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SEDIMENTATION AND TECTONICS OF THE SIWALIK GROUP OF THE TRANS-INDUS SALT RANGE, NORTHWESTERN PAKISTAN

M. JAVED KHAN

Department of Geology and National Centre of Excellence in Geology, University of Peshawar, Pakistan.

ABSTRACT

Sediment accumulation rates calculated for fluviatile sediments of the Trans-Indus Salt Range in northwestern Pakistan are generally higher than those of the Potwar Plateau. This indicates more rapid subsidence of the Trans-Indus area compared to the eastern Potwar Plateau area, as well as a continued supply of detrital material. The entire stratigraphic sequence, which covers a time span of 12.0–0.5 Ma, is conformable, suggesting that the only tectonic activity in this area over this period consisted of gradual subsidence of the depocenter. However, Siwalik sedimentation ceased at about 500,000 BP when the Trans-Indus region was uplifted during Pleistocene phase of the Himalayan orogeny. The uplifted terraces of recent alluvial deposits show that uplift is still an active process in this area.

INTRODUCTION

The Siwalik Group

The Siwalik Group, located in the Trans-Indus Salt Range of northwestern Pakistan (Fig. 1), consists of a sequence of alternating sandstone and siltstone units; whose thicknesses vary laterally as well as vertically. In the Potwar Plateau, where these sediments have been studied extensively (for detailed references, see Pilbeam *et al.*, 1977), the sandstone/siltstone ratio has been used to define various formations. The basal part of the Siwalik Group, with thicker siltstone than sandstone units, is defined as the Chinji Formation. The Nagri Formation conformably overlies the Chinji Formation and consists of thicker sandstone than siltstone units. Almost equal thicknesses of sandstone and siltstone units constitute the Dhok Pathan Formation, a sequence that conformably overlies the Nagri Formation. The Soan Formation comprises the uppermost part of the Siwalik Group and is composed of a greater proportion of sandstone units than in the Dhok Pathan Formation. This formational division was considered synchronous with faunal stages and thus lithologic boundaries were assumed to be isochronous. However, when studied at other than the type localities, it became clear that the formational boundaries are not isochronous (Middlemiss, 1919, Morris, 1938). This, as well as the distinct and rapid lateral and vertical facies changes, sparked further interest in the geologic history of Siwalik sedimentation, although an absolute time frame in the Trans-Indus was not established until the recent paleomagnetic studies of Khan and Opdyke (1981) and Khan *et al.* (in press).

THE SIWALIK GROUP OF THE TRANS-INDUS SALT RANGE

The Siwalik Group of the Trans-Indus Salt Range consists of a basal red bed zone in which siltstone units are thicker than sandstone units. This red bed zone is conformably overlain by a sequence (1–6 km thick) of sandstone that increases in thickness from the Marwat/Khasor Ranges toward the Makarwal anticline (Fig. 1). Overlying this thick sandstone is a series of alternating sandstones and siltstones of mostly equal thickness. The top of the Siwalik Group is made up of a sandstone (100–500 meters thick) that is commonly conglomeratic in the upper part. In the Marwat Range, the base of the Siwalik sediments is not exposed, but drilling in the northern part of the Marwat Range has shown that red beds underlie thick sandstone. In the northwestern part of the Makarwal anticline, an alternating sequence of sandstones and conglomerates forms the upper part of the Siwalik Group, and the thickness of this sequence is lesser than the lower series.

This general lithologic division of Siwalik Group, however, does not apply to the Siwalik Group in the Bhittani Range, where the entire stratigraphic sequence is made up of sandstone and siltstone couplets. Here, the lower part consists of brown siltstone units and dark grey to brown sandstone units. The upper part of the group consists of light brown to greyish-orange siltstone and light grey sandstone units. Also the base of the Siwalik Group is not exposed, and drilling results are not available for this area.

