone may have grown to a considerable extent simultaneously with the emplacement of the thrust pile of the Axial Zone. This is suggested by the concordant structure of the Paleocene limestone with that of the underlayers and the clino-unconformity between the Eocene formations and their underlayers.

There is a characteristic feature of the major folds in the northern margin of the Calcareous Zone to the south of the Saplai Tor Ghar ultramafic rock body (Fig. 1). It is symmetrical with respect to the NNW-SSE trending line which passes through the southeastern corner of the Saplai Tor Ghar body. The arrangement of the fold axis shows a sinistral echelon pattern and plunging ENE in the area on the west of the datum line, and vice versa on the east. This structure also suggests that the emplacement direction of the Saplai Tor Ghar body is from NNW to SSE.

It is quite difficult to estimate the emplacement distance of the thrust pile in the Axial Zone, but our new data give it some constraints. According to the analysis of the tectono-sedimentary environments of the Triassic formations in the Axial Zone, the basin floor on which the false Parh Group was deposited is more distant from the Indian continent than that of the false Alozai Group, although both were deposited on the basin floor to which the olistostromes from both the continental shelf and the mid-oceanic ridge were possible to reach. Accordingly, it is easily concluded that the displacement distance of the thrust sheet of the false Alozai Group is smaller than that of the false Parh Group. The problem of how far the olistostromes were transported, is uncertain now, but the displacement distances of the false Alozai Group and the false Parh Group may be several tens of kilometer and 100 km, respectively.

The displacement distance of the ultramafic rocks, including the Saplai Tor Gar and Jang Tor Ghar rock bodies, is surely the largest. However, it is difficult to be estimated from the sedimentary environments, because they are not associated with the sedimentary rocks. When we assume that the obductional emplacement started at the Late Cretaceous subduction zone, the emplacement distance is nearly equal to the distance from the trench to the volcanic arc in the Late Cretaceous, i.e. 200–300 km.

Ophiolites are widely distributed not only in the Muslim Bagh area but also in the Bela region. The latter was emplaced in Paleocene (Allemann, 1979). There is another wide distribution of ophiolites in the area to the south of Kabul which is a northern extension of the Eocene to Oligocene Flysh Zone on the west of the Axial Zone. The distribution pattern of these ophiolites suggests that they were obducted as huge blocks and formed a basement of the Flysh Zone. Accordingly, they may be a western continuation of the Muslim Bagh-Bela ophiolites, and it is considered that the ophiolitic rocks may be widely distributed beneath the Flysh Zone.

In Iran and Oman, very extensive overthrust sheets of ophiolites are known. They were emplaced in the Late Cretaceous or Paleocene which is nearly the same time as that of the Muslim Bagh-Bela ophiolites. Some particular causes may be considered to explain such a simultaneous and extensive emplacement of the ophiolites. One possible cause may be related with the "India's northward rapid flight" (Johnson et al., 1976). The abnormally high convergence rate between Eurasian plate and Indian plate during 80–53 Ma period may hence be a cause of the extensive obduction.

After the obduction of the Axial Zone in the Paleocene and the Early Eocene, the tectonics of the Baluchistan region entered into a new stage, that is the formation of the new sedimentary basin of the Flysh Zone.

CONCLUSIONS

1) The Muslim Bagh area is divided, from N to S, into: Flysh Zone (Eocene to Miocene), Axial Zone (Triassic), and Calcareous Zone (late Triassic? to Neogene). The Mesozoic formations in the Axial Zone are different in both geologic age and lithology from those in the

Calcareous Zone. They are characterized by pillow basalt, basaltic hyaloclastites, olistostromes, and hemipelagic sediments.

2) The Axial Zone sequence is divided into three parts tentatively named as "false Parh Group", "false Alozai Group" and "false Loralai Limestone".

3) The lower part of the false Parh Group is composed of pillow basalt and basaltic hyaloclastites. The middle part is characterized by olistostromes which include olistoliths of gabbro, basalt, chert and minor amount of limestone. The matrix is hemipelagic papery shale. The upper part is composed of hemipelagic shale interbedded with thin beds of micritic limestone. The middle part is Lower and Upper Triassic, and the upper part is Upper Triassic.

4) The false Alozai Group is composed mainly of hemipelagic shale interbedded with thin beds of micritic limestone and minor amount of olistostromes. Its age ranges from Lower to Upper Triassic as that of the false Parh Group. It is distinguished from the false Alozai Group by a minor amount of olistostromes, olistoliths of reefoid limestone being more abundant, and shale being more tuffaceous.

5) The false Loralai limestone is mainly composed of bedded micritic limestone interbedded with thin beds of shale. The age is Upper Triassic or younger.

6) These fomations were deposited in a narrow basin which was bounded on the north by a mid-oceanic ridge and on the south by the Indian continent. The false Parh Group and the false Alozai Group were deposited on the basin floor of the mid-oceanic ridge side and continent side, respectively.

7) The tectono-sedimentary environment of the Triassic formations suggests the breakup of continent and the initial stage of the mid-oceanic spreading which is similar to the Red Sea at present. This is regarded as a constituent of the breakup of the Gondwanaland. The lithofacies change from Lower to Upper triassic suggesting the progress of spreading on the mid-oceanic ridge.

8) During the short period of the latest Cretaceous, the oceanic plate of the Tethys Sea was subducted under the Indian continent. It brought about the temproal island arc volcanism of the Bibai Formation.

9) The Triassic sequence and the oceanic lithosphere of the Tethys Sea were obducted south-southeastward on the northern margin of the Indian continent during Paleocene and Early Eocene. As a result, they formed a thrust pile.

10) The obducted oceanic lithosphere was hot enough so that the underlying Triassic formations were metamorphosed into greenschist and amphibolite schist.

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