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PRELIMINARY SEDIMENTOLOGY OF THE SIWALIKS GROUP OF KACH AND ZARGHUN AREAS, BALUCHISTAN

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ABSTRACT

Sedimentary structures, palaeocurrent directions and vertical variations of facies associations were studied in the Siwalik Group of Kach area show derivation of detritus from the nearby mountain ranges. Furthermore, it is proposed that the Nagri Formation is a deposit of braided channel system and the Dhok Pathan and Soan Formations, those of meandering channel systems. Although the Dhok Pathan and Soan Formations are the products of meandering rivers, they show contrasting facies associations. The Soan Formation is characterised by pebble and cobble conglomerate members in their lower part pointing to relatively low-sinuosity and high energy conditions. Such conglomerate members are lacking in the Dhok Pathan Formation in which clay units dominate over sandstone units and suggest a relatively high-sinuosity and low energy conditions.

INTRODUCTION

Following Danilchik and Shah (1967) the Stratigraphic Committee of Pakistan subdivided the Siwalik Group into the Chingi, Nagri, Dhok Pathan and Soan Formations. The name Siwalik Group is extended to similar suite of rocks of Lower Indus Basin and Baluchistan, including the "Sibi" and "Urak" groups of Hunting Survey Corporation (1961). In Baluchistan, however the lower part of the Siwalik Group i.e. the Chingi Formation is not recognised.

The Nagri Formation of Lewis (1937) has been accepted by the Stratigraphic Committee of Pakistan which in Baluchistan represents the lower most part of the "Sibi Group" and "Urak Group" of Hunting Survey Corporation and "Uzhda Pusha Formation" of Kazmi and Raza (1970). It consists of fine to coarse

grained or even pebbly sandstone and very minor claystone. The sandstone is greenish to bluish grey, poorly sorted, subangular to subrounded and having a profusion of sedimentary structures. The pebbly beds have varied thicknesses and contain various types of igneous and sedimentary fragments. In Kach area (Fig. 1)

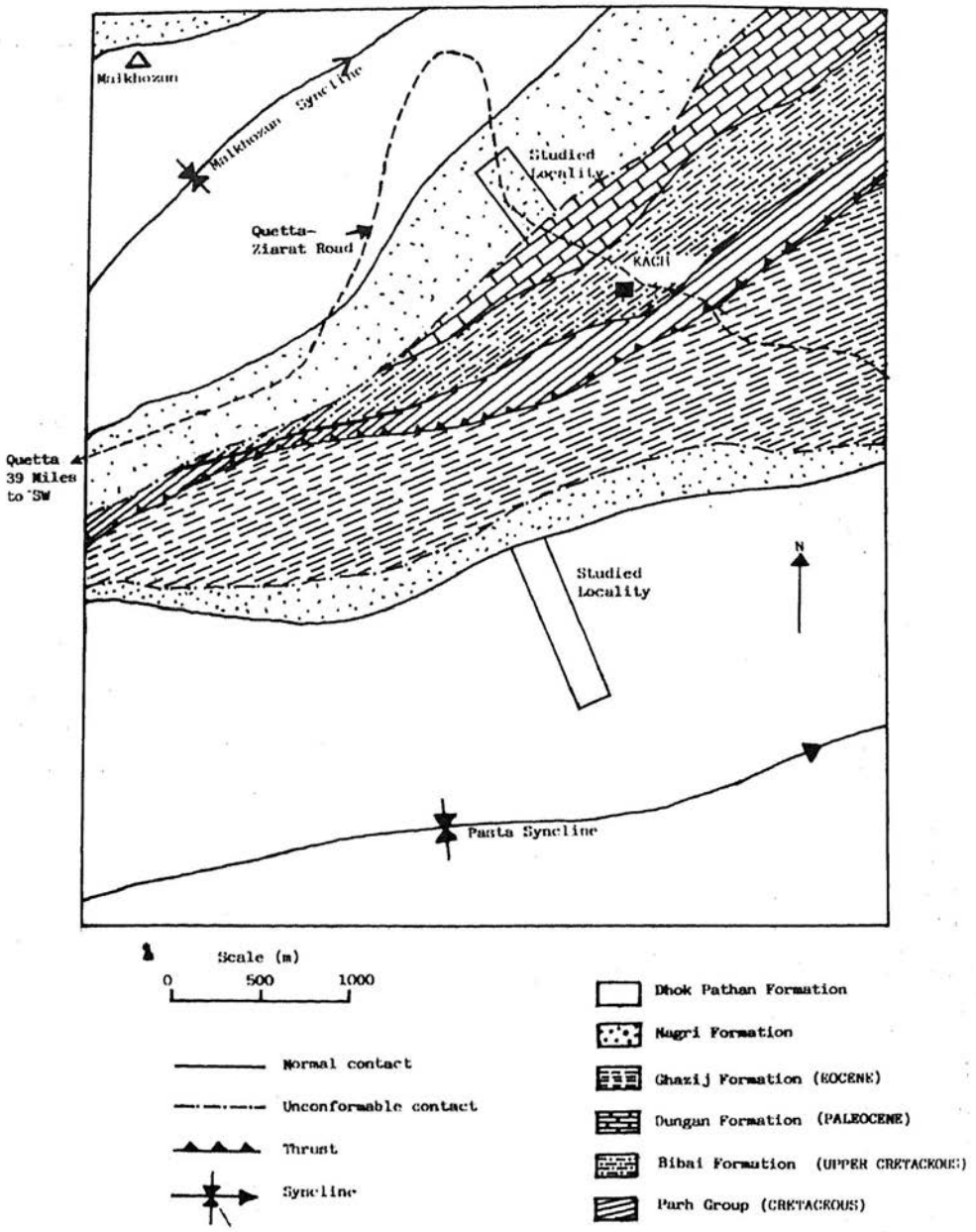

Fig. 1. Geological map of Kach area showing studied localities.

the formation unconformably overlies the "Parh Group" (Cretaceous), Bibai Formation (upper Cretaceous), Dungan Formation (Palaeocene) and Ghazij Formation (Eocene) with a very clear angular discordance and underlies the Dhok Pathan Formation with transitional conformable contact. The Oil and Gas Development Corporation of Pakistan (1965, unpublished reports) assigned a Middle to Late Miocene age to the formation in the Sibi-Quetta area.

