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STRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER SIWALIK GROUP, SAKHI SARWAR AREA, SOUTHERN ZINDAPIR ANTICLINE, SULAIMAN RANGE, PAKISTAN

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ABSTRACT

The Zinda Pir anticline, forming foothills east of the Fort Monro anticline, exposes the Siwalik Group along its periphery. The Siwalik Group exposed in the area includes Vihowa, Litra and Chaudhwan Formations. The Vihowa Formation consists of grey and brown sandstone and red to brownish-red siltstone. The overlying Litra Formation comprises of light-grey sandstone with subordinate brown to reddish-brown siltstone. The Chaudhwan Formation overlies Litra Formation and predominantly consists of conglomerates with ancillary interbedded pale-grey sandstone. Sedimentological studies of the upper Litra Formation reveal presence of siltstone/claystone as overbank deposits, and conglomerate, trough cross-bedded sandstone, low-angle plane-bedded sandstone and planar cross-bedded sandstone as channel deposits. Whereas the Chaudhwan Formation dominantly comprises conglomerates, deposited as diffuse gravel sheets during high flow, with minor sandstone and siltstone/claystone units. Paleocurrent analysis suggests a SSE-ward paleo-flow. The sandstones of the Litra and the Chaudhwan Formations are texturally similar. Moderate angularity and sorting, along with high content of feldspar indicate textural immaturity of these sandstones and substantial contribution from a northern provenance. Whereas, the petromict orthoconglomerates of the Chaudhwan Formation indicate a predominant western provenance (i.e., Fort Monro anticline).

INTRODUCTION

The Siwalik Group represents syntectonic molasse sequence deposited in a foreland-basin. The detritus for this sequence was derived from the newly formed Himalayan mountain belt, therefore, this sequence provides a remarkable record of the Himalayan orogeny. Furthermore, this sequence also records changes in surficial sedimentary patterns, that resulted due to concurrent tectonic activity.

In view of the significance of these synorogenic molasse sequences, their sedimentologic studies can provide important clues regarding (1) the evolution of sedimentary systems in response to the advancing deformation front, (2) changes in paleocurrent directions (3) unroofing and uplift history of the adjacent orogens. Chronological studies of such a molasse sequence can further lead to a better understanding of the dynamics of evolving foreland-basins (Burbank et al., 1988).

Thus far, most sedimentologic studies of the Miocene-Pleistocene molasse of northwestern Pakistan, have been confined to Kohat-Potwar plateaux and the Trans-Indus Ranges (e.g., Visser & Johnson, 1978; Opdyke et al., 1979; Johnson et al., 1979; Raynolds, 1980; Behrensmeyer & Tauxe, 1982; Burbank, 1983; Johnson et al., 1982; Johnson et al., 1985a; Johnson et al., 1985b; Tauxe & Badgley, 1988; Khan et al., 1988, and Ahmed, 1989). At present, no such data are available for the Siwaliks of Sulaiman Range.

Therefore present studies are directed towards sedimentologic studies of the Upper Siwalik sequence exposed in the Sakhi Sarwar area of southern Zinda Pir anticline, Sulaiman Range (Fig. 1). This work is a step towards understanding Siwalik sedimentation and the contemporaneous tectonic activity in the Sulaiman foreland basin. Further expansion of current study, and eventual, chronologic as well as lithologic correlation with Siwaliks of the Kohat-Potwar Plateau, and Trans Indus Ranges, will help in developing a broader understanding of temporal as well as spatial evolution of the Himalayan orogen and its related foreland basins, in Pakistan.

PLIOCENE-PLEISTOCENE STRATIGRAPHY

Siwalik Group

The Siwalik Group in Waziristan area and Sulaiman fold belt comprises a molasse sequence of about 3000 m that has been divided into three formations (Hemphill and Khidwai, 1973). This sequence includes (in younging order) Vihowa Formation, Litra Formation and Chaudhwan Formation.

Vihowa Formation

The Vihowa Formation is predominantly composed of red to maroon, sandy and silty claystone, with subordinate greenish- grey, thick bedded sandstone. The sandstone consists of subangular, medium to coarse grains, and is commonly cross-bedded. The formation is exposed all along the foothills of the Sulaiman Range and varies in thickness from 313 m to 770 m. An unconformity between Vihowa Formation and the underlying Chitarwata Foramation has been reported from a locality close to the present study area (Eames, 1950). Further north (in the Bunnu quadrangle), where

