TECTONICS AND SEDIMENTATION OF THE ROCKS BETWEEN MANDI AND ROHTANG, BEAS VALLEY, HIMACHAL PRADESH, INDIA.

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ABSTRACT

Between Mandi and Rohtang in western Himachal Pradesh, four principal tectonostratigraphic units are recognised. In ascending order they are 1. Larji-Rampur window Group, 2. Chail Group, 3. Jutogh Group and 4. Vaikrita Group. Larji-Rampur window Group consists of quartzarenite and penecontemporaneous basic volcanics together with gneissose Bandal Granite of Rampur Formation tectonically underlain by platformal stromatolitic limestone of Shali Formation. The Chail Group comprises predominently of low grade sericite-chlorite phyllite with occasional development of garnet, mylonitised gneiss and intrusive body of Mandi Granite. The Chail Group is overthrust by Jutogh Group which consists of medium grade metamorphics, foliated micaceous quartzite and fine grained banded gneiss. High grade metamorphics of Central Crystallines (Vaikrita Group) of the Higher Himalaya overlies the Jutogh Group with a tectonic contact. The Vaikrita Group is made up mainly of sillimanite-kyanite-garnet schist, coarse grained biotite rich banded gneiss with tourmaline and foliated micaceous quartzite. Detailed study of penetrative planer and linear structures reveals that the Chail Group, Jutogh Group and Vaikrita Group rocks have suffered at least three phases of deformation, the first of which is absent in Larji-Rampur window Group. The rocks of the Chail and Jutogh Groups have moved southward along the thrust sheets during the first phase of deformation.

A large antiform called *Beas Antiform* trending NNW-SSE and a complimentary synform (*Hanogi Synform*) have folded the Larji-Rampur window, Chail and Jutogh Groups. Another major antiform trending NNW-SSE lies in the central part of the Larji-Rampur window zone. The sediments of the Larji-Rampur window Group are the product of subtidal, intertidal and coastal sand bar-beach-Shoal complex depositional environment (quiet stable shelf conditions) in which the sedimentation kept pace with subsidence of the basin to accumulate the huge pile of sediments.

INTRODUCTION

The rugged topography of Mandi-Rohtang area falls in the Survey of India toposheet Nos. 53A, 53E and 52H on 1 : 250,000 scale. The area is bound by East longitudes 76°45′-77°30′ and North Latitudes 31°30′-32°22′. The 5000 sq. km. area of investigation is drained by the River Beas and its tributaries.

The metamorphic rocks in Himachal

Himalaya grouped under 'Jutogh Nappe' into which Dalhousie, Dhauladhar, Mandi, Karsog and Chor granites have intruded (Bhargava, *et al.*, 1972; Anand, 1976; Chatterjee, 1976 and Sharma, 1977). According to Bhargava (1980), the Rampur Group is framed on all sides by the Salkhala thrust sheet (Jutogh of Bhargava *et al.*, (1972).

Valdiya (1980) while describing the geology of Kumaun Himalaya, suggested that in the Satluj valley, Himachal Pradesh the Rampur Quartzite with basic volcanics exposed in the window are the northwest prolongation of the Berinag under the crystalline sheet of Jutogh (Munsiari).

Virdi (1981) suggested the presence of two crystalline thrust sheets in the Himachal Lesser Himalaya and included the Kulu metamorphics within Chails and the metamorphic sequence to the east of Manikaran within Jutogh.

TECTONOSTRATIGRAPHY

The rocks of Mandi-Rohtang area from SW to NE are divided into six tectonostragraphic units: 1. Siwalik Group; 2. Dharamshala Group; 3. Larji-Rampur window Group; 4. Chail Group; 5. Jutogh Group and 6. Vaikrita Group (Figs. 1 and 2). Siwalik Group, forming the southwestern most unit of the area is separated from the overlying rocks of the Dharamsala Group along the Sarkaghat Thrust. Dharmashala Group is overlain by the rocks of Shali Formation along the Main Boundary Thrust. The Rampur Formation tectonically rests over the Shali Formation along the Garsa Thrust and is made up of volcanics at the lower level and Rampur Quartzite towards the top.

The Bandal Granite intrudes the Rampur Quartzite near the village Manihar. The Larji-Rampur window Group is overthrust by the low grade metamorphics of Chail Group (Chail Nappe). The Chail metamorphics are intruded by Mandi Granite. The demarcating boundary between the Larji-Rampur window Group and Chail Group is known as the Chail Thrust. The Chail Group is tectonically overlain by the huge succession of medium grade metamorphics of Jutogh Group (Jutogh Nappe) separated along the Jutogh Thrust. The Jutogh Group is overlain by the high grade metamorphics of the Vaikrita Group along the Vaikrita Thrust. In the north of Rohtang, low grade metasedimentaries with 500 my dated Jaspa Granite (Frank, *et al.*, 1977), called the Haimanta Group, overlie the Vaikrita Group of Higher Himalayan zone along the Tethyan Thrust. The tectonic suecession is given in Table 1. A brief account of the characters, age and correlation of each unit is summarised as under:

SIWALIK GROUP: The southwestern part of the area around Sarkaghat is occupied by autochthonous Siwalik Group rocks. It is separated from the overlying para-autochthonous rocks of Dharamsala Group along the Sarkaghat Thrust. In the immediate vicinity of this thrust, the Siwalik Group comprises mainly conglomarate with medium to coarse grained sandstone, claystone and siltstone. The inclination of the Sarkaghat Thrust is 40° to 45° due northeast.

Karunakaran and Ranga Rao, (1976) assigned Lower Pleistocene to Middle Miocene age to the Siwalic rocks.

DHARAMSALA GROUP: Thrust over the Siwaliks, succession of fine grained micaceous sandstone, purple-green clay, claystone and micaceous siltstone has been named as the Dharamsala Group. It covers a vast area between Main Boundary Thrust and Sarkaghat Thrust, the outcrop roughly trending NNE–SSW. The belt varies in width from 8 km to 20 km and in thickness from 1000 m to 2000 m. The width of the belt increases in the north and decreases towards the south.

Karunakaran and Ranga Rao, (1976) and Mathur, (1984) assigned Lower Eocene to Early Miocene age to the Dharamsala rocks.