The Dhok Pathan Formation was proposed by Cotter (1933) and adopted as such by the Stratigraphic Committee of Pakistan and extended to represent the middle part of the "Sibi Group" and "Urak Group" of Hunting Survey Corporation (1961) and the "Shin Matai Formation" of Kazmi and Raza (1970). It consists of monotonous cyclic alternations of sandstone and claystone. The sandstone is brownish-grey, reddish-brown, thick bedded, moderate to well sorted and occasionally pebbly. Various types of sedimentary structures may be found. The claystone is reddish-brown, red, maroon or yellowish-grey, calcareous and sandy in places. Minor mottled, yellowish-brown and reddish-brown siltstone intercalations are also found. The Dhok Pathan Formation has a transitional contact with the underlying Nagri Formation. The upper contact with the Soan Formation is not known in Kach area, however, the contact in Zarghun Ghar (Fig. 2) near Sor Range is transitional. The conglomerate horizons in Zarghun Ghar gradually increase upwards. Its age has been reported as Early to Middle Pliocene.

The name Soan Formation of Kravtchenok (1964) was adopted by Stratigraphic Committee of Pakistan for the upper Siwalik Group. It also represents the upper part of the "Sibi Group" and "Urak Group" of the Hunting Survey Corporation (1961) and the "Urak Formation" of Kazmi and Raza (1970). The formation consists of compact and massive conglomerate with interbeds of sandstone and siltstone/claystone. The conglomerate is poor to moderately sorted, subrounded to well rounded and consists of cobbles and pebbles of limestones (of various types), sandstones, chert and igneous rocks embedded in a sandy matrix. The claystone is reddish- to brownish-grey, light brown and occasionally light grey. The formation in Zarghun area transitionally overlies the Dhok Pathan Formation. The upper contact with the Lei Conglomerate has been reported to be transitional by the Hunting Survey Corporation (1961). Kravtchenko (1964) assigned an Early Pleistocene age to the Soan Formation.

PREVIOUS WORK

Stratigraphic study of the area was initiated by the Hunting Survey Corporation (1961) by giving local names to groups and formations, which were subsequently standardised by the Stratigraphic Committee of Pakistan. Kazi and Raza (1970) also contributed to the local stratigraphy of Quetta region and proposed their own local names. Petrography and genesis (Krynine, 1937), petrology, geochemistry, palaeontology and palaeomagnetic studies have been carried out (Opdyke, 1979; Shah *et al.*, 1979; Hussain, 1979; Abbasi *et al.*, 1983; Khan, 1984), mostly in the Kohat-Potwar plateau.

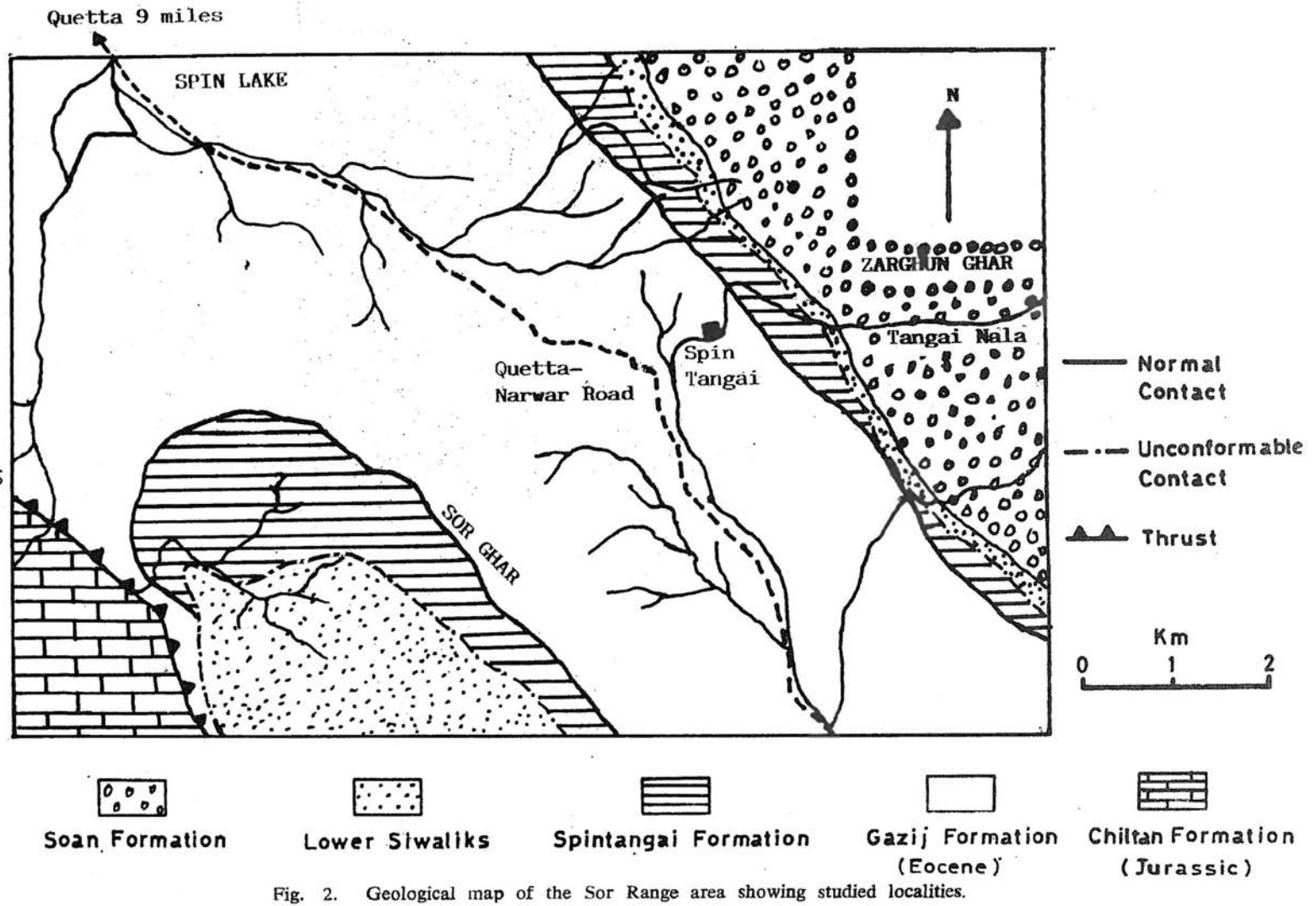

Fig. 2. Geological map of the Sor Range area showing studied localities.

