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LARGE SCALE VERTICAL AGGRADATION OF SANDSTONES IN THE KAMLIAL FORMATION OF THE KOHAT BASIN, PAKISTAN

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ABSTRACT

The Kamlial Formation in the Kohat fold-thrust belt is composed dominantly of thick sandstone, interbedded with siltstone and intraformational conglomerate. The sandstone bodies are over 100 metre thick in the upper part and, on the average, 30 metre thick in the lower and middle part of the formation. The sandstone bodies are multistoried and their large thicknesses are due to vertical and lateral amalgamation of sand bodies deposited in a slowly subsiding foreland basin. An average thickness of 4-6 metre has been estimated for the individual sand bodies deposited by 6-8 metres deep, intermediate to high sinuosity streams. Tabular sand bodies interbedded with overbank fines were deposited by high sinuosity streams. The drainage system during the deposition of the Kamlial Formation in the Kohat foreland basin was mainly flowing to the east which is consistant with that of the Potwar Plateau.

INTRODUCTION

The early detritus shed by the Himalayan orogenic belt was deposited in the Kohat-Potwar foreland basin (Fig. 1) as a coarsening upward sequence, known as the Rawalpindi Group. The Rawalpindi Group is comprised of the Murree Formation lying unconformably over the Eocene limestone, and Kamlial Formation which has a transitional contact with the overlying Siwalik Group (Shah, 1977)(Fig. 2). These sediments are characterized by a succession of transient depocentre which migrated outwards from the orogenic belts as the deformation rippled southwards (Raynolds & Johnson, 1985). The molasse sediments comprising the Rawalpindi and Siwalik Groups in the Kohat-Potwar fold-thrust belt during the last two decades have been the focus of multidisciplinary studies including magnetostratigraphy (Opdyke et al., 1979; Johnson et al., 1979, Jounson et al., 1982, 1985; Burbank, 1983, Khan, 1983, 1984; Tauxe & Badgely, 1988), biostratigraphy (Pilbeam, 1982; Raza, 1983; Raza et al., 1984),