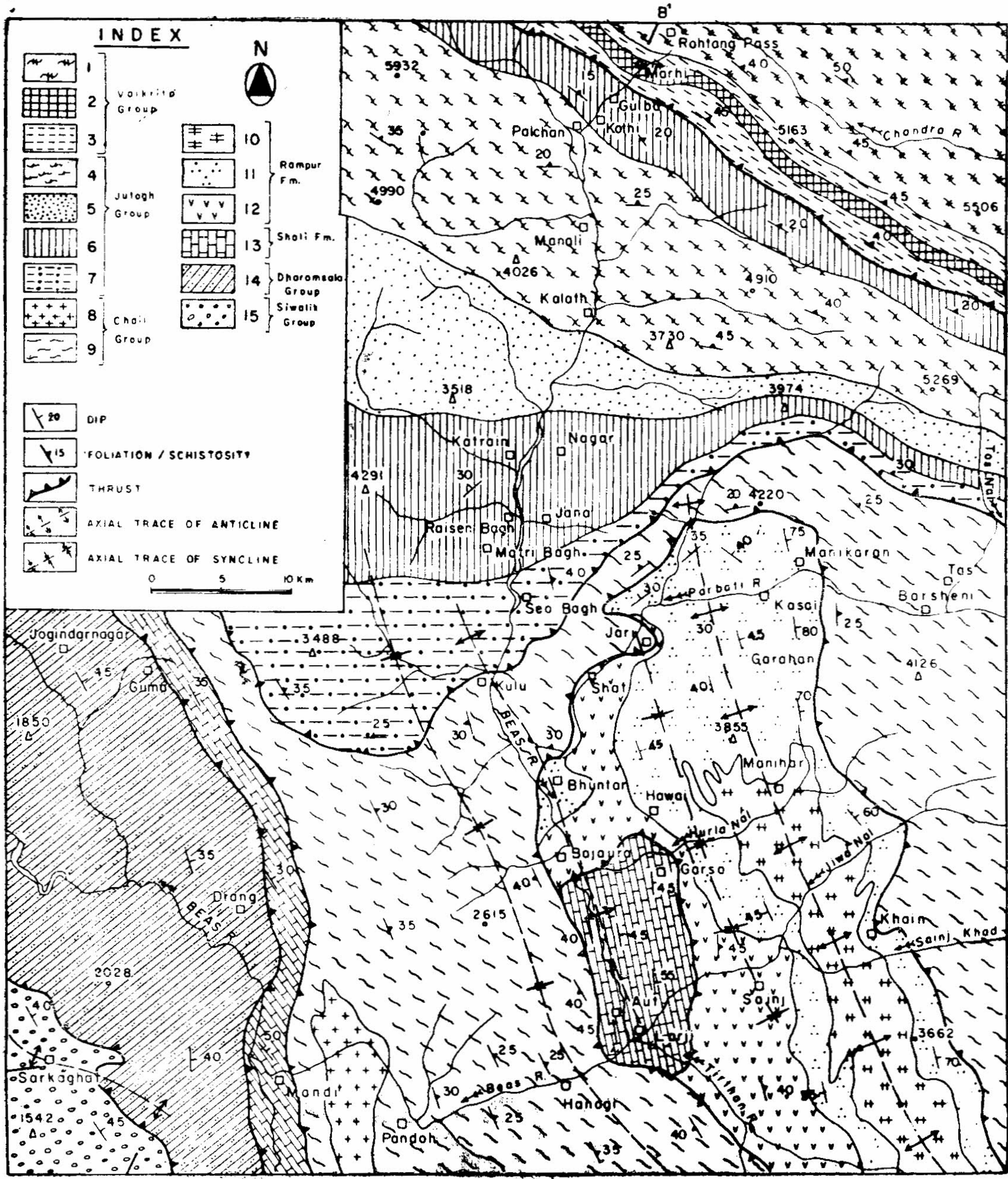

Fig. 1. Geological map of Mandi-Rohtang Area, Himachal Pradesh, India. Legend: 1. Coarse grained qurtzo- feldspathic biotite rich banded gneiss with tourmaline. 2. Quartz biotite garnetiferous schist interbedded with foliated micaceous quartzite. 3. Kyanite-sillimanite schist and gneiss. 4. Fine grained banded gneiss. 5. Foliated micaceous quartzite. 6. Biotiteschist with foliated micaceous quartzite. 7. Garnetiferous-biotite phyllonite and schist. 8. Intrusive Mandi Granite. 9. Sericite-chlorite phyllite, quartzite, mylonitized gneiss, quartz porphyry, Carbonaceous slate with thin bands of limestone. 10. Intrusive Bandal Granite. 11. Rampur Quartzite. 12. Volcanics. 13. Dolomite, limestone, quartzite, volcanics, shale and slate, 14. Fine grained micaceous sandstone, purple-green clay, claystone and micaceous siltstone, 15. Mainly conglomerate with medium to coarse grained sandstone, claystone and siltstone.

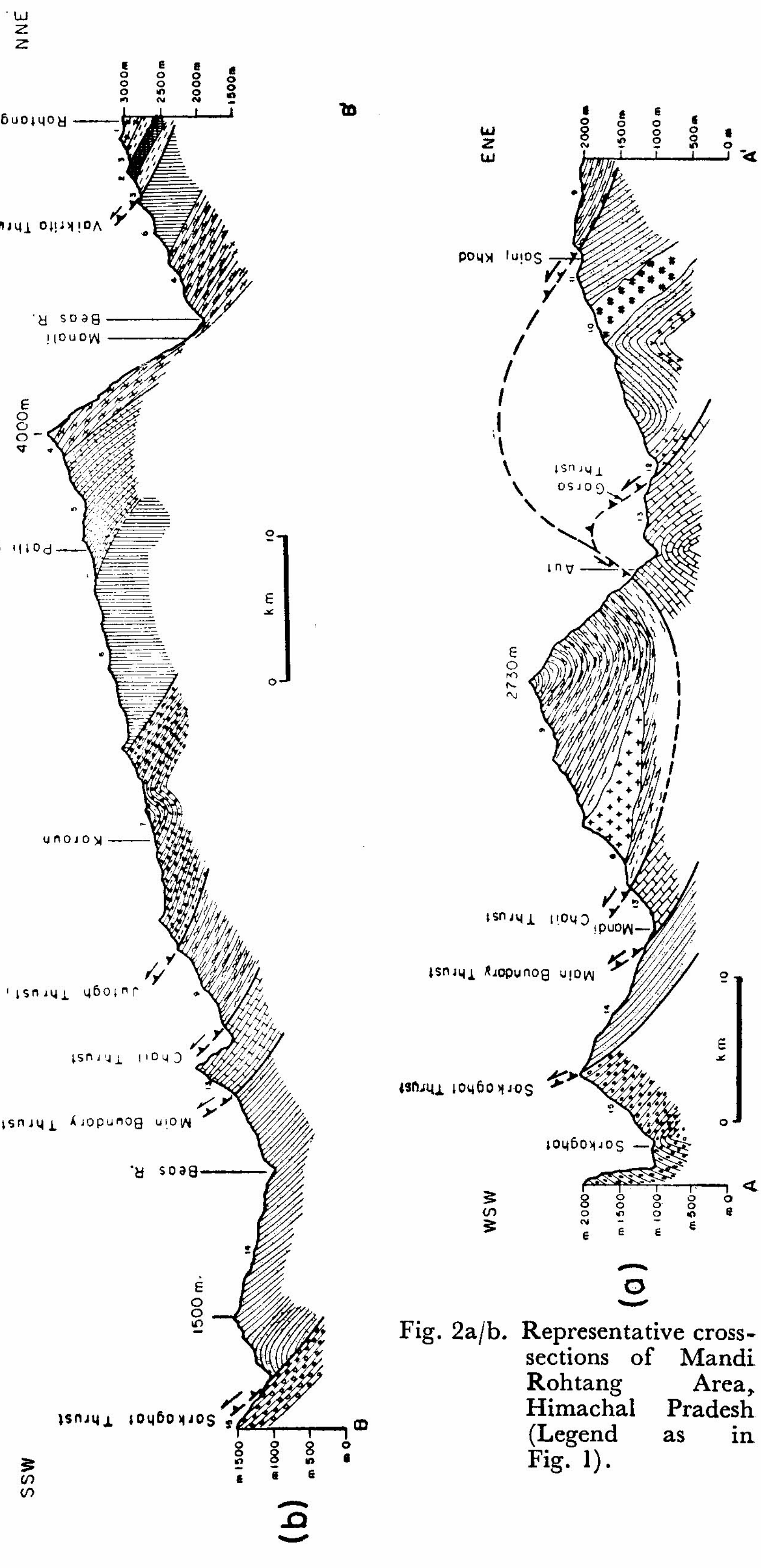

Fig. 2a/b. Representative cross-sections of Mandi Rohtang Area, Himachal Pradesh (Legend as in Fig. 1).