The present paper is an attempt to interpret vertical facies associations of the Siwalik Group in Kach and Zarghun areas of Baluchistan (Fig 1, 2) by comparing them with the existing facies models of other fluvial deposits proposed by various investigators (Allan, 1965b; Rust, 1978; Miall, 1977; Jackson, II, 1978).

SEDIMENTARY STRUCTURES

All members of the Siwalik Group in Kach and Zarghun area are rich in various types of sedimentary structures. The Nagri Formation displays a variety of sedimentary structures including trough and tabular cross-strata which are deformed in places, current ripples of straight as well as sinuous crests, sole marks, convolute laminae and load casts and associated flame structures. Grity and conglomeratic beds of lenticular geometry are commonly found, some of which are up to 4 m thick and represent channel-fill deposits. The cross-stratification is commonly of trough-type and some of the troughs are up to 3 m wide. Current ripples (height = 1–2 cm, wavelength = 15 cm) are also commonly present. Flute marks (Fig. 3), longitudinal ridges and other irregular sole marks are present on the base of the channels overlying clay and siltstone units. In cross-section the formation shows a cut-and-fill pattern of lenticular channels and bars. The Dhok Pathan Formation displays cross-strata, current ripples and sole

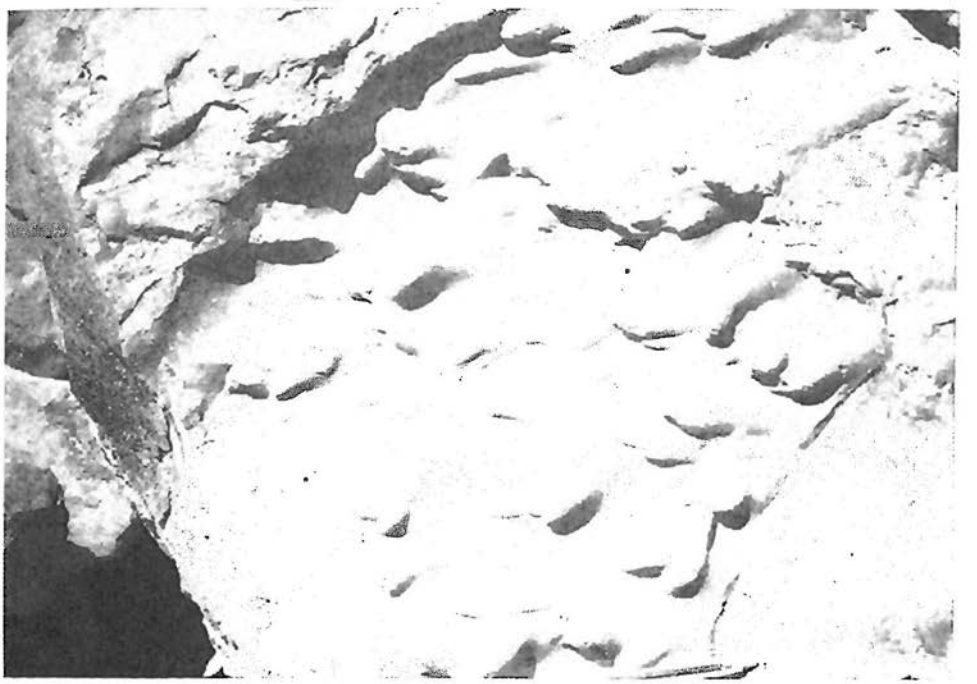

Fig. 3. Flute marks in Nagri Formation, Malkhozun Syncline, Kach area (Gr. Ref. 238522).

marks which include flute marks, longitudinal ridges (Fig. 4), load casts, mud cracks and lenticular channels. Bioturbation is particularly common and in places mottled sandstone and siltstone horizons may be found. The channels are 1–3 m deep. Current ripples having heights of 0.5–2 cm and lengths of 7–10 cm are present. Foreset beds are deformed (overturned) in places. Load casts are very common on the lower bedding surfaces of the sandstones, some of which are unusually large (50 to 70 cm across and over 30 cm deep). In the Dhok Pathan Formation most of the sedimentary structures are observable in the sandstone units.

The Soan Formation represents cyclic alternations of conglomerate sandstone and siltstone/mudstone and also displays a variety of sedimentary structures including sole marks, cross-strata and current ripples. Sole marks are common on the lower erosional surfaces of the conglomerate members. They include very large sized longitudinal ridges, huge crescent-like structures (Fig. 5) and load casts (Fig. 6). The longitudinal ridges are 20 to 60 cm wide, 30 to 40 cm deep and up to 4 m long. The load casts are up to 3.5 m wide and 1.5 m deep. The sandstone units of the formation are cross-stratified and rippled. The sandstones are rarely and siltstones commonly bioturbated and occasionally mottled.

Fig. 4. Longitudinal ridge marks in Dhok Pathan Formation Posta Syncline, Kach area (Gr. Ref. 252484).