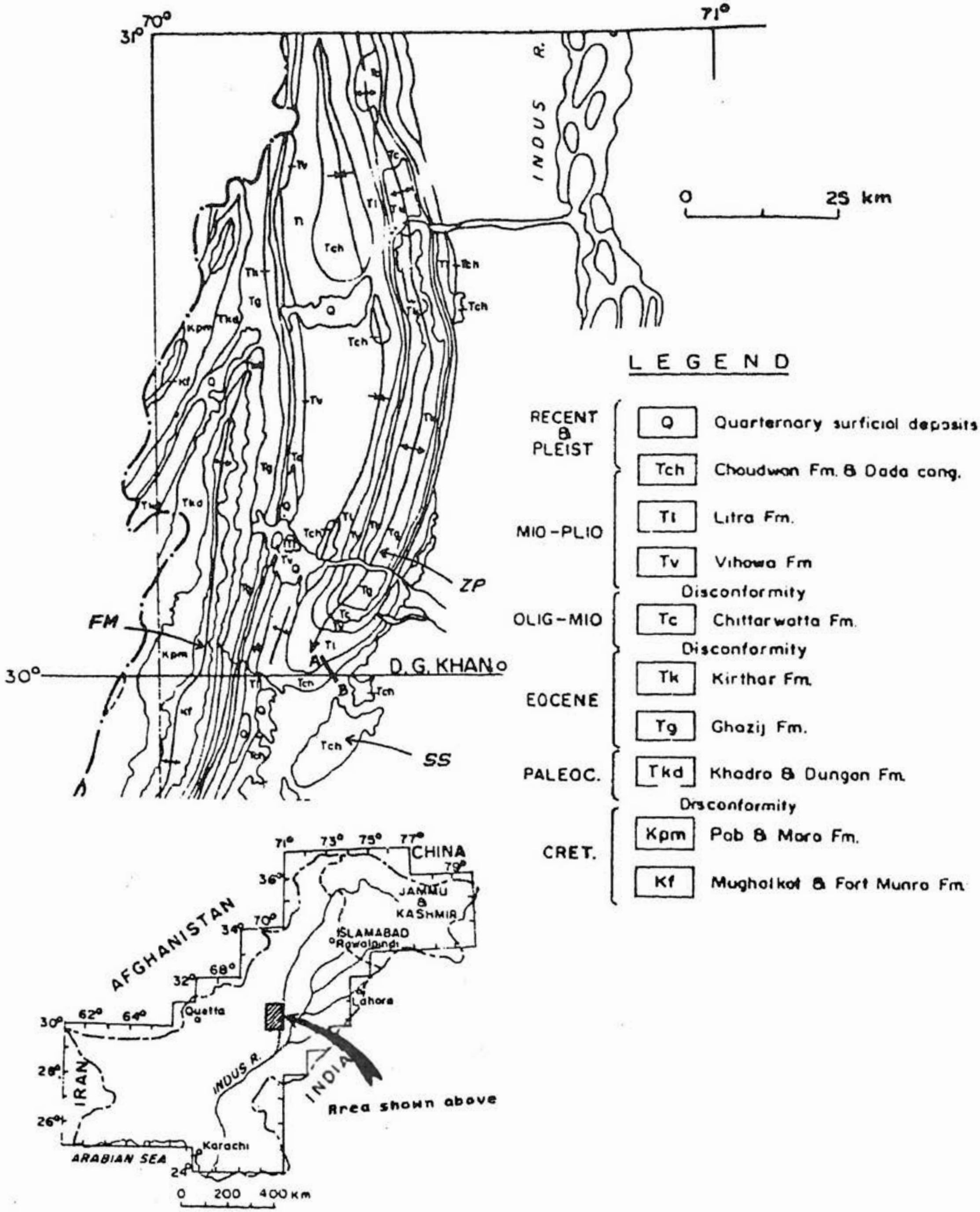

Fig. 1. Geological Map of part of Sulaiman Range. FM = Fort Monro anticline; ZP = Zinda Pir anticline; SS = Sakhi Sarwar anticline.

Chitarwata Formation is missing (or not recognized), the contact with the underlying formations is disconformable and sharp. The upper contact with Litra Formation is transitional.

Litra Formation

The Litra Formation represents the middle unit of the Siwalik Group in Sulaiman fold belt. Light grey fraible sandstone makes up the larger portion of this formation. Some red to reddish-brown clay beds are also present. Moderate angularity and sorting, along with the high content of feldspar evince the textural immaturity of these sandstones.

A detailed stratigraphic column depicting the upper 700 m of the Litra Formation is shown in Fig. 2. On the basis of preliminary magnetostratigraphic studies of upper Litra Formation, it has been assigned a late Pliocene age (Ahmad, 1990). This correlation is supported by the late Pliocene Hipparion fossil reported from middle part of Litra Formation (Hemphill and Kidwai, 1973), in the vicinity of the present study area.

In Sulaiman fold belt the thickness of this formation varies from 1300 m to 2000 m. However, in the Sakhi Sarwar nala of southern Zinda Pir anticline, only the upper 700 m of the Litra Formation were measured. Lower portion of the Litra Formation is composed of massive multistoried sandstone and is not included in present studies. The upper contact with Chaudhwan Formation is apparently conformable in the study area.

Chaudhwan Formation

This is the upper most formation of the Siwalik Group in the Sulaiman fold belt. It predominantly comprises calcite-cemented petromict orthoconglomerate made up of granule-, pebble-, cobble- and boulder-sized phenoclasts. The voids are generally filled with arenaceous matrix. The phenoclasts comprise mostly of limestone (mostly Plaeocene-Eocene as evinced by the fossil fuana), sandstone (some of which bear semblence to the Pab Sandstone), quartzite, chert, along with some intrabasinal pebble-sized rip-up clasts of mudstone. Almost 90% of the phenoclasts are limestone while sandstone and the other types account for the rest.