Table 1 : Tectonic Succession of the Mandi-Rohtang area

Haimanta Group
——————Tethyan Thrust——————
Vaikrita Group
——————Vaikrita Thrust——————
Jutogh Group
——————Jutogh Thrust——————
Chail Group
——————Chail Thrust——————
Rampur Formation
——————Garsa Thrust——————
Shali Formation
——————Main Boundary Thrust——————
Dharamsala Group
——————Sarkaghat Thrust——————
Autochthonous Siwalik Group

LARJI-RAMPUR WINDOW GROUP: Thrust over the Dharamsala, the Larji-Rampur window Group is made up of Shali Formation below and Rampur Formation above. The Shali Formation comprises dolomite, stromatolitic limestone, intraclastic-oolitic dolomite, cherty limestone, quartzite, volcanics, shale and slate. It is tectonically overlain by the huge succession of quartzite and penecontemporaneous basic volcanics of Rampur Formation exposed in the form of a tectonic window (Rampur Window) beneath the Chail metamorphics.

SHALI FORMATION: The orthoquartzite-carbonate sequence of the Shali (=Larji) Formation exposed around Larji in the Beas valley was subdivided by Sharma (1977) into three members namely; Naraul Slate and Phyllite below, Hurla Quartzite in the middle and Aut Dolomite at the top. However, Naraul Member is only locally mappable and regionally indistinguishable from the Hurla Quartzite. The Shali Formation, therefore, has two main subdivisions. The detailed lithologs showing lithology, sedimentary structures, facies change and environment of deposition prepared along Larji-Sainj and Hurla-Garsa sections in Beas valley are shown in Fig. 3.

The terminology followed is after Ginsburg (1975), and Reineck and Singh (1980).

HURLA QUARTZITE: The lower part of the Shali Formation is known as the Hurla Quartzite comprising pink, purple, white and grey fine to coarse grained orthoquartzite, volcanics, shale and slate. The orthoquartzite consists of 95-98% quartz and at places show colour and textural banding (Plate I/a and I/c). Dark colour laminae show rich concentration of heavy minerals

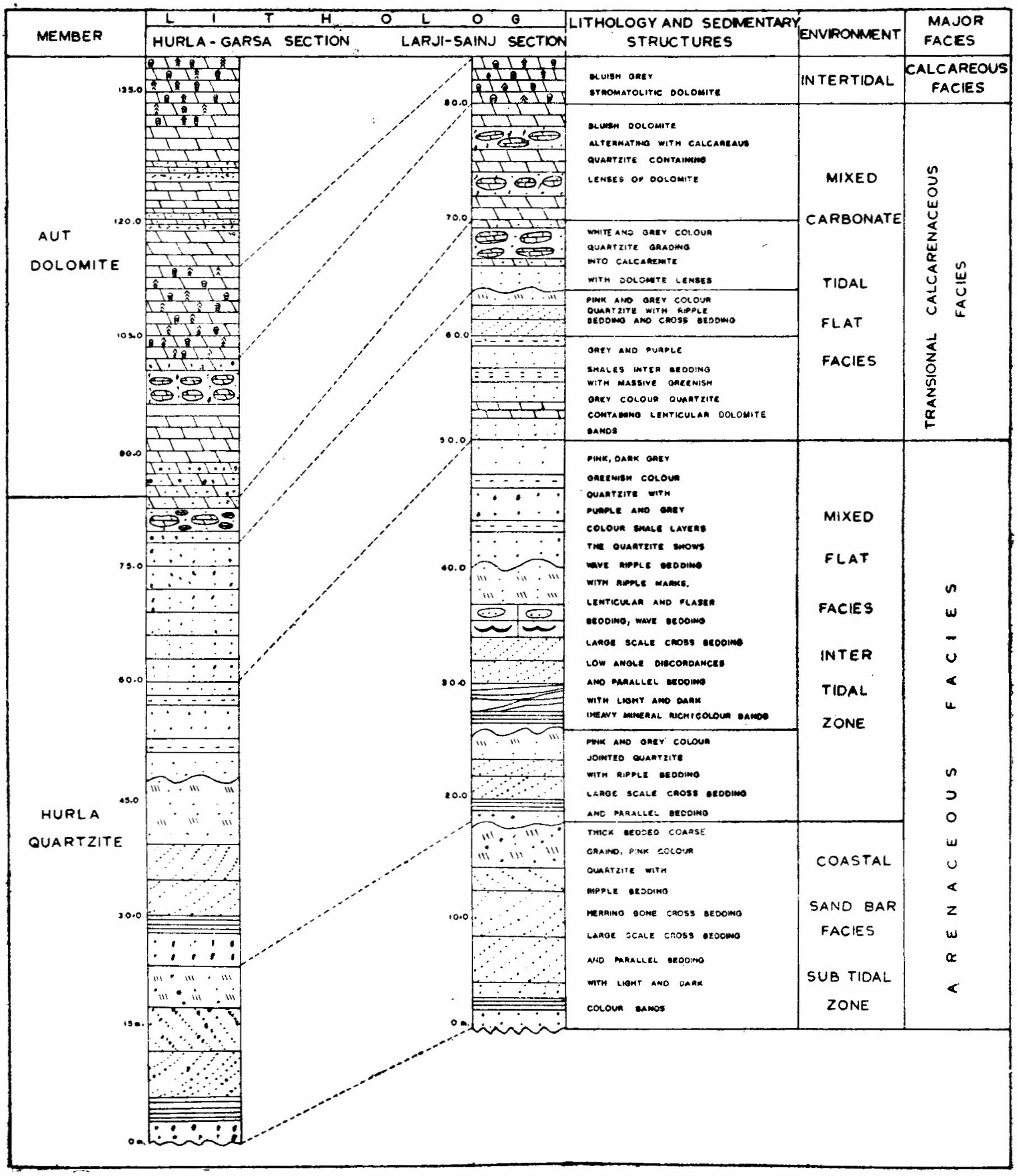

Fig. 3. Detailed litholog of Shali Formation showing lithology, distribution of sedimentary structures major facies change and environment of deposition in Hurla-Garsa and Larji-Sainj section.

mainly zircon and tourmaline besides magnetite and haematite are also present. The quartzite is thickly bedded and thickness varies from 20 cm to more than a meter. It is observed that at many places the quartzite contains shale and slate partings of dark purple, greyish and greenish colour which varies in thickness from few cms to a metre. These partings are invariably calcareous and contain lenses of grey and pink dolomite. The quartzite are jointed and fractured (Plate I/a).

The sedimentary structures such as parallel bedding (evenly laminated sand), scale cross-bedding (mainly sand bar type), wave ripple bedding, ripple marks (interference or rhomboid type), trough cross-bedding, lenticular and flaser bedding, etc. (Plate I/a, b, c and d) present in the Hurla Quartzite are characteristic of shallow marine environment (mainly in subtidal-intertidal zones of tidal flat).

The Hurla Quartzite shows gradational contact with the overlying dolomite (Aut Dolomite). In the upper part of the quartzite near the contact with dolomite, some lenticles of dolomite appear in the quartzite. This mixed zone of quartzite and dolomite (transitional calcarenaceous facies) grades upward into a thick sequence of interbedded dolomite and limestone (calcareous facies which is stromatolitic) belonging to Aut Dolomite Member.