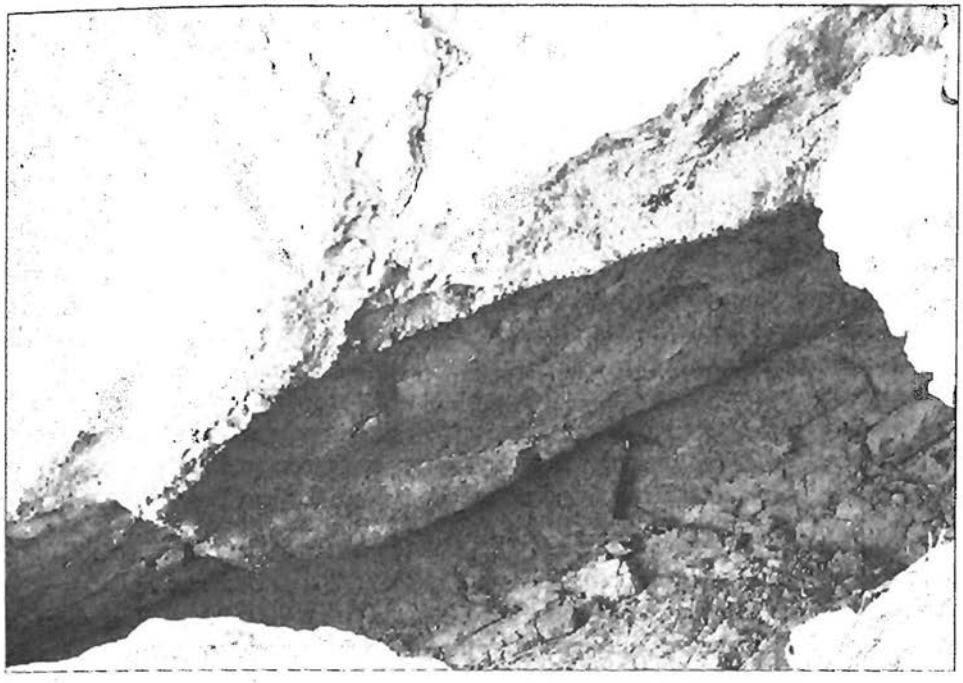

Fig. 5. Current-crescent like structure on the base of a conglomerate bed in Soan Formation, Zarghun Ghar (Gr. Ref. 190217).

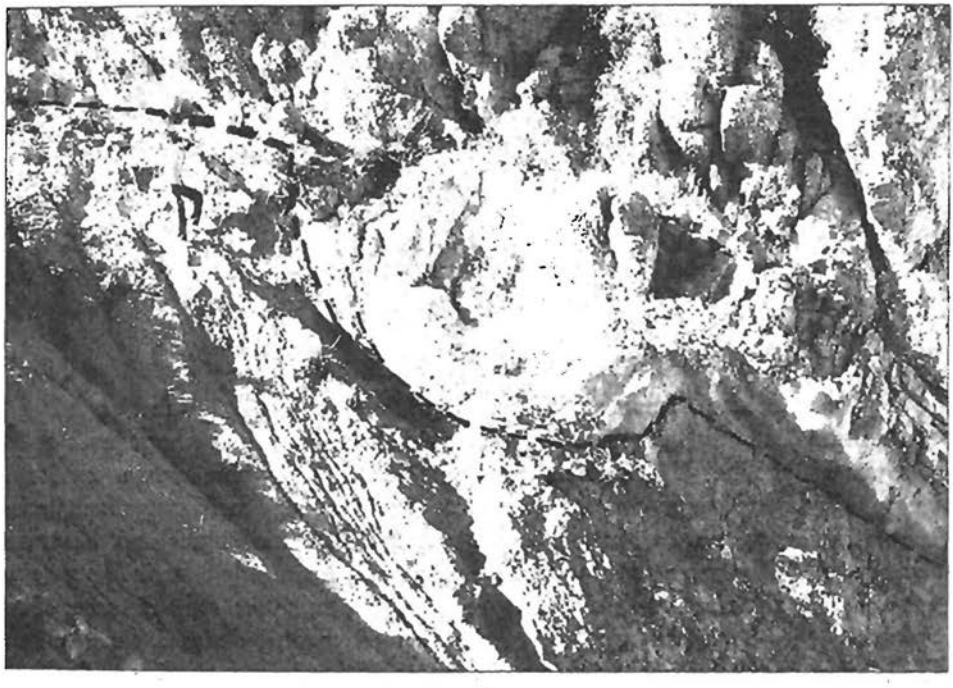

Fig. 6. Huge load cast showing deformed conglomerate horizon in Soan Formation, Zarghun Ghar (Gr. Ref. 190217).

PALAEOCURRENT DIRECTIONS AND SOURCE AREA

Most of the data obtained for determining palaeocurrents was taken from the lowermost Nagri Formation. The palaeocurrent directions taken from cross-strata, current ripples, orientations of plant fragments and sole marks were plotted directly (Fig. 7). Before considering the palaeocurrent pattern it would be more appropriate to consider briefly the geological set-up of the area. The geological map of the area (Fig. 1) shows that the Siwalik Group unconformably overlies the older marine and deltaic rocks ranging in age from Triassic to Eocene. During Oligocene the older rocks were folded, deformed and uplifted forming mountain ranges and troughs (Kazmi, 1979). During Miocene these mountain ranges were subsequently subjected to denudation and the acquired detritus deposited by rivers in linear troughs between the ranges, which were again subjected to folding in Pliestocene. In Kach area the Siwalik Group is represented by the Malkhozun Syncline to north and Pasta Syncline south of Kach Levees Post (Fig. 1).

Plot of the palaeocurrents (Fi.g 7) show that the Siwalik Group of Malkhozun Syncline north of Kach were derived from southeast and those of the Pasta Syncline south of Kach were derived from northwest. The opposed pattern of palaeocurrents suggest that the source area was a mountain range present between the positions of Malkhozun and Pasta Synclines. It may be noted that the data of palaeocurrents was obtained from the lower most Nagri Formation which has been interpreted as a deposit of a braided channel system (see next section). It is suggested that the Nagri Formation deposited in the form of overlapping alluvial fans on the northern and southern foot of the intermediate mountain range. Data of palaeocurrents from the Dhok Pathan and Soan Formations was not adequate enough to be plotted, however, in Zarghun area a few observations of palaeocurrents in the Soan Formation indicate a northeasterly derivation.

From the above discussion it may be concluded that the material of Siwalik Group in Kach area has been derived from the nearby mountain ranges and deposited in the foot of the ranges and adjacent linear troughs.

LITHOFACIES ASSOCIATIONS

Study of the Lithofacies of the Nagri Formation was carried out along a road section just north of Kach Levees Post (Fig. 1) on the southern flank of the Malkhozun Syncline. The columnar profile (Fig. 8) show that coarse sandstone and conglomeratic sequences dominate over the fine and medium grained facies. Only a few very thin (a few cm to 10 cm) units of mudstones and siltstones were found. The coarse sandy conglomeratic units are mostly lenticular showing "cut-and-fill" structures and may not be traced laterally for long distances. Such a pattern (Fig. 8) is characteristic of the braided channel deposits found on the alluvial fans at the foot of the mountain ranges. The columnar profile of the Nagri Formation is comparable to the sand-dominant braided channel system of Rust (1978) and Bijou Creek type model of Miall (1977).