The lithology of the Siwalik Group represents typical deposits of a well developed meandering river system (Allen, 1965a, b). These fluvial sediments consist of channtl deposits (sandstone) and associated floodplain deposits (siltstone/claystone). Preservation of a sequence of these alternating channel and floodplain deposits indicates lateral migration of a meandering river channel on a geologic time scale. However, continued recurrence of the axial zone of the river channel in the same area results in the erosion of floodplain deposits and preservation of multistoried sandstone units. Both of these features are well documented in alternating sequences of sandstone and siltstone, representing con-

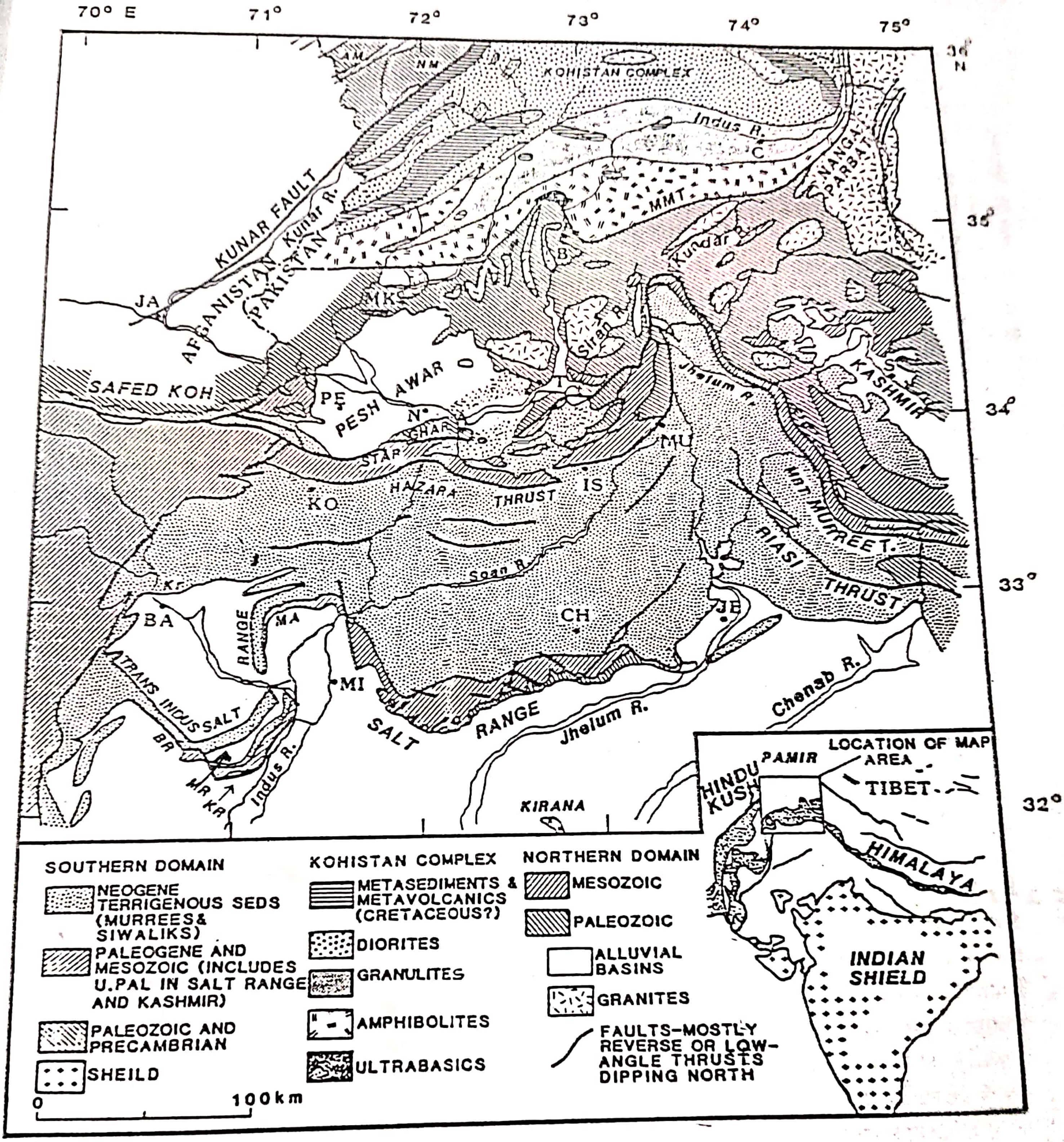


Fig. 1. Geologic sketch-map of northern Pakistan. Adopted from: Gansser (1964), Desio (1964), Calkins, *et al.* (1975), Tahirkheli and Jan (1979), *et al.* (1979). Explanations: A = Attock, AM = Asiatic mass, B = Besham, BR = Bhittani Range, CH Chakwal, IS = Islamabad, Ja = Jalabad, JE = Jhelum, KR = Khasor Range, KO = Kohat, KT = Kurram River, MBT = Main Boundary Thrust, MA = Makarwal anticline, MK = Malakand, MR = Marwat Range, MI = Mianwali, MU = Murree, NM = Northern Megashear, N = Nowshera, P = Pattan, PE = Peshawar, S = Srinagar, T = Tarbela.

tinuous lateral migration of river channels and associated overbank floodplain deposits. The thick, multistoried sandstones lacking siltstone units represent areas repeatedly occupied by the river channels.

A three-dimensional block diagram was constructed, based on thickness of the stratigraphic sequence and the type of sedimentation at corresponding section localities (Fig. 2). It is evident that the thick stratigraphic sequence exposed in the vicinity of the Chichali-Chani Khel sections starts pinching out toward the Khora Baroch-Spalmai Tangi sections to the west. The Siwalik Group sequence is thinnest in the northern part of the Marwat and Khasor Ranges. However, west of the Walewal and Spin Qammar sections, a trend of gradually increasing thickness is evident, corresponding to the fact that the Siwalik Group attains maximum thickness in the Potwar Plateau east of the Chichali-Chani Khel sections (Johnson *et al.