*Geol. Bull. Univ. Peshawar, 1990, Vol. 23, pp. 123-133*

# LITHOFACIES ASSOCIATIONS AND PALEOCURRENT PATTERNS IN THE NAGRI FORMATION OF THE SIWALIK GROUP IN KACH-ZARGHUN AREA OF NORTHEAST BALUCHISTAN

AKHTAR MOHAMMAD KASSI, AMJAD RASHID QURESHI &
DIN MOHAMMAD KAKAR

Department of Geology, University of Baluchistan, Quetta

## ABSTRACT

*The Nagri Formation of the Siwalik Group contains at least eight distinct lithofacies types, the most dominant, in descending order, being the horizontal bedded sandstones (Sh) mixed with the low angle crossbedded types (Sl) and the trough crossbedded sandstone (St) which are mostly very coarse grained, pebbly and poorly sorted. Other lithofacies like the massive sandstones (Sm) and also those having erosional scours alongwith mud interclasts at their base (Se), plannar crossbedded sandstones (Sp), massive sandstones with slump structures (Ssm), laminated slump sandstones (Ssl) and the occasional finely laminated siltstones and mudstones (Fl) are also observable. These associations suggest frequent surges of high energy floods with antidunes, scourfills and plannar bed flows along with periods of normal flows causing dunes and ripples.*

*Paleocurrent patterns based on directions of maximum inclination of foreset beds in trough crossbedded sandstones of the Nagri Formation suggest a northerly and southeasterly derivation in the Spera Ragha-Gogai Syncline north of Kach Thanna and a dominant north and northeasterly derivation in Pasta-Zarghun Synclines south of Kach Thanna. These patterns suggest that basin was deriving its detritus from a landmass to the north of Zarghun, east of Gogai and south of Spera Ragha. However, paleocurrents on the northern flank of Spera Ragha-Gogai Synclines suggest derivation also from a landmass to the north of Rud Malazai, Malkhezun and Umai.*

## INTRODUCTION

The Stratigraphic Committee of Pakistan (Fatmi, 1974) subdivided the Siwalik Group into Chingi, Nagri, Dhok Pathan and Soan Formations among which the lower-

most Chingi Formation is not recognised in Baluchistan. Here the Nagri Formation overlies unconformably various older formations ranging in age from Triassic to Eocene with angular discordance, whilst, its upper contact with the Dhok Pathan Formation is transitional. The Nagri Formation consists mostly of sandstones with very minor amount of claystone and siltstone partings. The formation has been interpreted (Kassi, 1987) as a deposit of braided channel system which have derived its detritus from the nearby mountain ranges.

The present paper is based on the study of the lithofacies associations of the Nagri Formation in two sections on Quetta- Ziarat road near Kach Levy Post (Fig. 1) and paleocurrent patterns in 25 localities around Zarghun, Kach, Gogai, and Rud Malazai. New proposals are made and amendments proposed in earlier work (Kassi, 1987) regarding lithofacies associations and paleocurrent patterns and the study area extends to Ahmadun, Gogai, Tangai, Rud Malazai and various other localities around Zarghun.

## PREVIOUS WORK

In Baluchistan the stratigraphic study of the Siwalik Group was initiated by the Hunting Survey Corporation (1961) which was subsequently standardised by the Stratigraphic Committee of Pakistan (Fatmi, 1974). Kazmi & Raza (1970) also described the local stratigraphy of the Siwaliks in Quetta region and proposed local names of the formations. Kassi (1987) and Kassi et al. (1987) described the preliminary sedimentology and petrology of the Siwaliks of Kach and Zarghun areas and made comments on their paleoenvironments and provenance. Kassi (1989) also commented on the grain size parameters of the conglomerate units of the Soan Formation.