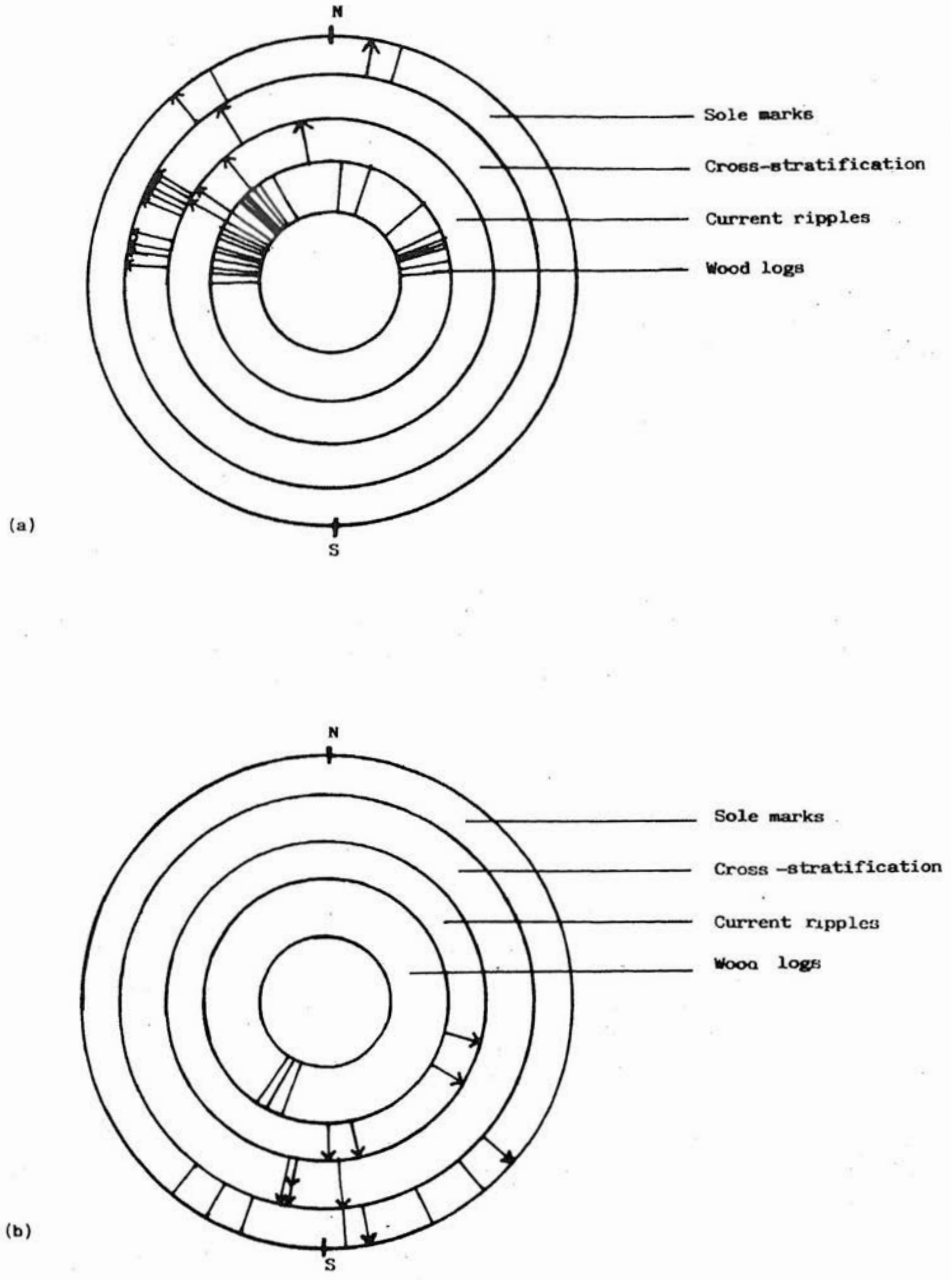

Fig. 7. **(a) Palaeocurrents in Siwaliks of the Malkhozun Syncline.**
(b) Palaeocurrents in Siwaliks of the Pasta Syncline.

Lithofacies of the Dhok Pathan Formation were studied on the northern flank of Pasta Syncline (Fig. 1) and the columnar profile (Fig. 9) shows alternations of sandstone and mudstone/siltstone sequences. At least 38 cycles can be recognised out of which 27 were studied. In the individual cycles mudstone/siltstone strata are comparatively thicker (2.5 to 66 m) than the sandstone strata (2.5 to 22 m), which in most of the cycles are no more than 10 m thick. The thicknesses of the individual cycles range from 5 m to 76 m. These cyclic sequences closely resemble the finging-upwards cycles formed by the meandering rivers (Allen, 1965b). The scarcity of coarse conglomeratic units and dominance of mudstone, siltstone units over the sandstone point to the low-energy and high-sinuosity of the rivers. This conclusion is also supported by plotting width and depth values of the measured channels in Leader's (1973) diagram of width-depth relationship, in which the channels of the Dhok Pathan Formation fall into the high-sinuosity field.

The Soan Formation was studied in a stream section east of Spinthangai Village at the western side of Zarghun Ghar (Fig. 2). Its columnar profile (Fig. 10) shows that fining-upwards cycles ranging from 20m to 50m are present in which well-defined conglomerate, sandstone and mudstone/siltstone units are recognised from base to top respectively, in each cycle. The conglomerate beds have very sharp erosional base showing spectacular sole marks. Occasional sandstone lenses may also be found within the conglomerate units showing parallel and cross-laminae. The intervening sandstone beds are mostly cross-stratified, occasionally bioturbated and are usually thinner than the conglomerate and mudstone/siltstone beds. The mudstone/siltstone beds commonly display cross-laminae, bioturbation and include occasional thin and fine grained sandstone horizons which are commonly cross-laminated and bioturbated. The sequences constitute fining-upwards cycles showing a general decrease in grain size from cobbles and pebbles in the lower most conglomeratic units to silt and mud in the uppermost siltstone/mudstone units. Such cycles are repeated several tens of times through many hundred meters thick succession. Allen (1965b) suggested that such cycles are characteristic of the meandering river deposits, in which the lower conglomeratic strata represent deposition in channels, the intervening sandstone strata in point bars and the uppermost siltstone/mudstone strata in flood plain. Such successions are generated by the lateral migration of rivers across the flood planes and consequently the entire cycle is deposited. Thickness of the sequence is determined by the depth of the channel during flood stages and hence is related to the size of the river itself. The cyclic nature of the fining-upwards sequences is explained by the to-and-fro migration of the rivers across flood plain superimposed by a general tectonic subsidence.