Lithologic column of the Chuadhwan Formation exposed in the study area, is shown in Fig. 3. Lower part of the Chaudhwan Formation contains a few beds of pale-brown to brownish-red mudstone. Towards the base subordinate amount of pale-brown sandstone is present interbedded with the conglomerates. These clay- and sandstone-beds become scarce towards the top. Furthermore, along with the increase in frequency of conglomerate occurrence, the size of phenoclasts also gradually increase towards the top of the Chaudhwan Formation. The preliminary magnetostratigraphic studies suggest that the deposition of Chaudhwan Formation commenced around the beginning of the Brunhes Chron (i.e., about 700,000 yr. B.P.) (Ahmad, 1990).

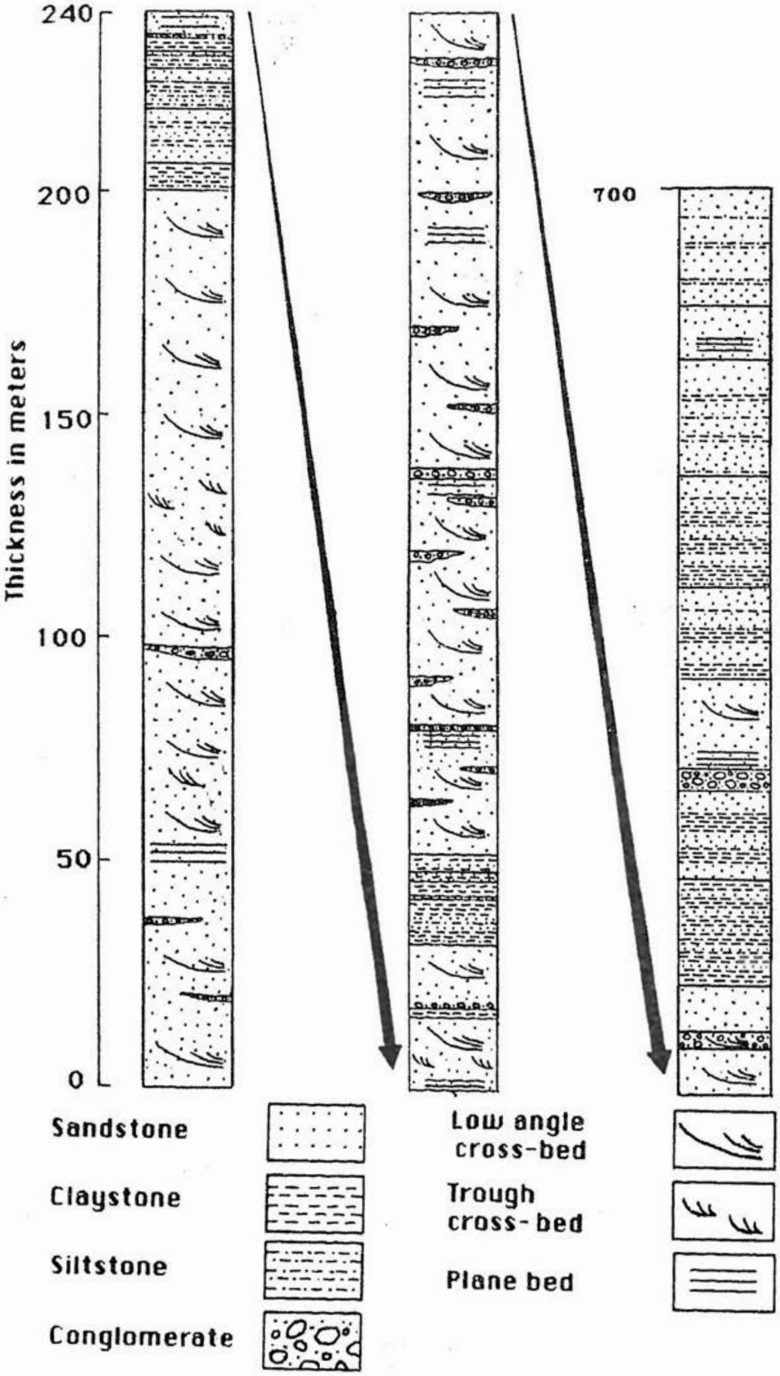

Fig. 2. Measured stratigraphic section of the upper 700 m of the Litra Formation exposed in Sakhi Sarwar Nala, southern Zinda Pir anticline.