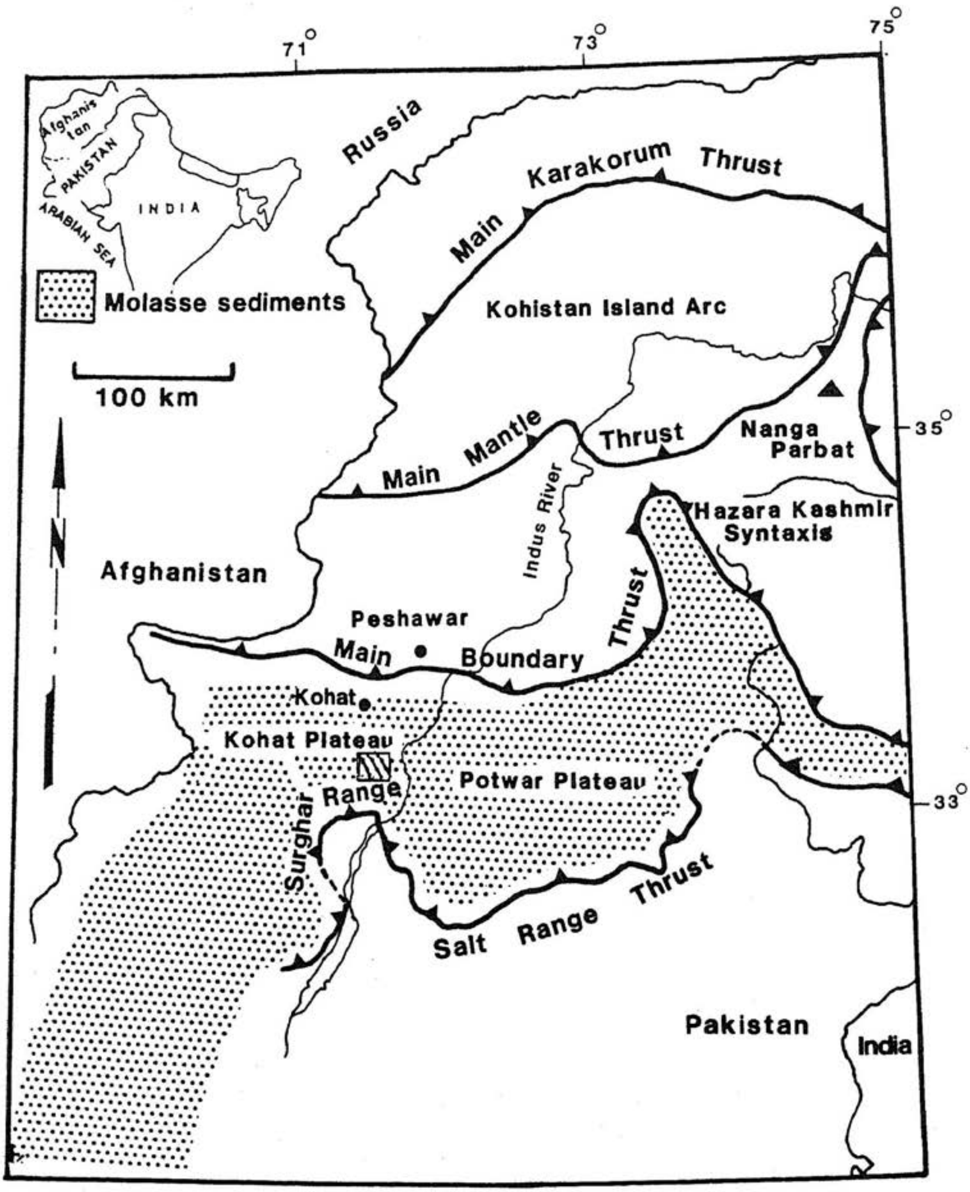


Fig.1. Sketch map of the Kohat-Potwar area, the study area around Shakardarra town is marked by the rectangle.

lithostratigraphy (Fatmi, 1973; Shah, 1977) and sedimentology (Visser & Johnson, 1978; Behrensmeyer & Tauxe, 1982). Most of these studies were, however, concentrated on the rocks of the Siwalik Group, whereas little informations are available regarding the sediments of the Rawalpindi Group. The Kamlial Formation in the Kohat-Potwar Plateau is comprised of greenish-grey sandstone (73 %), subordinate maroon siltstone (20 %) and minor intraformational conglomerate (7 %) (Fig. 3). The total measured thickness of the Kamlial Formation in the Shakardarra area, southeastern Kohat (Fig. 3), is 580 metres, but in the south thins out to about 50 metres in the Surghar Range (Meissner et al., 1974).

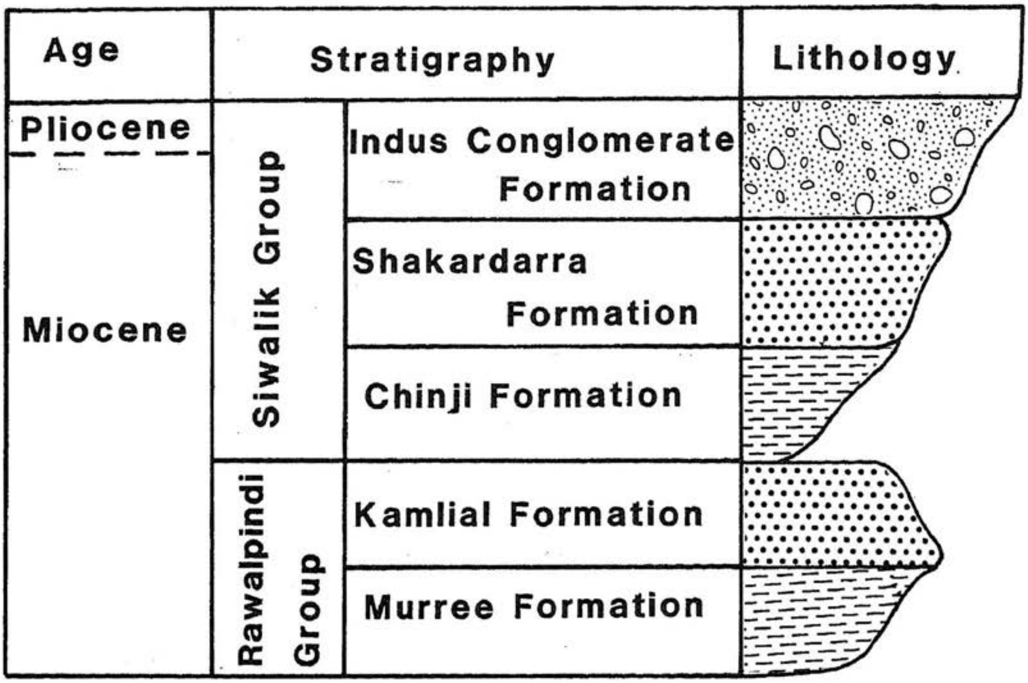
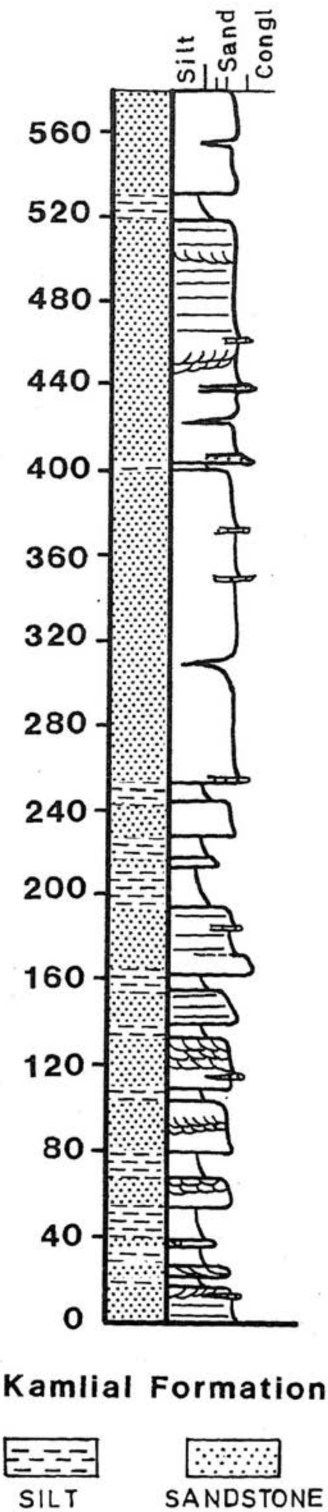