AUT DOLOMITE: It represents the upper part of the Shali Formation and is made up of pink and bluish grey limestone and shale. The bluish grey colour dolomite is siliceous, intraclastic oolitic and cherty. The carbonate rocks especially the intraclastic-oolitic dolomite shows effect of diagenesis, low grade metamorphism and deformation which has partly or wholly obliterated the oolitic structure (Plate II/a and II/b). The calcite grains have been replaced by dolomite (Plate III/a) and show extensive recrystallization, early dolomitization and late dolomitization stages of diagenesis. Pressure-solution phenomenon were also observed in the contact of carbonate oolites (Plate II/b). Recycling of earlier formed oolites is also observed (Plate II/b). The oolitic band in dolomite exposed in tectonic contact with the overlying dark green chlorite schist of Rampur Formation near the village Garsa shows effect of deformation (Plate II/c). It is interpreted that the oolites were mainly formed in the high energy intertidal conditions and the conical and columnar stromatolites were formed in protected intertidal zone of carbonate tidal flat.

In the west, the Mandi salt beds are found associated with Pracambrian Lower Shali limestone at Drang, Guma and Megal. The Lower Shali Limestone is characterised by Lower to Middle Riphean stromatolite assemblage *Conophyton cylindricus–Colonnella columnaris–Kussiella kussiensis*. The occurrence of salt in the tidal flat environment of Shali Formation suggests development of stromatolitic evaporite carbonate platform conditions. The Mandi salt beds have been correlated with the Saline Series (Precambrian) of Salt Range in Pakistan, Haqf Group of Oman and Hormuz Series of Iran (Srikantia and Sharma, 1972; Tewari, 1984 b).

PALAEOENVIRONMENTAL MODEL AND FACIES CHANGE:

Based on detailed studies of sedimentary structures in Larji-Sainj and Hurla-Garsa sections, following facies changes were noted and depositional environment interpreted.

1. The lower part of Hurla Quartzite show large scale cross bedding (sand bar type) (Plate I/d and I/b; Fig. 3). The foreset laminae show low angle of dips. Other structures are parallel bedding and planes of discontinuity. Ripple bedding is also seen (Plate I/c). This quartzite represents deposits of subtidal sand bars.

2. The sandy and interbedded purple shales occur alternately and represent a mixed tidal flat facies. The shale partings are purple and greenish in colour and the sandy parts are grey, pink and white in colour. This facies is characterized by lenticular and

flaser bedding (Plate I/b and Fig. 3) few cms to 24 cm in thickness, wavy bedding, parallel bedding, tidal bedding, small ripple bedding (Plate I/b and I/c) and ripple marks (wave ripple type and interference type) (Plate I/a). Ripples mostly show rounded crests. This succession of sedimentary structures suggest a mixed flat facies (Fig. 3).

3. The subtidal sand bar facies and intertidal mixed flat facies alternate with each other in both the sections (Fig. 3). Many such cycles have been observed in the Hurla Quartzite.

4. This facies grades into calcarenite facies which shows lenses of dolomite in quartzite and represent a mixed carbonate facies (Fig. 3). The limestone pepples have no orientation and vary in size from few cm to 15 cm.

5. Calcareous quartzite grades into the Aut Dolomite (purely calcareous stromatolitic facies). This facies is characterised by algal biostromes, oolites and intraclasts and represent medium to high energy protected intertidal sedimentation.

RAMPUR FORMATION : The lower part of the Rampur Formation comprises of amphibolite, dark green chlorite schist, tuffaceous phyllite, greenish to purple slate and subordinate greenish quartzite. It acquires a great dimension about 4 km wide and 1 km thick between Sarsari and Shat. The belt is traceable from south of Sainj and extends continuously northwards up to Shat. East of Shat it becomes narrow and finally sliced out to the west of Jari along the Chail Thrust (Fig. 1). The upper part of the Rampur Formation is made up of pink, purple, fawn, white and green, medium to coarse grained orthoquartzite interbedded with basic volcanics (Plate III/a). The outcrop is trending NNW-SSE. The belt is about 10 to 15 km wide and 2 km thick exposed in the Parbati valley between Malana in the north and Hawai in the south. The width decreases towards south of Hawai and south-east of Manihar. In the west of Larji, the Rampur Formation is missing and the Shali Formation is coming in direct contact with the overlying Chail Thrust (Fig. 2a, b). It may be emphasized that green tuffaceous chlorite schist and penecontemporaneous basic volcanics are essential components of the Rampur Formation specially in the Parbati valley of the present area.

Petrographic studies reveal that the Rampur Quartzite is medium to coarse grained subrounded to subangular metaquartzarenite consisting of 95-98% strongly undulant grains of quartz cemented together by silica. Subordinate amount of chlorite, sericite and iron oxides are also present. The accessory minerals are tourmaline, zircon, apatite and opaques. In the proximity of Chail Thrust the quartzite is cataclastically deformed. Sericite and chlorite are arranged in one direction and quartz grains show elongation parallel to foliation plane. Secondary outgrowth, recrystallisation, granulation of quartz along the margins, sutured boundaries are commonly observed along the Chail Thrust (Plate II/d).

The Rampur Quartzite is very poor in heavy mineral content and generally the ultrastable forms tourmaline and zircon are present. The other stable heavy minerals are apatite, magnetite, biotite and muscovite. The tourmaline and zircon occurs as rounded to sub-rounded grains. The heavy minerals indicate a complex source for the Rampur Quartzite.

The primary sedimentary structures in the quartzite are parallel lamination, low angle cross lamination, herringbone cross lamination and wave ripple marks (Fig. 4 and Plate II/e and II/f) and suggest a high to medium energy coastal sand bar-shoal-intertidal shallow water depositional environment. The influx of terrigenous material brought to the depositional basin was balanced by the subsidence and maintained the same environment for a long period in a single sedimentary cycle. Thus, it can be safely suggested that the Rampur Quartzite represent deposits of a shallow marine coastal (stable shelf) environment.