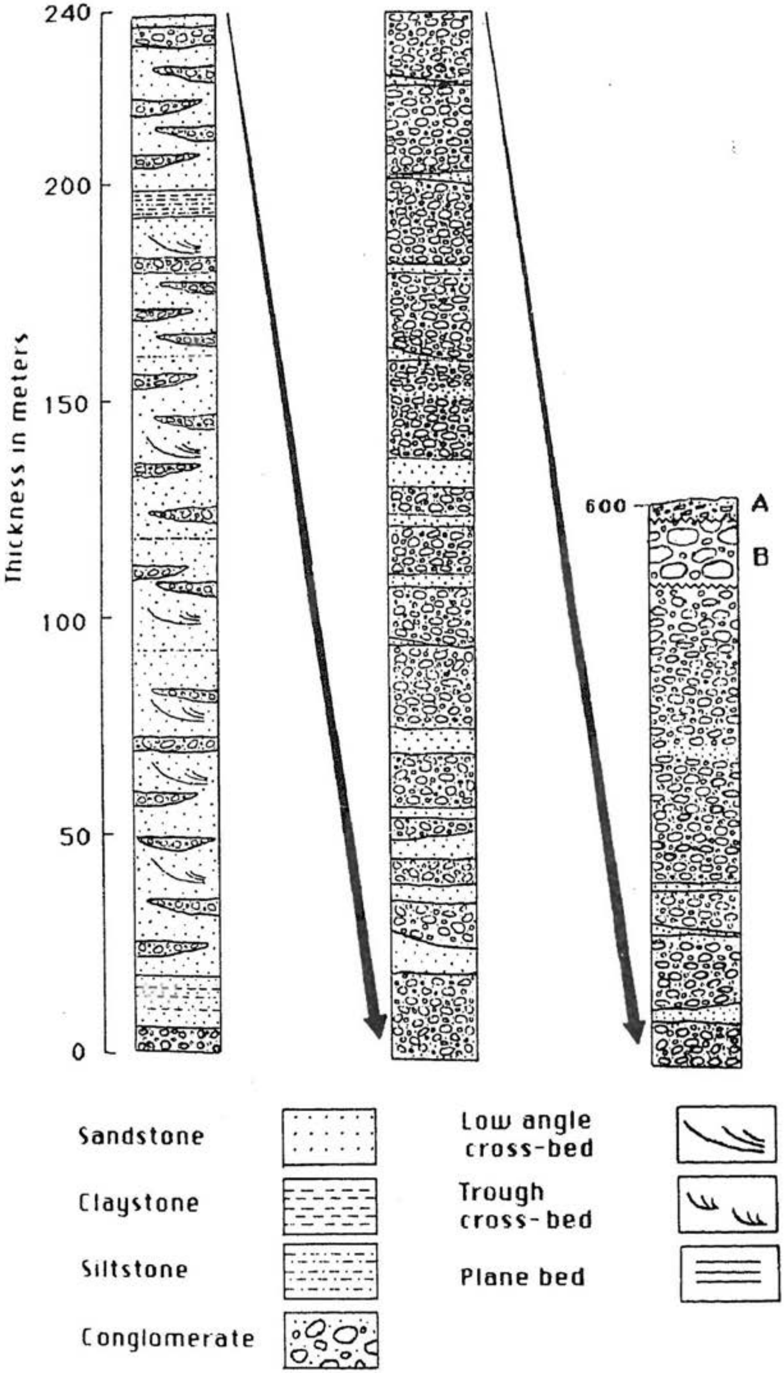

Fig. 3. Measured stratigraphic section of the Chaudhwan Formation and the overlying alluvial fan deposits in the Sakhi Sarwar Nala of southern Zinda Pir anticline.

Along the eastern foothills of the Sulaiman Range the Chaudhwan Formation is 130 m to 1400 m thick (Kaleem et al., 1987). In the present study area (i.e., Sakhi Sarwar nala) the formation is 571 m thick. The upper contact of this formation with the overlying boulder-bed is unconformable, as is indicated by the differential tilt of the beds (Fig. 4).

Recent Alluvial Fan Deposits

The Siwalik Group in the study area is overlain by Recent (50,000 to 10,000 yr. B.P., for details see Ahmad, 1990) boulder- and cobble-size alluvial fan deposits (Fig. 5). These boulders and cobbles are mostly unconsolidated or loosely cemented. Like the conglomerates of Chaudhwan Formation, these boulders and cobbles are dominantly of limestone (Paleocene-Eocene) along with sandstone (mostly from Cretaceous Pab Sandstone).

Around the study area, these alluvial fan deposits range in thickness from 8-15 m. Due to the youngest phase of tectonic uplift in the area, these fan deposits are also tilted (<10). Therefore, the subsequent reworking of these deposits has resulted in formation of a 2-4 m thick vaneer of present-day fanglomerate deposits, that crowns the sedimentary sequence in the area (Fig. 4).

SEDIMENTOLOGY

Upper Litra Formation

Generally, two dominant types of deposits can be distinguished in most sandy fluvial sequences. These comprise of (a) overbank or interchannel deposits formed by vertical accretion and (b) channel deposits, usually formed by lateral accretion (Allen, 1965). The upper Litra Formation contains both of these two types of deposits.

Overbank Deposits:

Siltstone/Claystone: These deposits are characteristic of inter-channel areas, and record the deposition of fine grained particles from suspension. Red coloration of such deposits generally indicates subaerially exposed floodplains. Whereas, a grey sequence points to the formation of these sediments in perennial swamps or shallow lakes that form in interchannel areas (Collinson, 1986). The overbank deposits in the upper Litra Formation are red to reddish-brown in colour. At places the top of these overbank deposits contains mudcracks filled with overlying sand. These features indicate deposition in subaerially exposed floodplains.