It is proposed by the general consideration of the maximum grain size and large scale of some of the cross-strata and parallel laminae that the proposed low-sinuosity braided channels of the Nagri Formation were considerably great in discharge magnitude and flow power than the overlying high-sinuosity channels of the Dhok Pathan Formation. The Dhok Pathan and Soan Formation both are

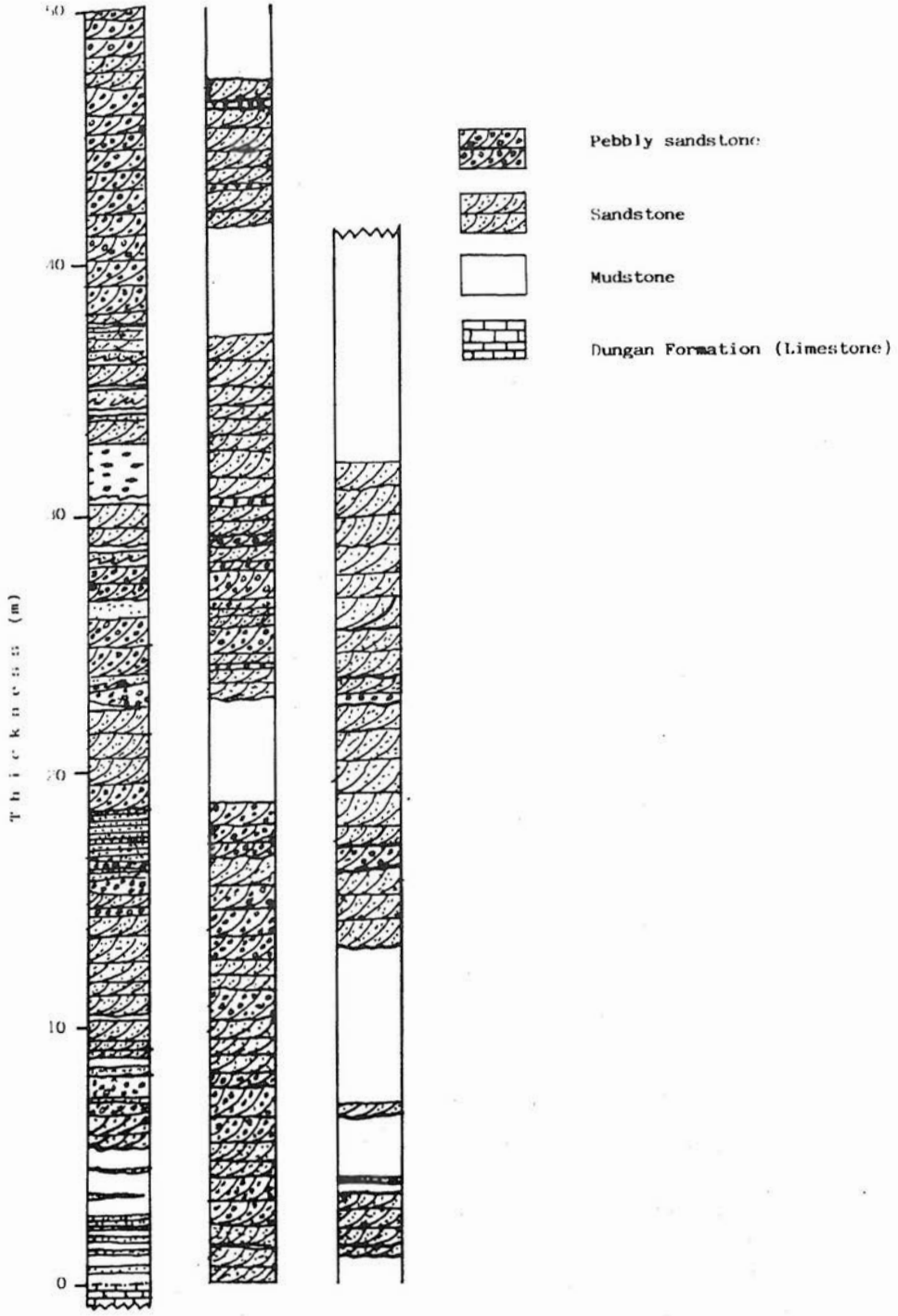

Fig. 8. Columnar profile of the Nagri Formation in Malkhozun Synclines Kach area.