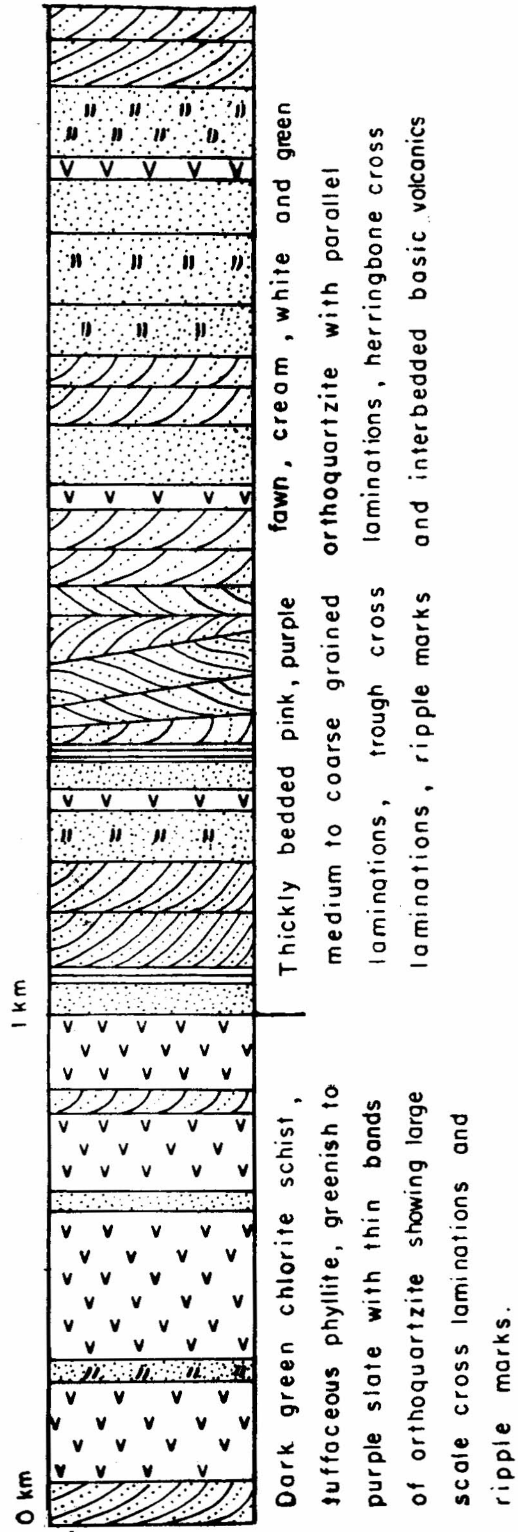

Fig. 4. Detailed litholog of Rampur Formation showing lithology and distribution of sedimentary structures in Parbati valley.

AGE OF LARJI-RAMPUR GROUP:

Sharma (1977) regarded the Larji-Formation (=Shali Formation of the present authors) to be mainly Permian in age without any fossil evidence. However, presence of Riphean stromatolites (Sinha, 1977 and Tewari, 1983, 1984a, b, 1985) makes it Precambrian carbonate belt equivalent of Deoban (Gangolihat)-Tejam belt of Kumaun Lesser Himalaya. Valdiya (1969), Kumar and Tewari (1978) and Tewari (1983, 1984b) on the basis of stromatolites suggested that the Gangolihat Dolomite belong to the transitional period between the Lower and Upper Riphean, that is Middle Riphean. The range of the Gangolihat (Shali) would be between 1300-1000 m. y. In the northwest, the extension of Shali is known as Dharamkot Limestone which also contains Lower to Middle Riphean stromatolites (Tewari, 1985), and further extends westward and join with the Jammu (Great) Limestone.

The volcanosedimentary succession of Rampur Formation is intruded by Bandal Granite near Manihar which give two radiometric ages i. e. 1800 m. y. (Frank, 1973-74) and 1220 m. y. (Bhanot *et al.*, 1976). The U-Pb isotopic ages of uraninites from Manikaran Quartzite (=Rampur Quartzite) of Kulu area and Berinag Quartzite of Kumaun (Bhalla and Gupta, 1979) gives 725 m. y. age.

CHAIL GROUP: The Larji-Rampur window Group is tectonically overlain by the 5 to 6 km thick and 2 km wide sequence of low grade metamorphics of the Chail Group (Chail Nappe of Pilgrim and West, 1928) along the Chail Thrust. The following sequence is observed in the Chail Group from base to top:

(*iii*) Biotite phyllite, quartzite, carbonaceous slate with thin bands of crushed limestone.

(*ii*) Quartz-sericite-chlorite puckered phyllite with occasional development of garnet, quartz porphyry (Plate III/d) and foliated quartzite.

(*i*) Mylonitised gneiss (Plate III/b, c) and carbonaceous slate.

The Chail metamorphics are intruded by Dalhousie-Dhauladhar and Mandi-Karsog granitic batholith. Rb/Sr whole rock isochron age for Chail gneiss in Sutlej valley in Nirath-Baragaon area is 1430±150 m. y. (Bhanot *et al.* 1978). The granites in the Chail Nappe were earlier regarded as Tertiary in age (McMahon, 1877; West, 1934-35). However, recent radiometric age determinations show that they are Precambrian in age. Jaegar *et al.* (1971) proposed 500±100 m. y. (Rb/Sr whole rock age for the Mandi Granite) while Mehta (1977) obtained 545±12 m. y. Rb/Sr age of the Mandi Granite. In the northwest, Bhanot *et al.* (1974) reported 456±50 m. y. Rb/Sr age for the Dalhousie Granite. All these ages show that the magma of these granites was produced during the late Precambrian-Cambrian (500-600 m. y.) times and intruded the Chail metasediments of Lower Riphean age (1200-1400 m. y.).

With regard to the existence of the Chail Thrust, the following evidences are significant:

(1) Throughout its contact with the underlying Larji-Rampur window Group, the Chail rocks are intensely mylonitised (Plate III/b,c) grading marginally into sericite-chlorite phyllite showing pronounced crumpling, crushing and even shearing. Similarly the underlying Rampur Quartzites at the contact are strongly sheared, pulverized and highly sericitized.

(2) The change in lithology across the thrust plane is very sharp, in addition to having discordant relationship. In the eastern part of the area, around Manikaran, the underlying volcano-sedimentary succession of Rampur Formation is overlain by the thick argillaceous sequence of the Chail Group. The Rampur Quartzites dip steeply 60° to 70° due NNE/NE, while the Chail rocks dip 20° to 30° towards NE/ENE. In the western part of the area, the Rampur Formation is missing so that the argillaceous Chail metamorphics rest directly over the calcareous sequence of Shali Formation across the Chail Thrust (Fig. 1 and Fig. 2/a).

(3) All along the contact, high degree of silicification of the rocks is noticeable. In the gneisses of the Chail Group, the quartz veins have been boudinaged parallel to the foliation and show development of tension gashes.

(4) The Chail Group shows three generations of fold trending ENE/NE-WSW/SW; NNW/NW-SSE/SE; NNE/NE-SSW/SW, in contrast, later two generations of fold trending NNW/NW-SSE/SE; NNE/NE-SSW/SW are present in the Larji-Rampur window Group. The first phase structures are isoclinal reclined folds with gently (20° to 25°) ENE/NE plunging fold hinge lines and having axial plane cleavage parallel to the foliation, dipping gently due ENE/NE. Conspicuous penetrative mineral lineation including stretched feldspars and mylonite banding in the gneiss is related to the first deformation, involving a considerable tectonic transport. The Chail Group rocks were developed as nappe and moved southward along the thrust sheet during the first phase of deformation. The second phase structures are open, upright antiforms and synforms, with their axes trending NNW/NW-SSE/SE, the axial planes dipping steeply either eastward or westward (Plate III/e). A large antiform of the second generation called *Beas Antiform* trending NNW-SSE and a complimentary synform (*Hanogi Synform*) has folded both the tectonostratigraphic units (Fig. 1). Another major antiform trending NNW-SSE lies in the central part of the Larji-Rampur window zone. The third-generation folds are represented by conjugate, asymmetrical, open folds and kink bands trending NNE/NE-SSW/SW (Plate III/f). The lineations formed during the second and third episode of deformation are mostly in the form of puckers parallel to the F_2 and F_3 fold hinge lines. The second and third phase structures are common in the Chail Group as well as in the tectonically underlying Larji-Rampur window Group.

(5) Landslides as well as the hot springs are very common along the Chail thrust.

(6) In the vicinity of the thrust zone, the basic volcanics (amphibolites) of the Rampur Formation have been altered to chlorite schist, and the quartzite shows weakly developed foliation (Plate III/a).

Thus, the evidences indicate that the Chail Group is an allochthonous mass thrust over the volcano-sedimentary succession of Larji-Rampur window Group.