Channel deposits

Conglomerates: In the Litra Formation conglomerates mostly occur as lenticular channel-fill and lag deposits, ranging from 0.5 metres to 2 metres in thickness (Fig. 6). However, a few thick (up to 4 metres), unstratified and laterally extensive conglomerate beds are also present. These may record deposition on a flat bed with vigorous grain

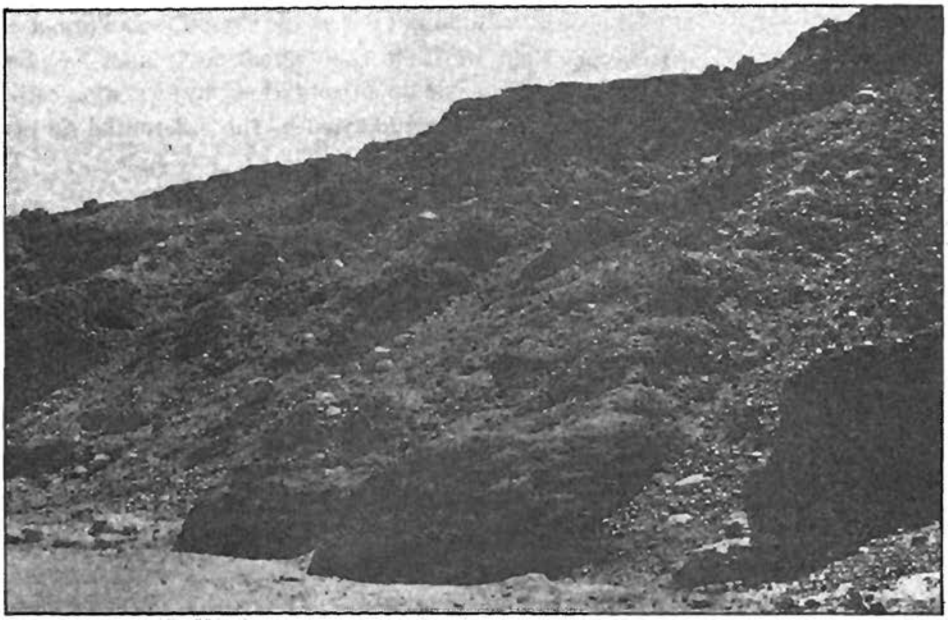

Fig. 4. Boulders and cobbles of alluvial fan deposits, lying on top of conglomerates of the Chaudhwan Formation (bottom of the picture). The boulders near the lower left corner of the picture are about 75 cm to 1 m in size.

Fig. 5. Channel infilled with conglomerate, cutting down into underlying sand. Upper Litra Formation.

transport that generally occurs on the top of a longitudinal bar or on a channel floor (Steel and Thompson, 1983).

Some conglomerate beds of this type are overlain by low-angle plane-bedded sandstone. Such a relationship can be the product of waning flood stages (Steel, 1974).

Trough cross-bedded sandstones: Trough cross-bedding is generally formed due to migration of lingoid or strongly sinuous sandwaves, or three dimensional dunes (Allen, 1982; Leeder, 1982).

This type of cross-bedding is the most eye-catching feature of the upper Litra Formation. Most of such cross-bedding is of large scale with cross-sets of up to 1.5 m thickness (Fig. 7). However, at some places small scale trough cross-bedding is also observed (Fig. 8).

Low-angle plane-bedded sandstones: In sandstones, low-angle plane-bedding is formed under upper regime plane-bed flow with intense sediment transport over a flat bed (Allen, 1964, 1982; Leeder, 1982). Low-angle plane beds can also be formed by shallow, high velocity flow into broad scours that are too shallow to permit flow separation and formation of true cross-strata (Rust, 1984).

Although sparsely present in the upper Litra Formation, the low-angle plane beds do occur at places and grade upwards into large scale trough cross-bedding (Fig. 9).

Planar cross-bedded sandstones: Planar cross-bedding is the manifestation of migrating two dimensional, straight crested dunes and megaripples (Allen, 1982; Leeder , 1982). These indicate flow conditions of lower energy than those depicted by low-angle plane-bedding.

At some places in the upper Litra Formation tabular cosets of planar cross-bedded sandstone are also present. These may represent periodic or quasi-periodic bedforms with water depths sufficiently high to allow deposition as cosets (Rust, 1984). In such cosets present in the upper Litra Formation, thickness of a single set varies from 1 - 1.5 m. Such thick tabular cosets generally indicate downstream accretion on oblique or longitudinal bars (Harms et al., 1982).

A prominent feature of the Litra Formation is occurance of mud-balls at various statigraphic levels. Trains of these mud-balls commonly lie along the cross-laminae in cross-bedded sandstones (Fig. 10). These mud-balls range from pebble- to boulder-size, and represent the eroded overbank-fines. Due to the soft nature of these mud-balls these are commonly eroded, leaving behind rounded nooks in the sandstone.