## GENERAL LITHOLOGICAL CHARACTERS

The Nagri Formation in studied area comprises fine to very very coarse grained and pebbly sandstone with very minor claystone and siltstone partings. The sandstone is light brownish gery, bluish and greenish grey, subangular to subrounded; coarse grained horizons are poorly sorted while medium and fine grained horizons moderately to well sorted. Sandstone beds are of varied thicknesses and contain verious types of sedimentary and igneous rock fragments and therefore have been classified (Kassi et al., 1987) as lithic arenite/calclithite. Sedimentary structures like trough crossbedding, ripple marks, horizontal lamination, parting lineation, load casts and associated flame structures are very common. Plant fragments, silicified wood fossils, and vertebrate bone fossils are also commonly present. Silicifed wood fossils are most common near

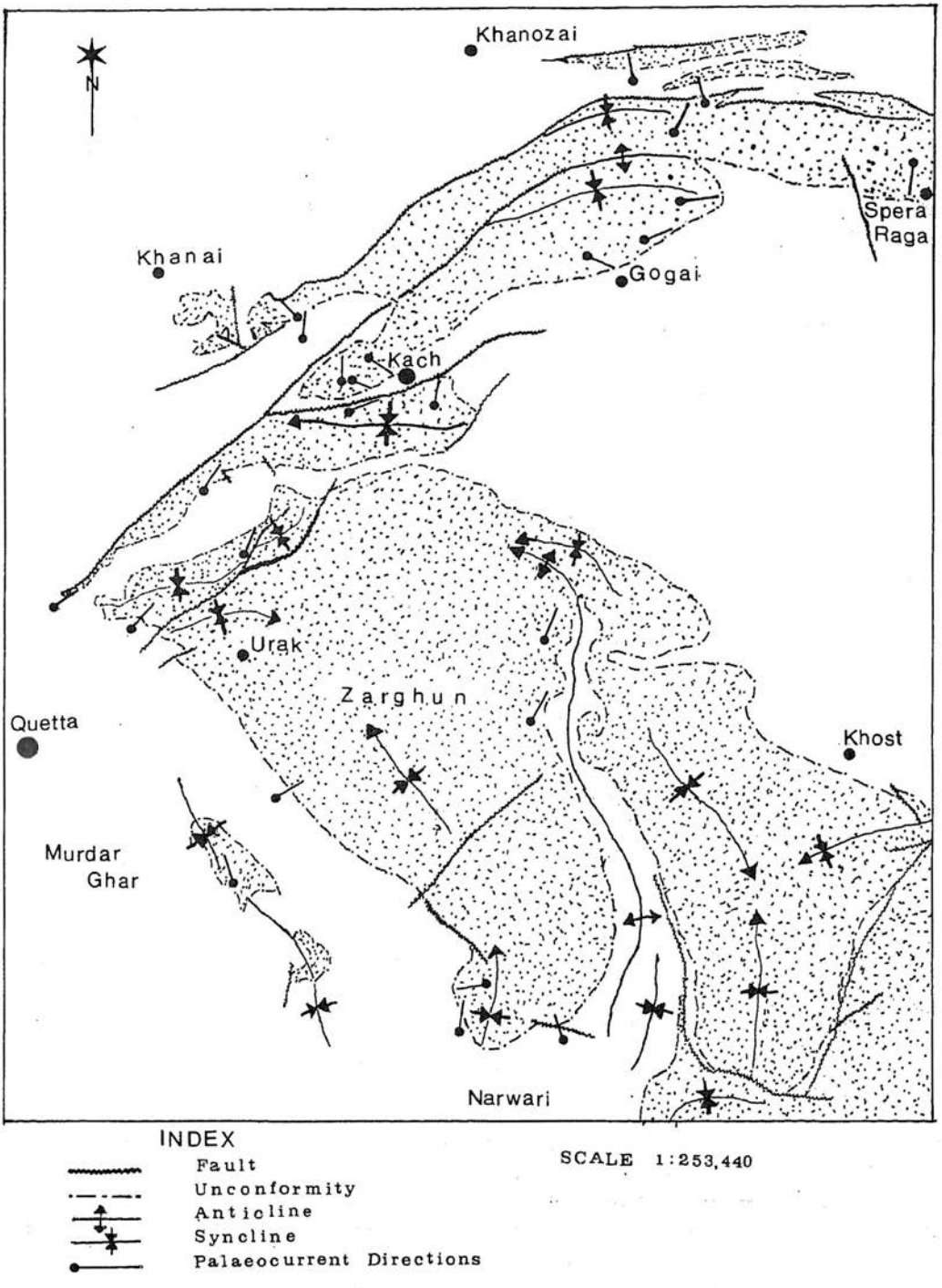



Fig. 1. Map of the studied area showing palcocurrent pattern. Stippled areas represent exposures of the Siwalik Group and unstippled areas are those where older rocks are exposed.