In the Garhwal Himalaya, the Bhatwari and Barkot granitic porphyroids (Valdiya, 1975, 1978) lying in southern Chamoli and southeastern Uttarkashi areas, represent southeastern extension of the Chail Group of the present area. In the Kumaun Himalaya, the Okhalkanda Gneiss and Rikhakot Schist (Misra, 1980, 1985) of Debguru Formation of Ramgarh Group (Valdiya, 1980) bear remarkable similarity with the mylonitised gneiss and sericite-chlorite schist of the Chail Group of the present area. In the east, in Bhutan, the sheared and mylonitized Samchi Granites described by Jangpangi (1974) are similar to the Chail Gneiss, Turning in west, the mylonitised gneissose granite of Dalhousie-Dhauladhar (Fuchs and Gupta, 1971; Bhatia and Kanwar, 1973) represent northwestern extension of the Chail Group of Kulu area.

JUTOGH GROUP: The Chail Group in the north of Kulu is overthrust by the medium grade metamorphics of the Jutogh Group (Jutogh Nappe of Pilgrim and West, 1928). The following lithological sequence is observed between Kulu and Rohtang from base to top.

(4) Fine grained banded gneiss.

(3) Foliated micaceous quartzite.

(2) Biotite schist with foliated micaceous quartzite.

(1) Garnetiferous-biotite phyllonite and schist.

The Jutogh Thrust is a low angle thrust dipping 20° to 30° due north and passes through north of Kulu, Malana and Barsheni (Fig. 1 and Fig. 2/b). The persistent band of garnetiferous-biotite phyllonite marks the base of the Jutogh Nappe. The Jutogh Thrust demarcates the plane of abrupt change of grade of metamorphism: the sericite-chlorite phyllite, sericite quartzite, mylonitized gneiss and carbonaceous slate of the Chail Group representing green schist facies of metamorphism, in contrast to the garnetiferous mica schist and gneiss of the Jutogh Group, shows amphibolite facies display inverted metamorphism. The grade of metamarphism in the Jutogh Group increases in the north towardst he top and decreases in the south. The underlying sericite-chlorite phyllites of the Chail Group shows crumpling, crushing and shearing along the Jutogh Thrust.

The age gap between the Chail and Jutogh has remained undefined till now. Majority of workers accepted that the Chail constitutes the younger (Algonkian) and least metamorphosed part of the Jutogh sequence, (Pascoe, 1950; Kumar and Pande, 1974; Srikantia, 1973). However recently Rb/Sr whole rock isochron age of Wangtu granitic gneiss (Satlej valley, H. P.) of the Jutogh Group indicate about 2000 m. y. (Bhanot *et at.* 1980).

The Jutogh Group of the present area extends southward along the strike across the Sutlej River towards Narkanda and Matiana where they join with the Jutogh of Pilgrim and West (1928), and further extends southeast into Kumaun, where it is called the Munsiari Formation at the base of the Higher Himalaya (Valdiya, 1980). In the east in Bhutan, the Thimpu Granitoids described by Jangpangi (1974) bear remarkable similarity with the Jutogh of the present area. Further east in the Kaemeng district of Arunachal Pradesh, the Bomdila Formation comprising mica schist, garnetiferous mica schist and porphyroblastic gneiss (Das *et al.* 1975) represent the equivalent of the Jutogh Group of Kulu Rohtang area of Himachal Pradesh.

VAIKRITA GROUP: The Jutogh Group in the north of Gulaba is overthrust by the high grade central crystallines of the Vaikrita Group (Valdiya, 1979) along the Vaikrita Thrust (Fig. 1 and Fig. 2/b). The Vaikrita Group shows the following lithological sequence in the Beas valley from base to top:

(3) Coarse grained quartzo-feldspathic biotite rich banded gneiss with tourmaline.

(2) Quartz-biotite garnetiferous schist interbedded with foliated micaceous quartzite.

(1) Kyanite-sillimanite schist and gneiss.

The NW-SE trending Vaikrita Thrust is a low angle tectonic plane dipping 15° to 20° due NE and passes through north of Gulaba. The Vaikrita Thrust demarcates the plane of abrupt change in grade of metamorphism and composition of lithology. The coarse grained kyanite-sillimanite schist and gneiss of the Vaikrita Group is tectonically underlain by the fine grained garnetiferous biotite schist, micaceous quartzite and gneiss. In the north of Rohtang, the Vaikrita Group is overthrust by the low grade metasedimentaries with 500 m. y. dated Jaspa Granite (Frank *et al.* 1977), called the Haimanta Group which forms the basal part of the Phanerozoic Tethys Himalayan sediments.

It is noticed that the rocks of the Vaikrita and Jutogh Groups show discordant relationship. Near the thrust plane, the underlying fine grained banded gneiss of the Jutogh Group are dipping gently 15° to 20° due NE, while the Vaikrita rocks having steep 40° to 50° inclination towards NE. Both the Jutogh and Vaikrita Groups of rocks show three phases of deformation but the style and pattern of folding seems to vary across the thrust plane. The Vaikrita rocks exhibit, the earliest (F_1) isoclinal recumbent folds trending NW-SE, the second (F_2) open to tight folds are coaxial with F_1 fold, and the third (F_3) asymmetrical and open folds plunging gently due NNE. The underlying Jutogh rocks show, the F_1 isoclinal reclined fold trending ENE/NE-WSW/SW, the F_2 asymmetrical and open folds trending NW-SE and the third (F_3) folds are mostly developed in the form of puckers trending NNE/NE-SSW. Throughout the extension of Vaikrita Thrust, the kyanite-sillimanite schist and gneisses are highly sheared aad mylonitized while the underlying fine grained micaceaus quartzite of the Jutogh Group is sericitised and crushed.

In the Rohtang area, Bhanot *et al.* (1975) determined an apparent age of 612± 100 (634) m. y. for a gneissic sample which was collected from south of Rohtang Pass, but almost near the top.

DISCUSSION AND CONCLUSIONS

A careful study of cross-bedding and ripple marks in the Rampur Quartzite reveals beds to be in normal stratigraphic order and there is no evidence to presume a large scale overturning as suggested by Sharma (1977). Sharma (1977) assigned Devonian to Carboniferous age of Banjar (Rampur) Formation and Permian age for Larji (Shali) Formation. However, the Rampur Formation is intruded by Bandal Granite which gives 1800 m. y. age (Frank *et al.* (1973-1974). If 1800 m. y. age of Bandal Granite is true then the Rampur sediments must be older than 1800 m. y. ard tectonically resting over the stromatolitic (*Conophyton-Baicalia* assemblage) limestone of Shali Formation dated as Middle Riphean (Sinha, 1977; Tewari, 1983; 1984 a, b).

Virdi (1981) included the Kulu metamorphics within Chails and metamorphic sequence to the east of Manikaran within Jutogh. According to him, the Chail on the eastern side of Rampur window is overlapped by Jutogh which rests directly over the Rampur along the Main Central Thrust. However, the present mapping reveals that the Larji-Rampur window Group is framed on all sides by the Chail metamorphics. The mylonitized gneiss, carbonaceous slate, phyllite and quartzite sequence of Chail Nappe exposed around Kulu extends continuously towards northeast through Jari, Malana and to the east of Manikaran. Hence, on the eastern side of Rampur window, the Jutogh tectonically rests on the Chails not directly over the Rampur as suggested by Virdi (1981).