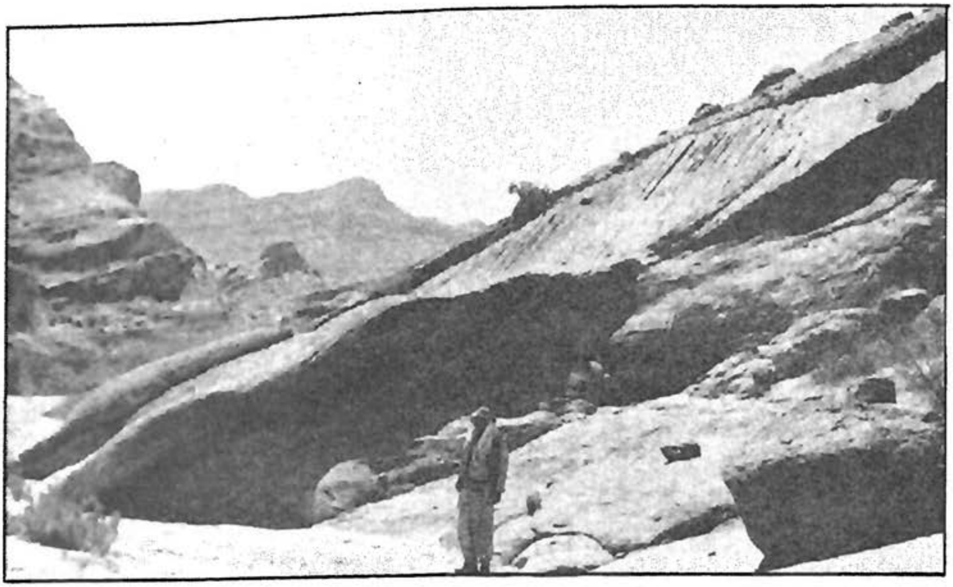

Fig. 6. Large-scale trough cross-bedding in sandstone of the Litra Formation (man pointing towards the paleocurrent direction, i.e., SSE, depicted by the cross-beds).

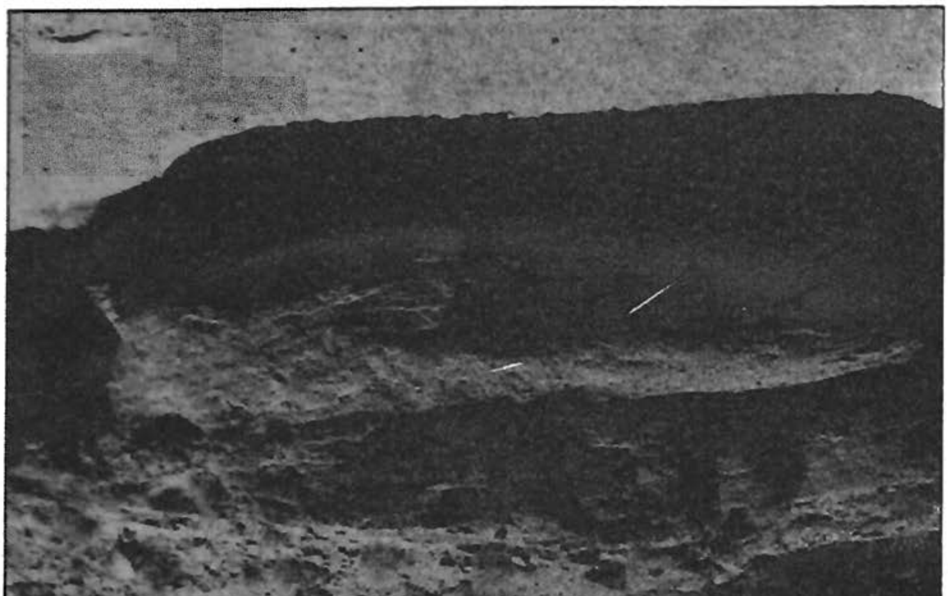

Fig. 7. Outcrop of a large trough in the sandstone of the Litra Formation (field of view is about 8 m).

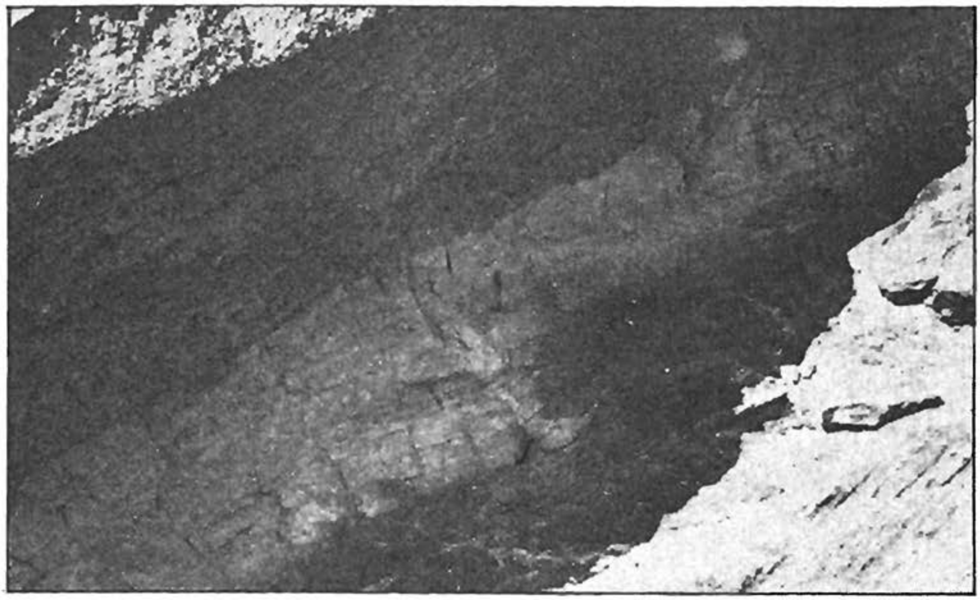

Fig. 8. Small-scale trough cross-bedding in sandstone of the Litra Formation.