Kach, Shin Ghundai (near Kach-Ziarat and Kach-Sharig roads junction) and Kili Bridge of the Zarghun area. Vertebrate bone fossils were observed in Shin Ghundai, road section on the southern limb of syncline east of Umai (northwest of Kach), road section northwest of Gogai and Obashtagai Nala section near Narwari. The thickness of the Nagri Formation is variable even within the studied area, ranging from several hundred meters on the northern margin of Zarghun to only a few tens of meters on the southern margin.

Except in Zarghun area, where the formation perhaps disconformably overlies the Kirther Formation of Eocene age, it overlies making an angular unconformity with various older formations ranging in age from Triassic to Eocene. The lower contact with the Kirther Formation on the southern margin of Zarghun south of Zardalu, Khost and Sharig is characterised by a 10-20 m thick oxidation zone comprising of pale and yellowish brown lateritic horizons of claystone mixed with highly fossiliferous limestone fragments of the Kirther Formation with a few very thin well developed limestone beds in between. This horizon is again followed by 7-8 m thick limestone bed of the Kirther Formation which is overlain by a highly ferrogenous conglomeratic horizon containing fragments of the underlying fossiliferous Kirther Formation which in turn is followed by sandstone beds of the Nagri Formation. The Oil and Gas Development Corporation (1965 unpublished reports) have assigned a middle to late Miocene age to the formation.

## LITHOFACIES ASSOCIATIONS

Study of the lithofacies associations was carried out in two localities -- one on road section near Kach Levy Post (Fig. 1) and the other on Shin Ghundai near Kach-Ziarat and Kach-Sharig roads junction. Thicknesses of various lithofacies in these sections were measured by ordinary steel made measuring tape perpendicular to the strike of the beds and columnar profiles (Fig. 2 & 3) prepared accordingly. Eight distinct types of lithofacies (Table 1) are recognisable and most of them categorised and coded according to the Miall's (1978) scheme.

Columnar profile of the Shin Ghundai section (Fig. 2) shows that trough-crossbedded very coarse pebbly sandstone (St) and mixed horizontal bedded sandstone (Sh) and low angle ($10^{o}$) crossbedded sandstone (Sl), in descending order, are the most abundant lithofacies associations (Fig. 4). In Kach Thanna section (Fig. 3), however, mixed Sh and Sl facies are most abundant (Fig. 5) and St type subordinate. Other important types, in descending order, are massive sandstones with interclasts (Se) and without interclasts (Sm), massive and slumped sandstones (Ssm) and laminated slumped sandstones (Ssl) (Fig. 6). Lithofacies like plannar crossbedded sandstones (Sp)

TABLE 1. LITHOFACIES AND SEDIMENTARY STRUCTURES (MODIFIED FROM MIALL, 1978), IN THE STUDIED AREA.

| Facies code | Lithofacies | Sedimentary structures | Interpretation |
|---|---|---|---|
| Sh | Sand, very fine to very coarse, may be pebbly. | horizontal lamination, parting or streaming lineation | plannar bed flow (l. and u. flow regime) |
| St | Sand, medium to very coarse, may be pebbly. | solitary or grouped trough crossbeds | dunes (lower flow regime) |
| Sl | Sand, medium to fine. | low angle (< $10^{o}$) crossbeds | scour fills, crevasse splays, antidunes |
| Ssm | medium to coarse | massive, slumped | antidunes, unstable conditions |
| Sm (+Se) | Sand, massive with crude erosional scours with or without interclasts. | crossbedding scour fills or horizontal bedding | |
| Ssl | Sand, medium to fine. | laminated, slumped | upper flow, regime unstable |
| Fl | sand, silt, mud | fine lamination, very small ripples | overbank or waning flood deposits |
| Sp | Sand, medium to very coarse, may be pebbly. | solitary or grouped plannar crossbeds | linguoid, transverse bars, sand sand (lower flow regime) |
| Fscsilt, mud | laminated to massive | backswamp | deposits |

finely laminated siltstones and mudstones (Fl) are massive and crudely laminated mudstones (FSc) are also present in very minor properties.