Fig.2. Neogene stratigraphy of the molasse succession in Shakardarra area. The Shakardarra Formation is equivalent to the Nagri Formation, and the Indus Conglomerate Formation is equivalent to the Dhok Pathan Formation in the Potwar area.

The Kamlial Formation contains comparatively higher proportion of siltstone in its lower and middle part than in its upper part. Sandstone sequences in its upper part are up to 100 metre thick, whereas in the lower part, the sandstones are up to 30 metres thick (Fig. 3). Bioturbation is common in the upper parts of the sand units and destroys depositional structures. Spheroidal weathering is also common and gives a rubbly, massive appearance to the sandstones. The Kamlial Formation despite its regional distribution has been devoid of any detailed sedimentological studies. The only study in



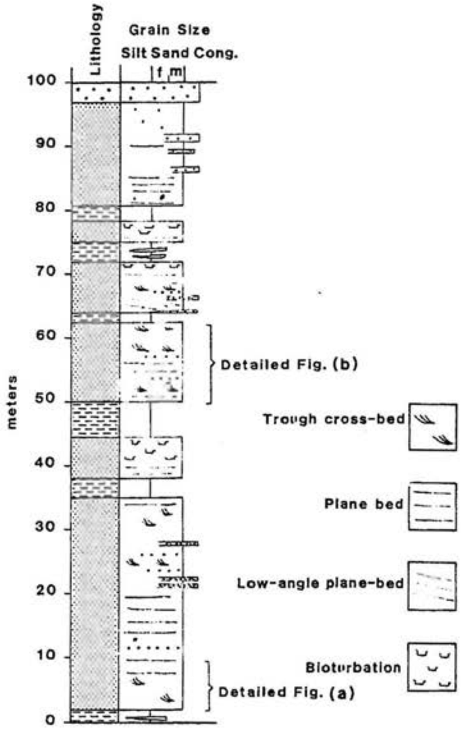


Fig. 3. (Left) Measured section through the Kamlial Formation in the Shakardarra area.

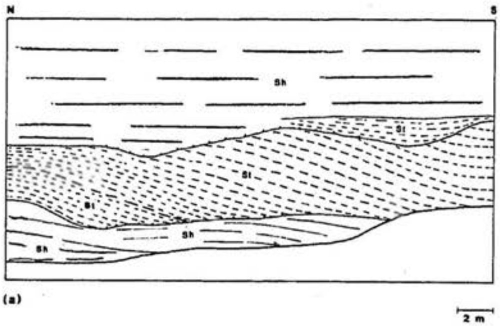
Fig. 4. (Right) Detailed measured section through the lower part of the Kamlial Formation.