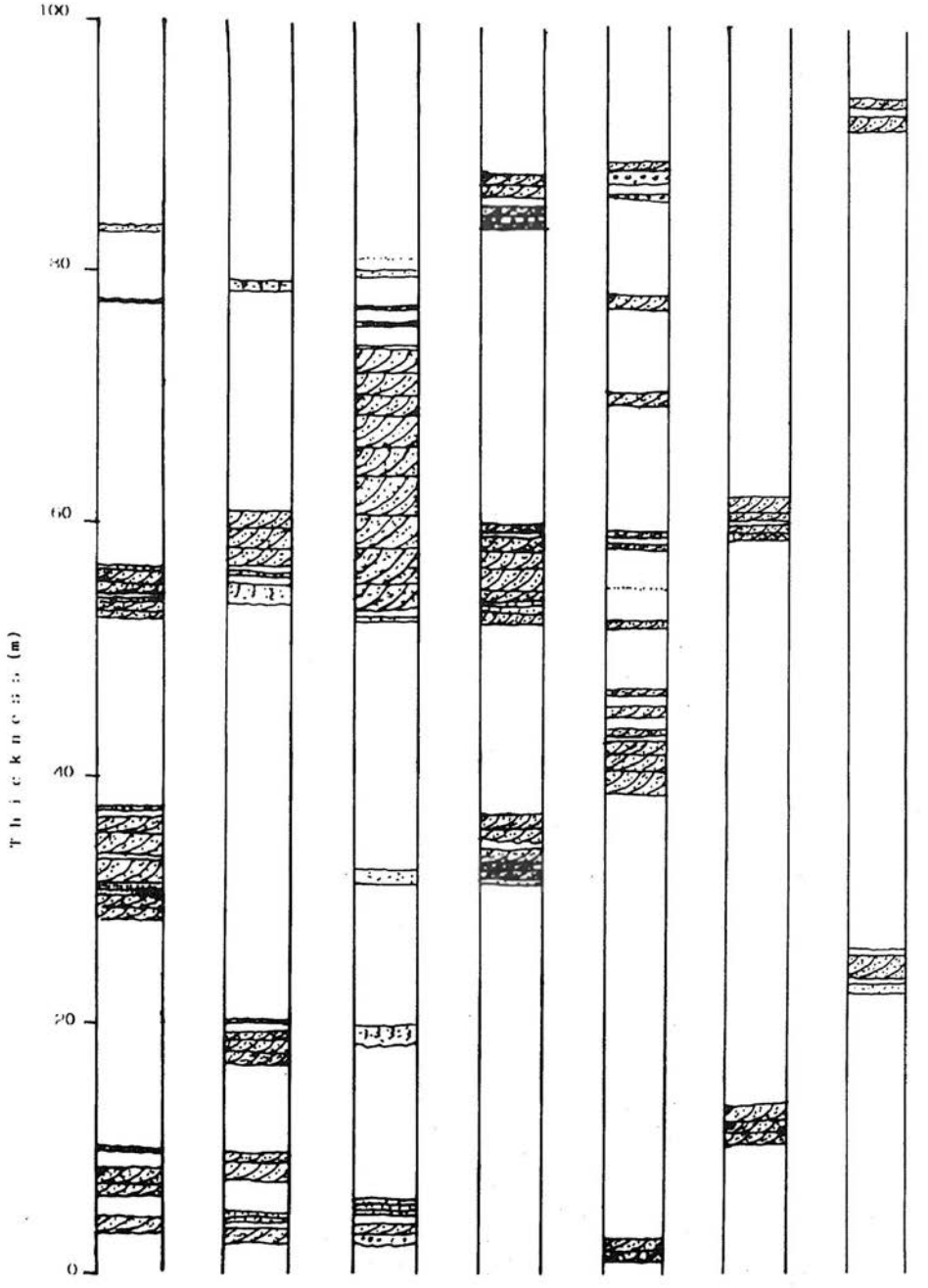

Fig. 9. Columnar profile of the Dhok Pathan Formation Pasta Syncline, Kach area. Succeeding columns are continuous with the preceding ones.

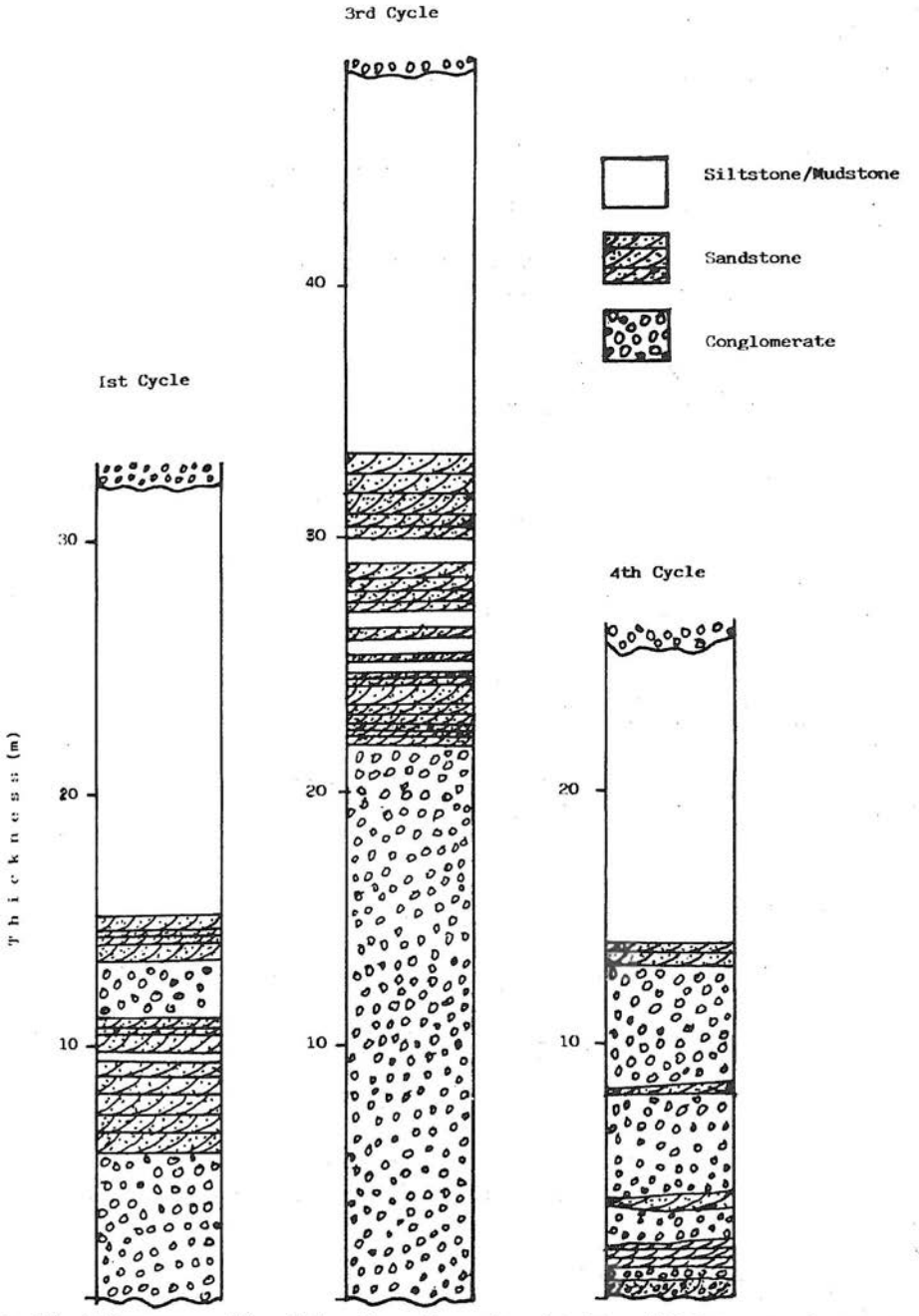

Fig. 10. Columnar profile of the Soan Formation in Tangai Nala west of Zarghun Ghar.

the deposits of high-sinuosity (meandering) rivers, however, they possess contrasting characteristics. The Soan Formation is typified by thick lower conglomeratic members which point to a relatively lower sinuosity index (Brice, 1964) and considerably higher stream power. The vertical facies associations from a braided to high-sinuosity system of relatively low energy and again to a high-sinuosity channel system of relatively higher energy suggest large scale regional variations. Allen (1970) has proposed that the influence of tectonism, climate and eustasy are vital in alluvial successions. Cyclic sequences of the Dhok Pathan and Soan Formations have achieved great thicknesses (hundreds of meters) and their preservation in a way just illustrated, require following conditions:

(a) Short life of channels

(b) Frequent avulsive events

(c) High rate of floodplain aggradation (especially in the Dhok Pathan Formation).