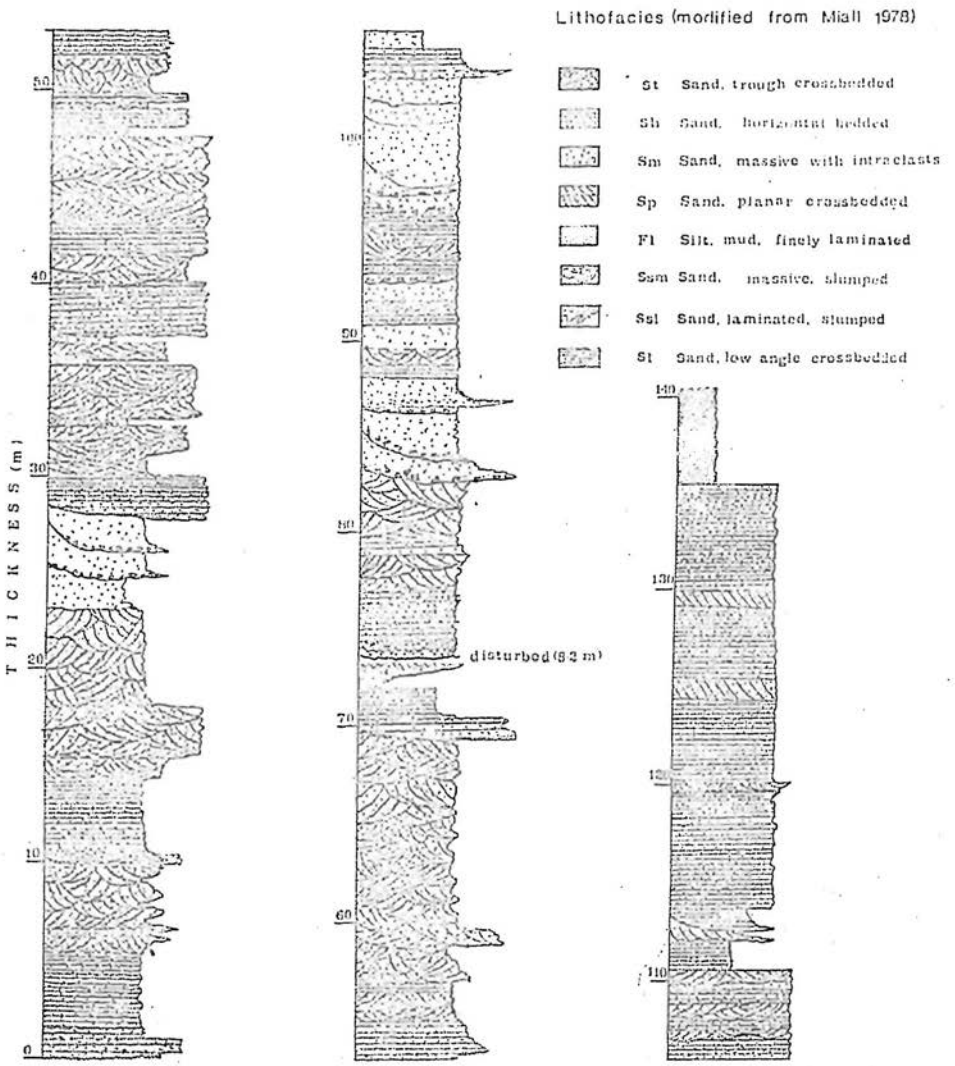