Fig. 9. Low-angle plane-bedded sandstone unit with large-scale trough cross-bedded sandstone units lying above and below it, Litra Formation.

Chaudhwan Formation

Conglomerates: The brownish petromict orthoconglomerates of Chaudhwan Formation commonly display horizontal stratification. According to Hein and Walker (1977), horizontally stratified conglomerates are emplaced as diffuse gravel sheets during high flow. These conglomerates range from 1 to 20 m in thickness, and laterally extend for hundreds of metres (Fig. 11).

Fig. 10. Pebble to boulder sized mud-balls lying along the cross- laminae in the cross-bedded sandstone of Litra Formation.

Large-scale trough cross-bedding is also a commmon feature of the granule, pebble and cobble bearing conglomerates of the Chaudhwan Formation (Fig. 12). The troughs are generally 15 to 20 m in width and 1 to 2 m in thickness. Larger phenoclasts (large cobble to boulder sized) form lenticular (mostly along the bottom of troughs formed by granule, pebble and cobble bearing conglomerates), as well as laterally extensive bodies.

Sandstones: The ancillary pale-brown sandstone of the Chaudhwan Formation varies in thickness from a few centimetres to 5 m. As the frequncy of conglomerate occurrence increases towards the top of the formation, the thickness of these interbedded pebbly

Fig.11. The petromict orthoconglomerate of Chaudhwan Formation showing well developed horizontal stratification that extends laterally for hundreds of meters.

sandstones decreases. Sandstone of the Chaudhwan Formation is generally pebbly and bears large-scale trough cross-bedding as well low-angle planar bedding.

Siltstone/Claystone deposits: Towards the base of Chaudhwan Formation some thin (a few centimetres to 1 m) beds of pale brown silty clay are present. However, these clay beds become sparse towards the top of formation. These fine grained sediments, where present, generally overly the sandy units that are interbedded with the dominant thick conglomerate sequence of the Chaudhwan Formation.

Paleocurrent Directions:

In the study area excellent three dimensional exposures of various lithosomes (e.g., troughs cross-bedded bedforms) are present (e.g., Figs. 8 and 12). Thus a concise idea about the paleocurrrent directions can be easily obtained.

Representative plaeocurrent analysis from the upper Litra and Chaudhwan Foramtions are shown in figure 13. From this figure it is clear that both formations depict a SSE-ward pleo-flow direction. However, it is interesting to note that the paleocurrent direction of Chaudhwan Formation has a greater eastward component than the paleocurrent directions of Litra Formation.

The SSE-ward paleocurrent direction is also depicted by the abundant sole structures (mostly flute casts) present at the base of the pebbly sandstone in the Chaudhwan Formation (Fig. 14).