(d) Additional supplier of fines.

The conglomerate and sandstone units are laterally continuous (on Km scale) and may represent whole meander belts. It is suggested that the succession of the Dhok Pathan Formation, representing a normal high-sinuosity (meandering) river deposit is comparable with lithofacies class 2, and those of the Soan Formation with the lithofacies class 5 of Jackson II (1978). The lithofacies of the Soan Formation is a startling departure from the standard facies model for meandering streams. Such lithofacies exist near or within the mountain ranges where rivers flow on comparatively steep slopes.

CONCLUSIONS

Following conclusions may be drawn from the fore-going discussion:

1. The Nagri Formation is a deposit of braided channel system and the Dhok Pathan and Soan formations are deposits of meandering systems. Although both the Dhok Pathan and Soan Formation possess characters of meandering river deposits (cyclic, fining-upwards sequences) they show constrasting facies associations and therefore, have been deposited by rivers of contrasting morphology and energy conditions. It is suggested that the Soan Formation has been deposited by meandering rivers of comparatively low sinuosity index and higher stream power than the Dhok Pathan Formation.

2. Vertical facies variations may have been influenced, among other variables, by tectonic activity and gradual subsidence.

3. Palaeocurrents show that detritus of the Siwalik Group in Kach area was derived from the adjacent mountain ranges and deposited in nearby available basins.

REFERENCES

Abbasi, I.A., Abid, I.A., Khan A.M. & Shah, M.T. 1983. Petrography and geochemistry of Siwalik Sandstones and its relationship to the Himalayan Orogeny. Geol. Bull. Univ. Peshawar 16, 65—83.

Allen, J.R.L. 1965b. Fining-upwards cycles in alluvial successions. Geol. Jour. 4, 229—246.

———,1970. Studies in fluviatile sedimentation: A comparison of fining-upwards cyclothems, with special reference to coarse-member composition and interpretation. J. Sed. Petrol. 40, 298—323.

Brice, J.C. 1964. Channel patterns and terraces of the Loup River in Nebraska. U.S. Geol. Surv. Prof. Paper. 422—D.

Cotter, G. de P. 1933. The geology o part of the Attock District, west of longitude 72° 45E. Mem. Geol. Surv. India 55, 63—161.

Danilchik, W. & Shah, S.M.I. 1967. Stratigraphic momenclature of formations in Trans-Indus Mountains, Mianwali District, West Pakistan. U.S. Geol. Surv. Proj. Report (IR) PK-33, 45p.

Hunting Survey Corporation, 1961. Reconnaissance geology of part of West Pakistan, Toronto, Canada.

Hussain, S.T., Mounthe, J., Shah, S.M.I., West R.M. & Lukacs, J.R. 1979. Neogene stratigraphy and fossil vertebrates of the Daud Khel area, Mianwali District, Pakistan. Mem. Geol. Surv. Pakistan 13.

Jackson II, R.G. 1978. Preliminary evaluation of lithofacies models for meandering aluvial streams. In: (Miall, A.D. ed.), Alluvial Sedimentology. Canada. Soc. Petrol. Geol. Calgary, Alberta, Canada.

Kazmi, A.H. 1979. The Bibai and Gogai Nappes in the Kach-Ziarat area of northern Baluchistan. In: (Farah, A & De Jong, K.A. eds.). Geodynamics of Pakistan. Geol. Surv. Pak. Quetta.

Kazmi, A.H. & Raza, S.Q. 1970. Water supply of Quetta Basin, Baluchistan, Pakistan. Ibid., Resc., 20 (2).

Khan, M.J. 1984 Brief results of the palaeomagnetic studies of the Siwalik Group of the Trans-Indus Salt Range, Pakistan. Geol. Bull. Univ. Peshawar 17, 176—78.

Kravtchenko, K.N. 1964. Soan Formation — upper unit of the Siwalik Group in Potwar. Science and industry, 2 (3), 230—233.

Krynine, P.D. 1937. Petrography and genesis of Siwalik Series. Amer. J. Sci. 5, 5th ser., 34, 422—446.

Leader, M.R. 1973. Fluviatile fining-upwards cycles and the magnitude of palaeochannels. Geol. Mag., 110, 265—276.

Lewis, G.E. 1937. A new Siwalik correlation (India). Amer. J. Sci. 5 (195), 191—204.

Miall, A.D. 1977. A review of the braided river depositional environment. Earth Sci. Revs. 13, 1—62.

Opdyke, N.D., Lindsay, E., Johnson, G.D., Johnson, N., Tahirkheli, R.A.K. & Mirza, M.A. 1979. Magnetic polarity stratigraphy and vertebrate palaeontology of the upper Siwalik sub-Group of northern Pakistan. Earth Planet. Sci. Lett. 27, 1—34.

Rust, B.R. 1979. A classification of alluvial channel systems. In: (Miall, A.D. ed.). Fluvial Sedimentology. Canad. Soc. Petrol. Geol. Calgary, Alberta, Canada.

Shah, S.M.I., Pilbeam, D. & others. 1979. Miocene sediments and faunas of Pakistan. Peabody Mus. Natural Hist. Yale Univ. Postilla, 179.

Stratigraphic Committee of Pakistan (A.N. Fatmi, compiler) 1974. Litho-stratigraphic units of the Kohat-Potwar Province, Indus Basin, Pakistan. Mem., Geol. Surv. Pakistan, 10, 1—80.