*, 1982; Tauxe and Opdyke, 1982). The thickness of the Siwalik Group in the Suleman Range, west and south of the Bain Pass area, is also greater than that exposed in the Pezu-Bain Pass area (Hemphill and Kidwai, 1973; Shah, 1977). This block diagram shows that the Chichali-Chani Khel area was repeatedly occupied by the axial zone of a river channel, resulting in the deposition of a thick sequence of sandstone. The area of the Marwat and Khasor Ranges was also under the influence of a recurring river channel, but for a lesser time period. The northwestern part of the Bhittani Range was in the recurring zone of a river channel for only short periods of time. This distribution of thick sandstone sequences suggests that the ancestral river responsible for the deposition of Siwalik sediments gradually migrated to the west and south and then back toward the east.

Another block diagram was constructed on the basis of age and type of sediment encountered at corresponding section localities (Fig. 3). The age of these sediments is based on the magnetostratigraphic studies of Khan (1983). Figure 3 shows that deposition of Siwalik sediments started at about 12 Ma in the vicinity of the Chichali area where the Siwalik Group overlies Paleogene sediments with angular unconformity. In the northern Marwat and Khasor Ranges, Siwalik sedimentation did not start until about 4 Ma. In the Bhittani Range, erosion was going on prior to 4.5 Ma; however, the time of onset of Siwalik sedimentation in this area is not known due to the lack of exposures of basal Siwalik sediments. This suggests that the oldest Siwalik sediments exposed in the Trans-Indus Salt Range are much younger than lower Siwalik sediments of the Potwar Plateau where Siwalik sedimentation antedates 15 Ma (Johnson *et al.*, 1982; Tauxe and Opdyke, 1982). This indicates that deposition of the Siwalik Group started earlier in the Potwar Plateau than in the Trans-Indus area. However, gradually, these fluviatile sediments started being deposited toward the west until about the longitude of the Walewal and Spin Qammar sections where the onset of Siwalik deposition is youngest (about 3 Ma). In the area now occupied by the Bhittani Range, Siwalik deposition antedates 4.5 Ma and the time of onset of Siwalik deposition is not known.