Facing page: 4a) Large scale trough cross-sets showing flow direction to the east. The co-set is bounded by the rosional surfaces; 4b) detailed section showing relationship between lithofacies Sh and St. Sh- horizontal or plane bedded sandstone, St- trough cross bedded sandstone.

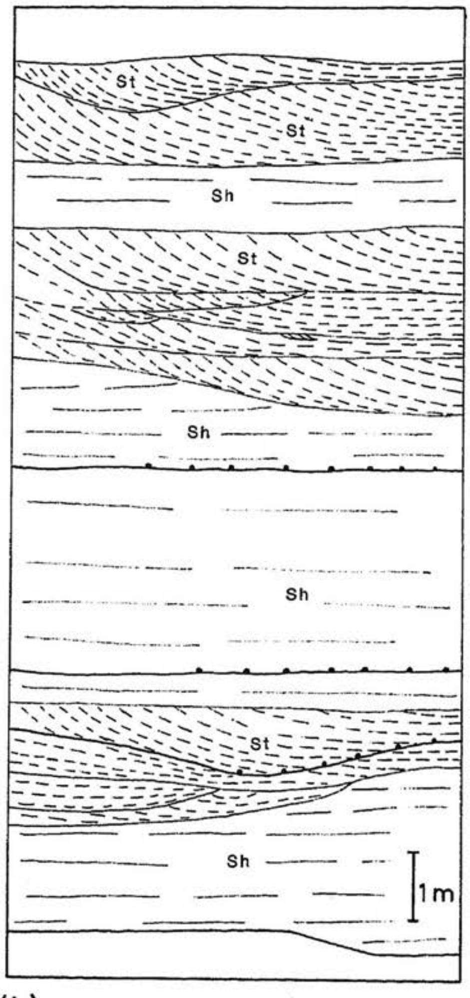
progress is that of Hutt (in prep) in the southern Potwar area. This sudy is first of its kind dealing mainly with sandstone body geometry and probable paleoriver system which deposited these sediments. Area around Shakardarra village in southeastern Kohat (Fig. 1) was selected and studied mainly along the stream sections.

SANDSTONE-BODY GEOMETRY

Sandstone-bodies in the Kamlial Formation can be divided into two major types, a) major channel type sand-bodies which constitute a significant proportion of the Kamlial Formation; b) flood-plain type tabular sand-bodies interbedded with siltstone.



(a)



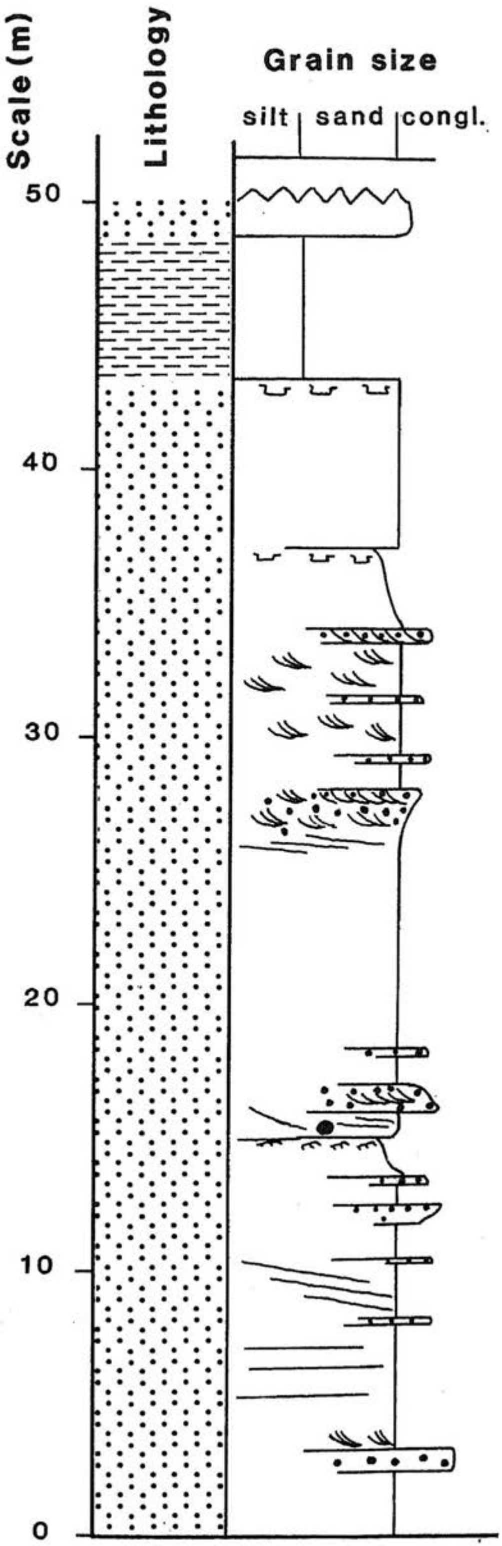
(b)