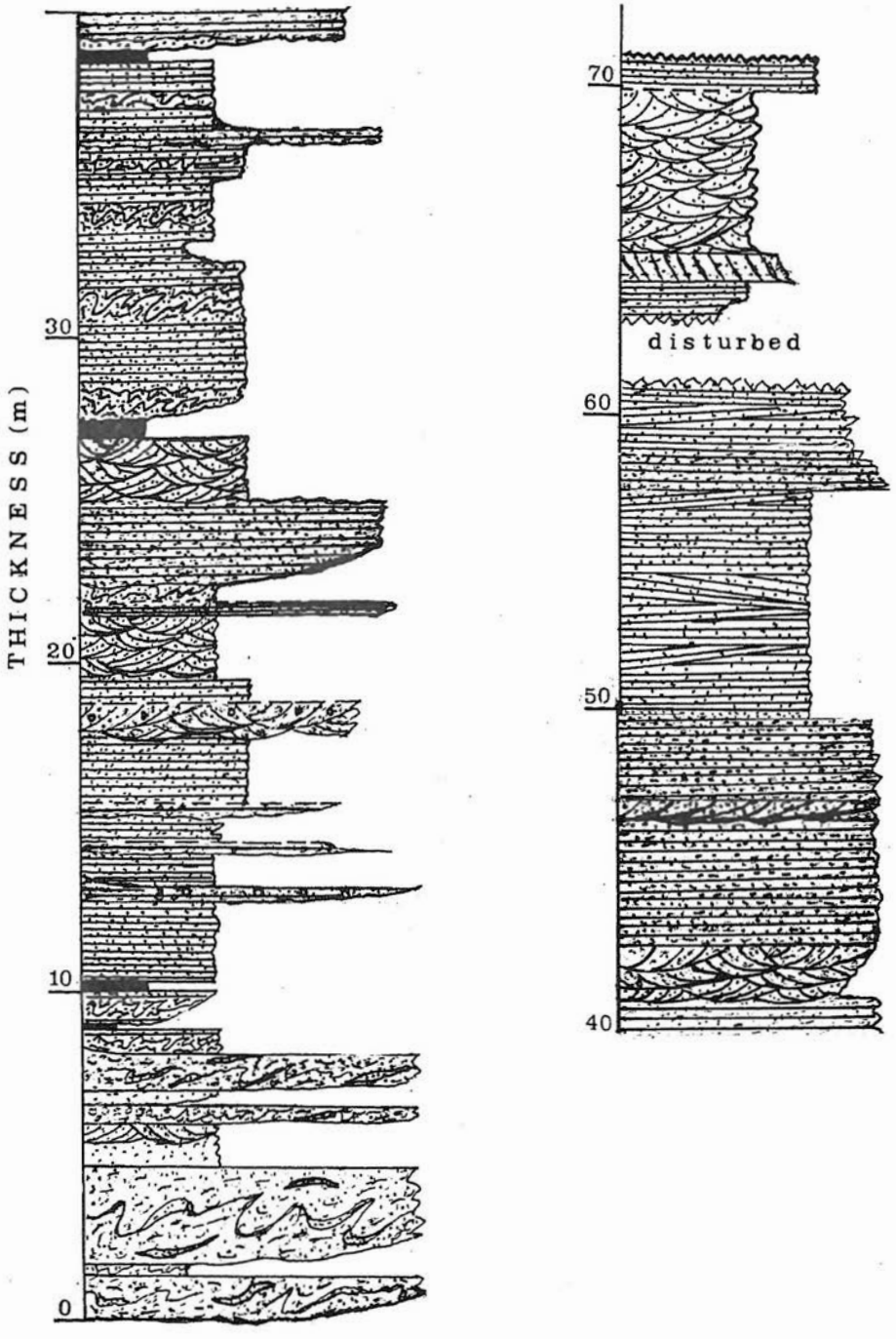