The volcano-sedimentary succession of the Rampur Formation is overthrust by the Chail metamorphics. The Rampur lithology highly crushed, shattered and pulverized is near the contact with Chail metamorphics indicating tectonic nature of contact marked by discordence of dip across the tectonic plane. The Chail metamorphics dipping gently 20° to 30° due NE/ENE rest over the steeply dipping 60° to 70° due NNE/NE Rampur quartzite along the Chail Thrust. The gneisses of the Chail, show very strong mylonitisation in the vicinity of the thrust zone.

In the west of Larji, the Rampur Formation is missing and the Shali Formation coming in direct contact with Chail metamorphics across the Chail Thrust. The thrust (*Garsa Thrust*) between the Shali Formation and Rampur Formation is concealed under the Chail Thrust sheet (Fig. 2/a).

The mylonitised gneiss marks the base of the Chail thrust sheet, the garnetiferous biotite phyllonite marks the base of Jurogh and the high grade kyanite-sillimanite schist and gneiss marks the base of Vaikrita above.

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EXPLANATION OF PLATES

PLATE—I

(a) Thickly bedded, jointed, fractured Hurla Quartzite showing colour and textural banding and wave ripple marks. Larji-Sainj section.

(b) Hurla Quartzite showing small and large scale cross laminations, parallel laminations, wave ripple bedding, lenticular and flaser bedding, planes of discontinuity, wavy bedding and tidal bedding. Lenght of pen=13 cm Larji-Sainj section.

(c) Hurla Quartzite showing evenly laminated sand (parallel bedding) textural banding and ripple bedding. Length of pen=13 cm. Hurla-Garsa section.

(d) Hurla Quartzite showing finely laminated sandy layers, parallel laminations, small and large scale cross laminations Length of pen=13 cm.
Hurla-Garsa section.

PLATE—II

(a) Microphotography of Aut Dolomite showing partially to completely replaced oolitic structure. The recrystallization and replacement of calcite by dolomite (dolomitization) has been observed crossed nicol).

(b) Microphotograph of Aut Dolomite showing various stages of diagenesis, recycling of earlier formed oolites as composite oolites and phenomenon of pressure solution (crossed nicol).

(c) Microphotograph of Aut Dolomite showing stretching and elongation of oolites. (crossed nicol).

(d) Microphotograph of the Rampur Quartzite showing sub-angular to sub-rounded quartz grains, suture boundaries and effect of recrystallization (crossed nicol). Locality-Manikaran, near the Chail Thrust.

(e) Rampur Quartzite showing parallel lamination, low angle cross lamination and large scale cross lamination. Length of hammer=30 cm.
Locality-Kasol in Parbati valley.

(f) Rampur Quartzite showing wave ripple marks. The bifurcation of ripple is clearly observed.
Locality-Parbati-Beas confluence.

PLATE—III

(a) Sheared dark green chlorite schist interbedded with the Rampur Quartzite near the Chail Thrust.
Locality-Kasol.

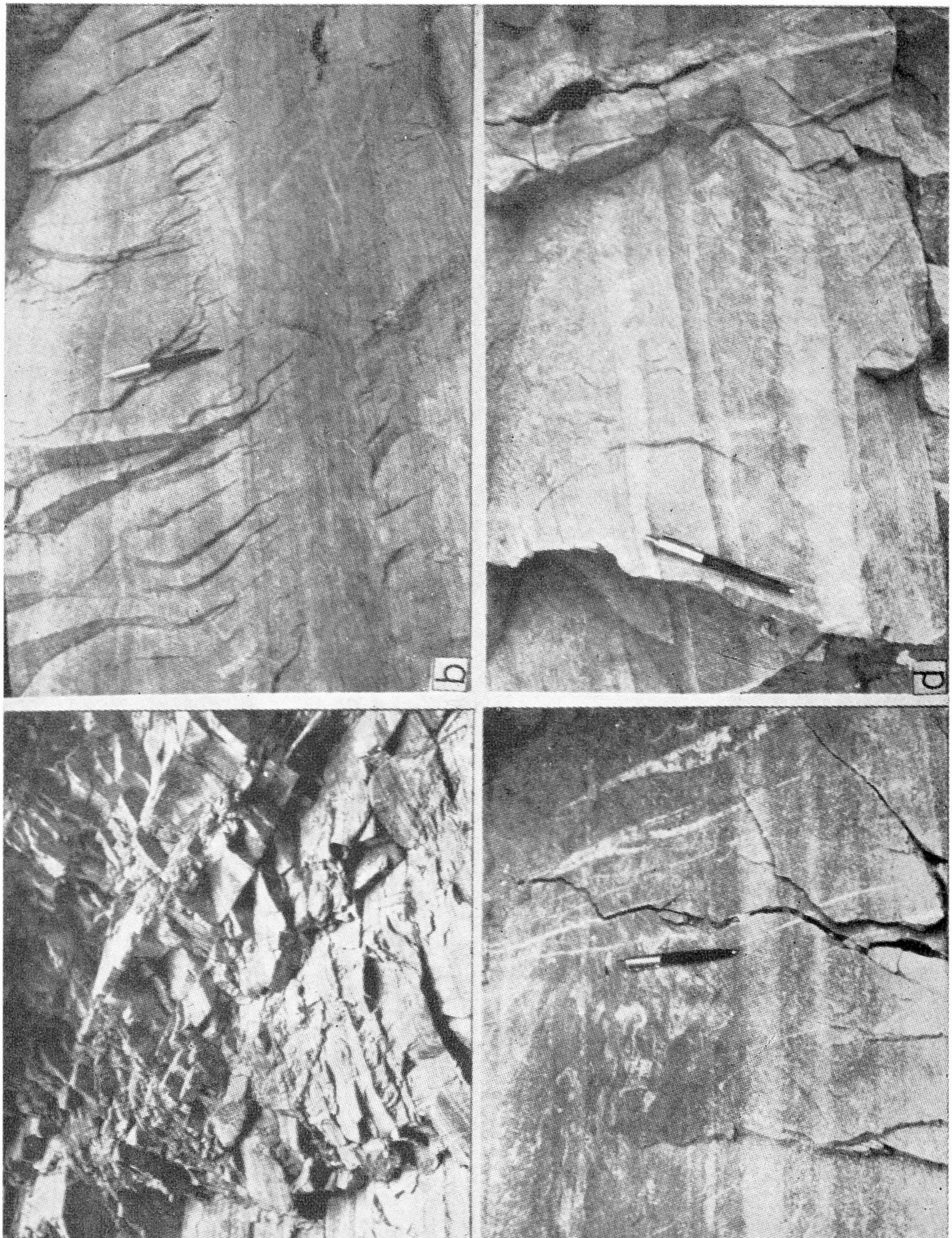
(b) Augen Mylonite.
Locality-Parbati-Beas confluence, near the Chail Thrust.