a) Major channel type sandstone-bodies:

The major sandstone bodies are composed of greenish-grey, medium grained sandstone. The sandstones in the middle and upper parts of the formation are up to 100 metres thick (Fig. 3), whilst in the lower part, the sandstones are only exceptionally up to 30 metres thick, more usually in the order of 15-20 metres (Figs. 3 and 4). Detailed observations of the sandbodies (Fig. 4 and 5) suggest that these are multistoried as reflected by the presence of a number of erosional surfaces commoly marked by thin lag deposits. A storey according to Friend et al. (1979) is defined as volumes of material within the sandbody which are separated by scour surfaces. The sandstone in Fig. 5 is 42 metres thick and contains at least a dozen erosional surfaces. A number of storeys within the sandstone-body show either fining or coarsening upward trends. Two fining upward sequences occur in the sandbody, one at the 15 metre level and a second at the 37 metre level. Each storey within the sandstone sequence represents the remaining post erosional thickness of a single depositional cycle, of the order of 3-4 metre thickness. Fig. 4 b. also shows a number of erosional surfaces within the sandstone sequence marked by the layers of lag deposits. Overbank fines between the storeys were either not deposited or had low preservation potential and were reworked into intraformational conglomerates by the major channels.

Interbedded siltstone beds in the sandstone sequences pinch-out laterally within short distances (Fig. 6). This is probably due to low preservation of the overbank fines which were eroded as a new channelized flow approched the area. In this example, the sandstone-body shows at least four siltstone beds which laterally pinch-out in the sandstone sequence. The overbank fine sequence F1 is about 3 metre thick in the western part, and contains a crevasse splay channel-fill feature. Siltstone-bodies F3 and F4 are up to 4 metre thick but are laterally eroded by the channel deposits. The sandstone-body (Fig. 6) which appears to be about 25 metre thick is composed of at least four tabular sandbodies, on average 8 metre thick individually and are vertically amalgamated to form a thick sandstone sequence. The sand-body in Fig. 6 is dominantly composed of plane-bedding (Sh) with trough cross-bedding along the base of the sand units. Plane-beds (Sh) probably indicate deposition by plane-bedded simple bars (Allen, 1982). Palaeocurrent measurements show a dominant flow direction to the east, except for a trough cross-bedded intraformational conglomerate (Gt) unit, which shows a flow direction to the west.

Individual storeys within the sandstone-bodies are composed of either a single lithofacies or combination of two lithofacies i.e. trough cross-bedding and plane bedding (Figs. 4 and 5). When two lithofacies are associated together, trough cross-bedding (St) usually lies at the base of storey, overlain by plane-bedding (Sh) and low angle plane-bedding (Sl). Occasionally individual cross-sets are up to 3 metres thick (Fig. 4 a), bounded by erosional surfaces both at the top and base. These large cross-sets were deposited by the migration of large dunes or megaripples. However, because there is



only one set in this case, it seems more likely that it was deposited in the form of a delta or tributary bar at the confluence of two channels. Alternatively this could represent a channel-fill feature deposited by a 4-6 metre deep channel flowing to the east. Bedding planes are well developed due to a high mica content. Plane beds commonly contain parting lineations in their upper part.