Fig. 2. (Above) Vertical profile of the Nagri Formation and Shin Ghundai section near Kach-Ziarat and Kach-Sharig roads junction.

Fig. 3. (Facing Page) Vertical profile of the Nagri Formation on road section just near Kach Thanna. Index of lithofacies as in Fig. 2.


THICKNESS (m)
30
20
10
0
70
disturbed
60
50
40

## PALEOCURRENT PATTERNS

Data related to paleocurrent directions were taken in 25 localities around Zarghun, Kach, Gogai, and Rud Malazai, Narwari and Bilal Kach (near Orak) areas. Most of the data are based on the direction of maximum inclination of foreset beds in trough-crossbedded sandstones and/or axes and plunge of troughs observed. In localities where dip of the beds was less than 25, current directions were taken directly. But in localities with higher dip angles, pitch angle of the current directions were taken and corrected stereographically by rotating them along the strike of the beds back to horizontal. Averages of the azimuths after corrections were calculated for the obtained readings of each locality. The number of obtained readings in different localities, depending on the availability of proper trough-crossbedded strata, range between 4 and 20 and in most localities (19 out of 25) was more than 10. The averages calculated were plotted on map (Fig. 1).

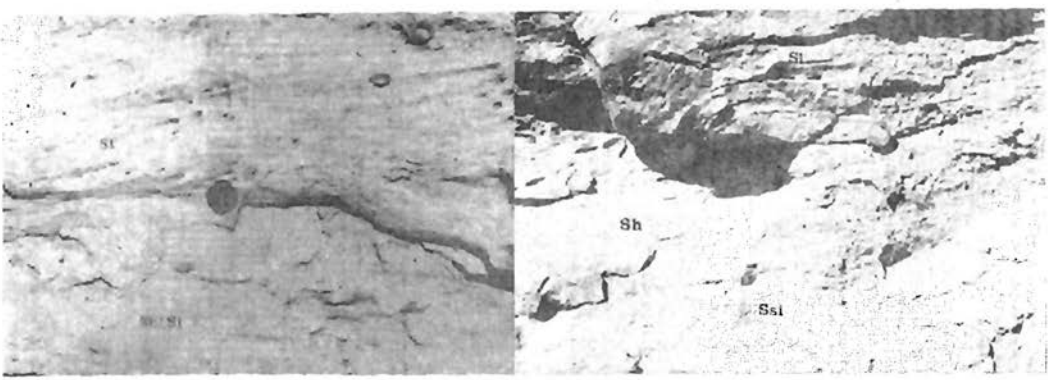



Fig. 4(Left). Nagri Formation showing trough-crossbedded sandstone (St), horizontal laminated sandstone (Sh), and/or low angle (10°) crossbedded sandstone (Sl).

Fig. 5(Right). Nagri Formation showing low angle (10°) crossbedded sandstone (Sl), horizontal laminated sandstone (Sh) and laminated slumped sandstone (Ssl).

It may be observed that on the southern flank of Spera Ragha-Gogai Syncline paleocurrents are mostly towards north, northwest and west, whilst on the northern flank mostly southwards. These patterns suggest that the area was deriving detritus from two different areas, one to the north of Rud Malazai and Umai (south of Khanai) and the other to the south of Spera Ragha, south and east of Gogai and north of Khost.

Paleocurrents in Pasta and Zarghun Synclines, on the contrary, show flow directions mostly towards south and southwest. Paleocurrent directions around Kach area (Fig. 1) suggest that the two basins were perhaps joined together. In support of this suggestion it may be argued that the Nagri Formation is very thick, coarse and pebbly

on the northern margin of Zarghun Ghar, around Kach and further northwards near Gogai, Spera Ragha and Rud Malazai, whilst on the southern and eastern margin of the Zarghun Ghar naer Mandazai village, Zari China, Sor Range and Narwari it is very thin, discontinuous and mostly medium to fine grained. These variations also suggest occurence of proximal lithofacies to the north of Zarghun and distal to the south, however, further work is needed to elaborate these ideas.

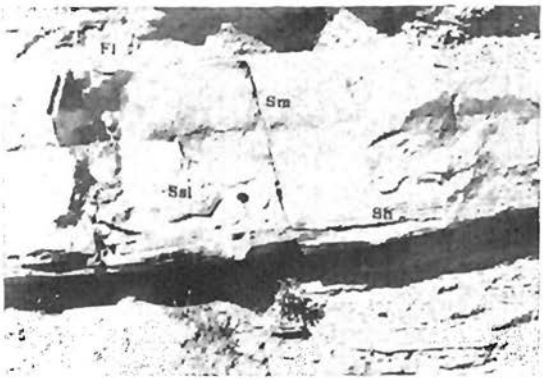



Fig. 6. Nagri Formation showing horizontal laminated sandstone (Sh), laminated slumped (load casted) sandstone (Ssl), massive sandstone (Sm), and finely laminated siltstone (Fl).

## ENVIRONMENTAL INTERPRETATIONS AND DISCUSSIONS

Environmental interpretations of these lithofacies associations, based on Miall's (1978) work (Fig. 2 & 3, Table 1) have been made. It may be concluded that Sh and Sl are the product of plannar bed flows and antidunes respectively and caused by very high swift floods (McKee et al., 1967). However, lithofacies St are the product of dunes formed in channels during normal flow conditions whereby their set thicknesses depending on the depth of channels. Columnar profiles of the Shin Ghundai section (Fig. 2) suggest a crudely fining-upwards trend. Plannar crossbedded sandstones (Sp), attributed to the linguoid transverse bars, are present in the upper parts of the sequences. Road sections near Kach Levy Post (Fig. 3) shows slumping and frequent occurences of load casts and associated flame structures suggesting unstable depositional conditions perhaps due to higher gradient.