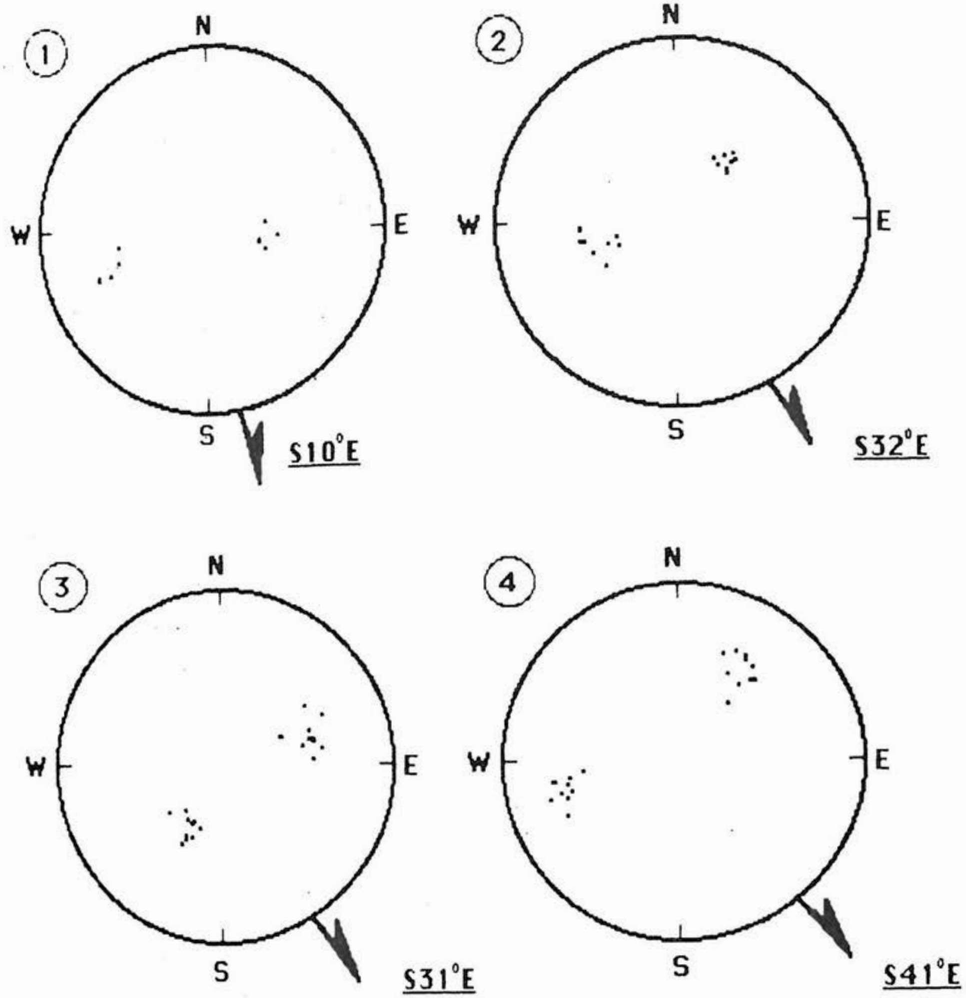

Fig. 12. Paleocurrent directions (solid arrows) of Litra Formation (1, 2 & 3) and Chaudhwan Formation (4). The points are poles of opposite limbs of troughs.

CONCLUSIONS

The Miocene-Pleistocene fluviatile molasse sediments of the Siwalik Group exposed in the eastern foothills of the Sulaiman Range include Vihowa, Litra and Chaudhwan Formations. These Formations comprise alternating sequences of sandstone, mudstone and conglomerate. The mudstone is predominant towards the base (Vihowa Formation), the sandstone is dominant in the middle (Litra Formation), and conglomerate is preponderant towards the top (Chaudhwan Formation) of the

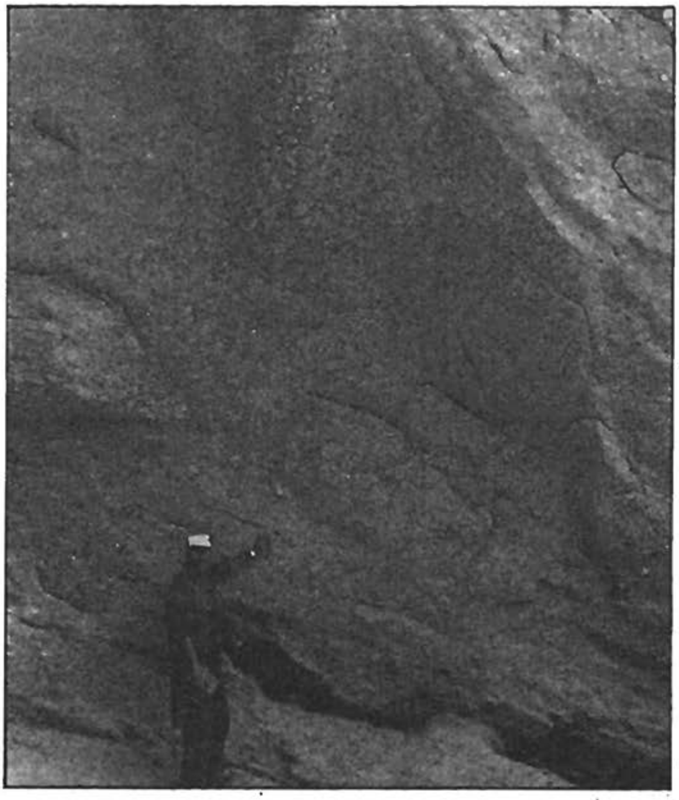

Fig. 13. A large flute-cast at the base of a pebbly sandstone of Chaudhwan Formation. The plaeocurrent direction measured for this flute-cast is S55°E.

Siwalik Group exposed in the area. Current studies were confined to the upper Litra Formation and the Chaudhwan Formation. Sedimentologic data obtained during present studies provides insight into the mode of late Pliocene to Pleistocene molasse deposition in the southern portion of of Zindapir anticline near Sakhi Sarwar area.

The sediments of the upper Litra Formation are predominantly derived from the northern provenance (including Kohistan Island Arc) as is indicated by the paleocurrent data. Sporadic occurrence of limestone (Paleocene-Eocene) and sandstone (Pab Sandstone) bearing conglomerates at various stratigraphic levels in the upper Litra Formation indicates that uplift along Fort Monro anticline became an additional source of clastic material being derived from western direction. The paleocurrent directions of the upper Litra Formation indicate that the drainage pattern was axial and the fluvial system that deposited these sediments flowed towards SSE, parallel to the deformation front.

The Chaudhwan Formation was deposited as a consequence to synchronous acute tectonic uplift along the Fort Monro anticline. This is evinced by the preponderance of limestone (Paleocene-Eocene) and sandstone (Pab Sandstone) bearing conglomerates. The paleocurrent directions of the Chaudhwan Formation indicate a greater eastward componenet than the paleo-flow directions from the upper Litra Formation. Thus it is suggested that at this time the fluvial system started to migrate eastward in response to uplift along the Fort Monro anticline.

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