Trough cross-beds in the Kamlial Formation show a dominant flow direction to the east (Fig. 7), with a spread from SW to NE. This is consistent with other data for the Potwar area (Stix, 1982).

b) Minor sandstone bodies in flood plain sediments

Siltstone sequences, mainly in the lower part of the formation, contain subordinate sandstone beds, commonly brownish-grey to brown in colour, and deposited from suspension. The interbedded thin (1-4 metre) sandstones were deposited either by crevasse splays or by local stream activity in the flood-basin (Fig. 8). The sandstone-body occurs interbedded with thick siltstone sequences and is composed of brownish-grey, medium grained sandstone and brown intraformational conglomerate. The sandstone-body has a sharp erosional basal contact with the underlying siltstone, and shows deposition by a high sinuosity mixed load (gravel and sand) stream. Lateral accretion surface dip

Fig.5. Detailed section through a thick sandstone sequence in the upper part of the formation. The erosional surfaces in the sand stone are marked by the presence of the lag deposits.

at approximately 20° to the horizontal and prograde from east to west, with the stream's mean flow direction oriented from south to north (Fig. 8). Internal structures include horizontal bedding and trough cross-bedding. Along strike these lateral accretion surfaces pass into a channel-fill containing intraformational conglomerates. The sandstone-body was deposited by a local high sinuosity stream or a large-scale crevasse splay

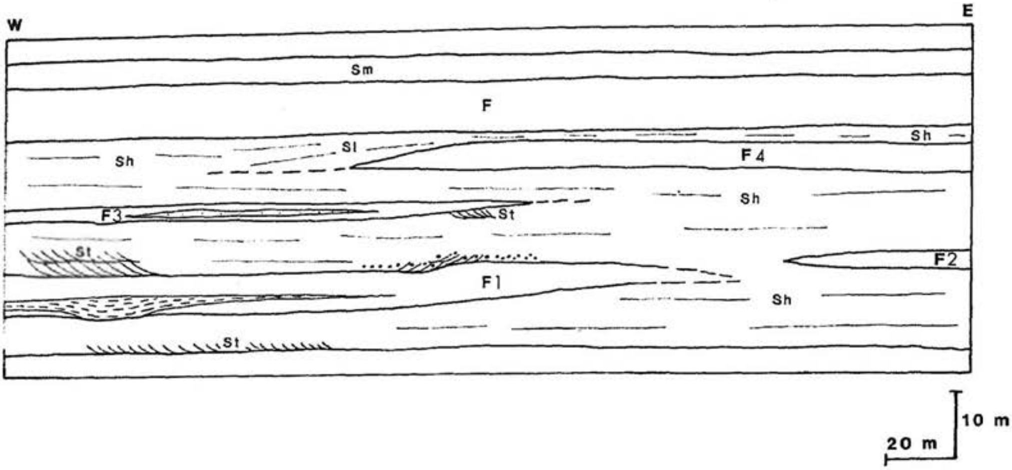


Fig.6. Siltstone interbeds (F1-F4) laterally die out or are eroded by the overlying sandstone. F1-F4 siltstone beds, Sh- horizontal bedded sandstone, St- trough cross-bedded sandstone, Sl- low angle plane bedded sandston

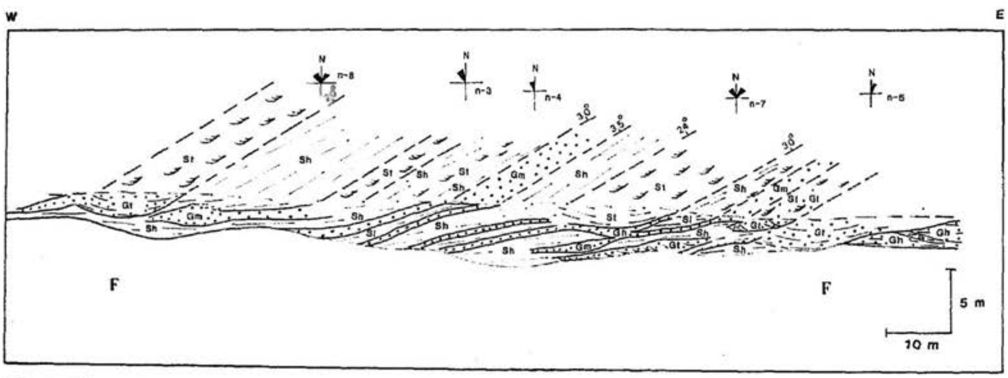


Fig.7. Three dimensional sketch of a minor sandbody interbedded with overbank fines. The broken lines show top of the sand-body. The gravel lags mark top of the sand bars and laterally accrete westward passing into a lag filled channel. The high sinuosity paleostream was flowing at right angle to the major paleoriver system. Gm- massive gravels, Gt- trough cross bedded gravels, Gh- horizontal bedded gravels, Sh- horizontal bedded sandstone, Sl- low angle plane bedded sandstone, St- trough cross bedded sand stone, F- overbank fines.