The high proportion of Sh, Sl, and St lithofacies types resemble with the Bijou Creek model of Miall (1978) and the sand dominant braided channel system of Rust (1978) which are the product of high energy flow conditions dominated by flash floods possibly of ephemeral nature.

The occurrence of lithofacies types Sh, Sl, and Se (including Sm) are coupled with very coarse, pebbly and poorly sorted nature of the snadstones which suggest simultaneous deposition of both pebbles and sand perhaps with minor current fluctuations. In this case the larger clasts are rarely larger than medium pebble size (15 mm). Lithofacies Sl is caused by lower-relief scours (Rust, 1978) and Sh analogus to horizontally laminated strata formed on longitudnal bars in proximal gravel systems. Se with mud interclasts, up to several cm across, is also an indication of high competency of the system. Combination of Sh, Sl and Se (alongwith Sm) assemblages with that of St (Fig. 2 & 3) reflect fluctuations in flow conditions and indicate that flow system was less ephemeral and resembles with the Bijou Creek and Malbai type of assemblages. During flood conditions the size of the dunes responsible for the formation of trough-crossbedding depends on the depth of the channel and thicker (up to 1 m) sets are formed (Cant, 1978), therefore, large troughs (0.6 m deep and 3 m wide) in coarse and pebbly sandstones are characteristic of the sinuous-crested dunes in large deep channels. Plannar crossbeds, on the other hand, are deposited by transverse linguoid bars with slip faces forming their downstream margins (Smith, 1970, 1971; Collinson, 1970).

## CONCLUSIONS

1. Eight distinct lithofacies associations namely the Sh (plus Sl), St, Sm, Se, Sp, SSm, SSl, Fl (in descending order) are characteristic of the Nagri Formation, Sh (plus Sl) and St being the most common lithofacies types.

2. Such a combination of lithofacies associations suggests frequent surges of high energy floods with antidunes, scourfills and plannar bed flows with intermittent periods of normal flows causing dunes and ripples.

3. Paleocurrent patterns suggest a common landmass to the north of Zarghun, east of Gogai and south of Spera Ragha, however, the northern flank of Spera Ragha and Gogai Synclines have derived its detritus from a land mass to the north of Rud Malazai, Malkhezun and Umai.

## REFERENCES

Cant, D.J., 1978. Development of facies model for sandy braided river sedimentation: Comparison of south Saskatchewan river and the Battery Point Formation. In: Fluvial Sedimentology (A.D. Miall ed.).Canad. Soc. Petrol. Geol. Calgary, Alberta, Canada.

Collinson, J.D., 1970. Bedforms of the Tana River. Geogr. Ann. 52A, 31-56.

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

Kassi, A.M., 1989. Grain size parameters of the conglomerate fraction of the Soan Formation, Zarghun Ghar, Baluchistan. Kashmir J. Geol. 6&7, 177-182.

Kassi, A.M., 1987. Preliminary sedimentology of the Siwalik Group of Kach and Zarghun areas, Baluchistan. Geol. Bull. Univ. Peshawar 20, 37-51.

Kassi, A.M., Salam, A. & Haque, A., 1987. Petrology and provenance of the Siwaliks of Kach area, northeast Baluchistan. Symp. Min. Res. Pakistan, Abstract.

Kazmi, A.H. & Raza, S.Q., 1970. Water supply of Quetta Basin, Baluchistan, Pakistan.

McKee, E.D., Crosby, F.J. & Berryhill, H.L., 1967. Flood deposits Bijou Creek, Colorado. J. Sed. Petr., 37, 829-851.

Miall, A.D., 1978. Lithofacies and vertical profile models in braided river deposits; a summary. In: Fluvial Sedimentology (A.D. Miall ed.), Canad.Soc. Petrol. Geol. Calgary, Alberta, Canada.

Rust, B.R., 1978. A classification of alluvial channel systems. In: Fluvial Sedimentology, (A.D. Miall ed.). Canad. Soc. Petrol. Geol. Calgary, Alberta, Canada.

Smith, N.D., 1970. Braided stream depositional environment; comparison of the Platte River with some Silurian clastic rocks south-central Appalachians. Geol. Soc. Am. Bull. 81, 2993-3014.

Smith, N.D., 1971. Transverse bars and braiding in the lower Platte River, Nebraska. Geol. Soc. Am. Bull. 82, 3407-3420.

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