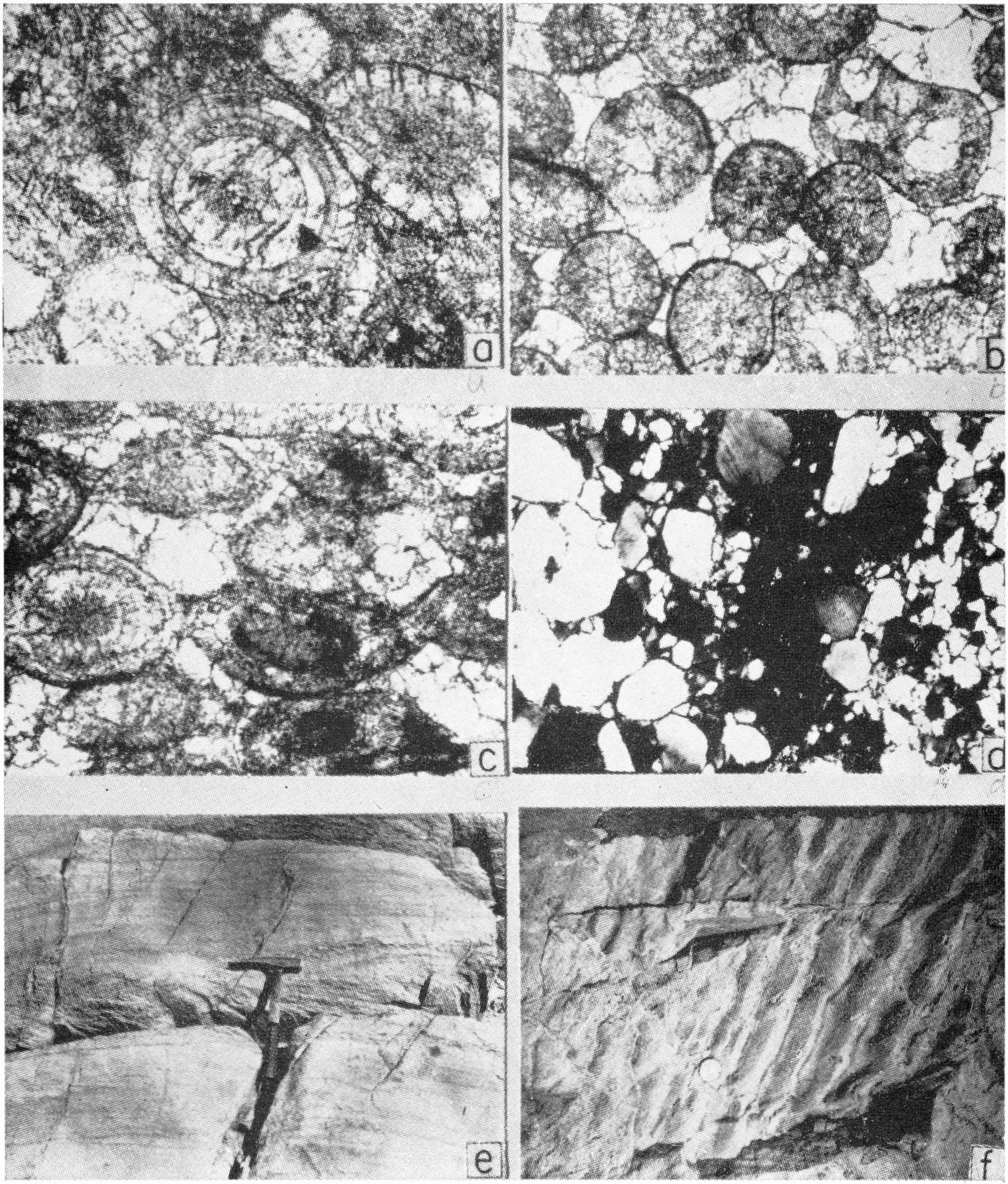
(c) Mylonitised gneissose quartz porphyry.
Locality-Kulu, near the Chail Thrust.

(d) Quartz Porphyry.
Locality-Kulu.

(e) Open fold F_2 in the sericite-chlorite schist.
The fold hingeline trending NW-SE.
Locality-Jari.

(f) Asymmetrical fold F_2 in the gneiss. The fold hingeline trending NE-SW. Locality-Parbati-Beas confluence, near the Chail Thrust.

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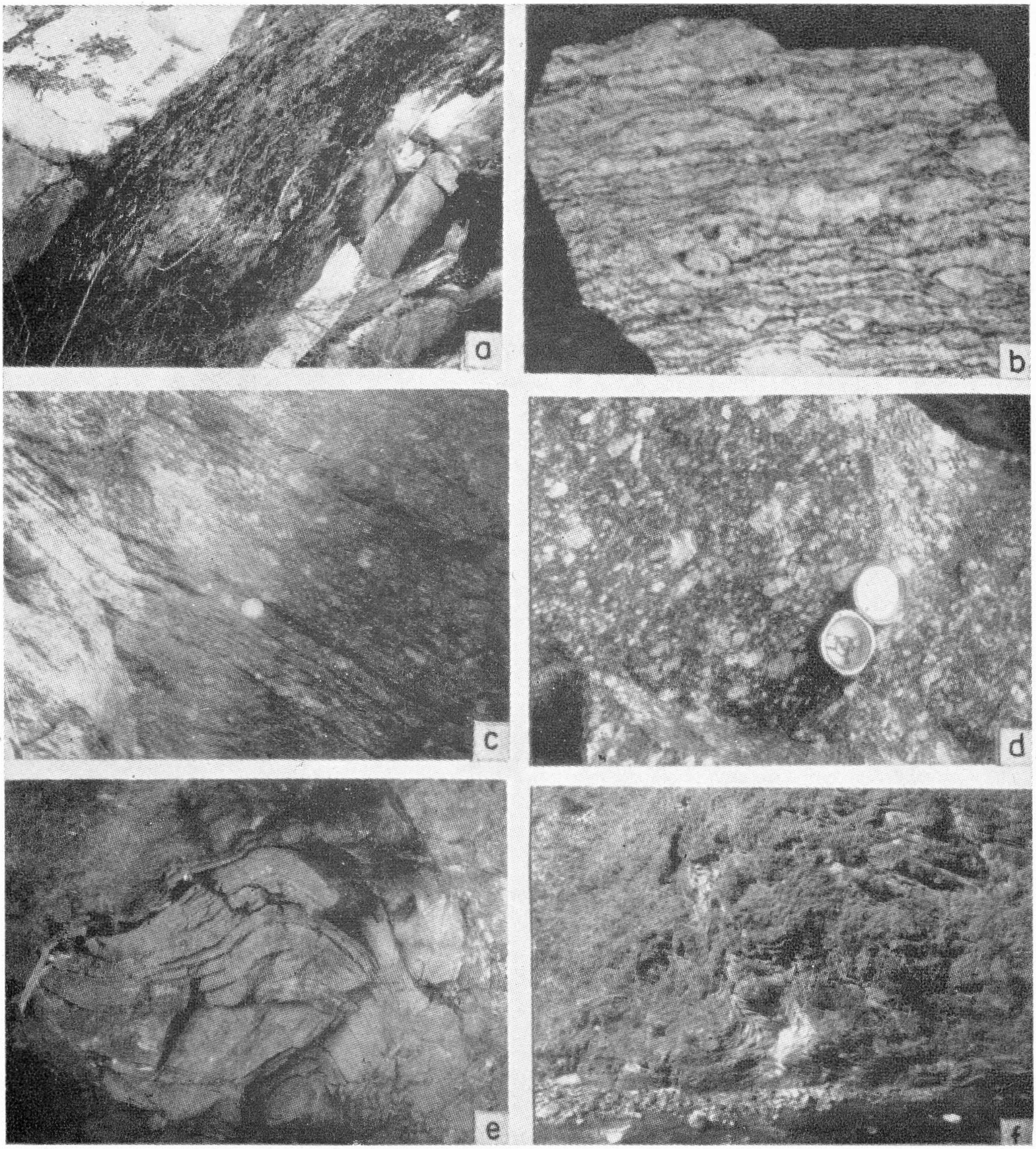

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