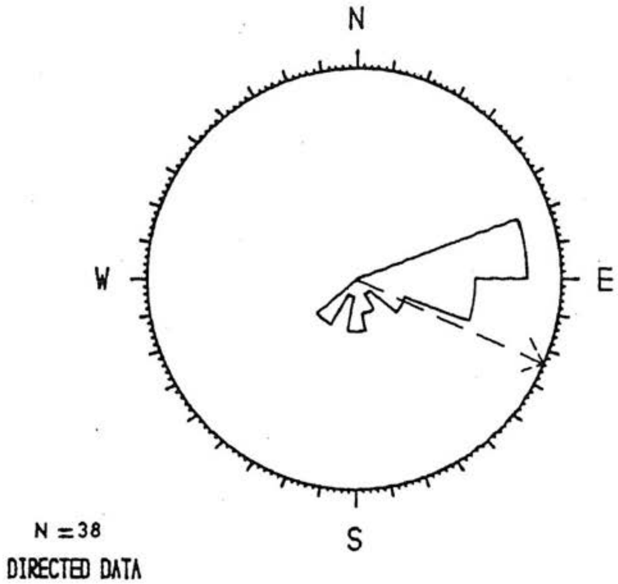


Fig. 8. Paleocurrent data from the Kamlial Formation. Mean flow direction is towards ESE.

flowing at right angle (north) to the flow direction of the main river (ESE). Such high sinuosity local streams were probably common in the flood- plain as reflected by the presence of abandoned channels filled with overbank fines in other parts of the sequence. Most of the minor sandstone-bodies interbedded with overbank fines are single storey and appear massive due to extensive bioturbation.

DISCUSSION

Molasse sedimentation due to orogenic uplift and southward migrating deformation was active in the Kohat-Potwar foreland basin since late Oligocene (Shah, 1977). Over 6 km thick sand-silt and conglomerate sequence was deposited by palaeoriver systems which changed their pattern with changing positions of the foreland basin with respect to the orogenic belt. Various proportions of sand-silt and conglomeratic facies across the molasse succession was mainly a function of changing river pattern, climatic conditions and subsidence rates in the foreland basin.

The palaeoriver system which deposited the sediments of the Rawalpindi Group was a medium to high sinuosity river system as reflected by the abundance of inchannel lithofacies St (trough cross-bedding) and Sl (low angle palne-bedding). The very thick sandstones (up to 100 metres) are clearly multistoried, with individual storeys in the order of 4-6 metre thickness, deposited by streams probably 6-8 metres deep. High proportions of intraformational conglomerate are due to reworking of overbank fines by major channels. No exotic conglomerates are found in the Kamlial Formation except a few volcanic and quartzitic pebbles in thick sandstones. This was probably due to the fact that the site of deposition was towards the distal part of the foreland basin where streams could not transport large clasts in sufficient amount.

Individual bar macroforms and channel-fills are difficult to interpret because of outcrop limitations in the study area. Thick sandstone deposits and vertical stacking of the sandstone-bodies was probably due to low subsidence rates in the basin coupled with a dominant sand supply from the source area into the foreland-basin. According to Allen (1978) and Kraus & Middleton (1987) higher interconnectedness of sandstone bodies results in a slowly subsiding basin as a result of low preservation of the overbank fines due to slow burial. Next in-channel flow can erode the overbank fines and deposit intraformational conglomerates.

The river system which deposited molasse sediments of the Rawal pindi Group probably entered the Kohat-Potwar foreland basin through Kohat area and deposited its earlier sediments in the Kohat part of the basin. The molasse sediments are generally diachronous, older in the Kohat area and comparatively younger in the Potwar area (Beck per.comm.).

High sinuosity local streams were active in the flood-plain on a smaller scale depositing small sandstone-bodies (Fig. 8). The major river system was flowing to the east (Fig. 7). The flow direction in the Kohat area during the deposition of the Kamlial Formation was similar to that of the Potwar area (Stix, 1982), suggesting that the river systems have been flowing in the same direction throughout the Kohat-Potwar foreland-basin.

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