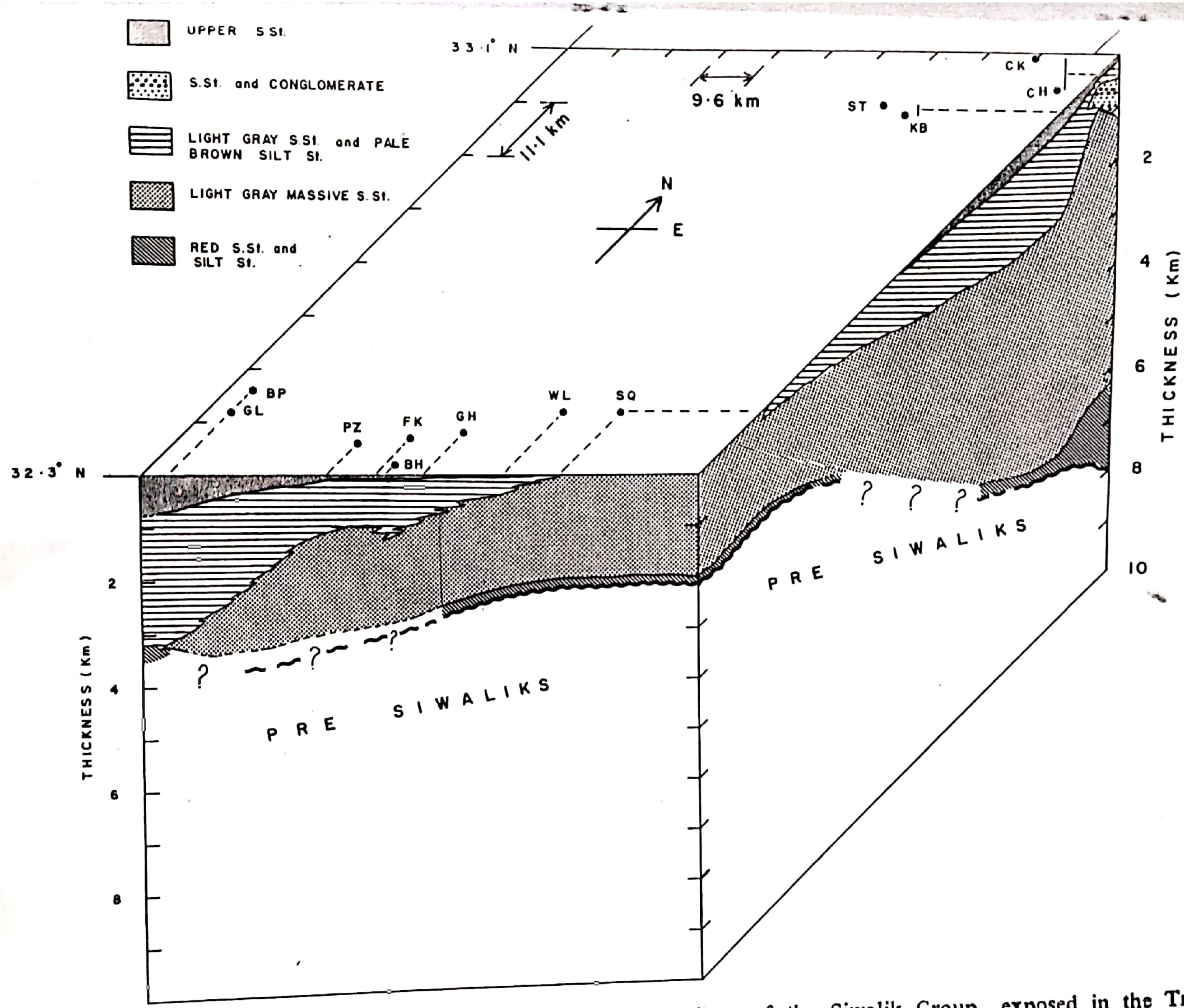


Fig. 2. Block diagram based on the thickness and the dominant lithology of the Siwalik Group exposed in the Trans-Indus Salt Range. Thickness was measured at each corresponding section location. The sections were located at these sites — BH = Bhandara, BP = Bain Pass, CH = Chichali, CK = Chani Khel, FK = Faqir Kili, GH = Gharangai, GL = Garhi Landa, KB = Khora Baroch, PZ = Pezu Pass, SQ = Spin Qammar, ST = Spalmai Tangi and WL = Walewal. The sections measured at KB—ST and CH—CK constitute one stratigraphic sequence each, and therefore data is plotted at an intermediate location.

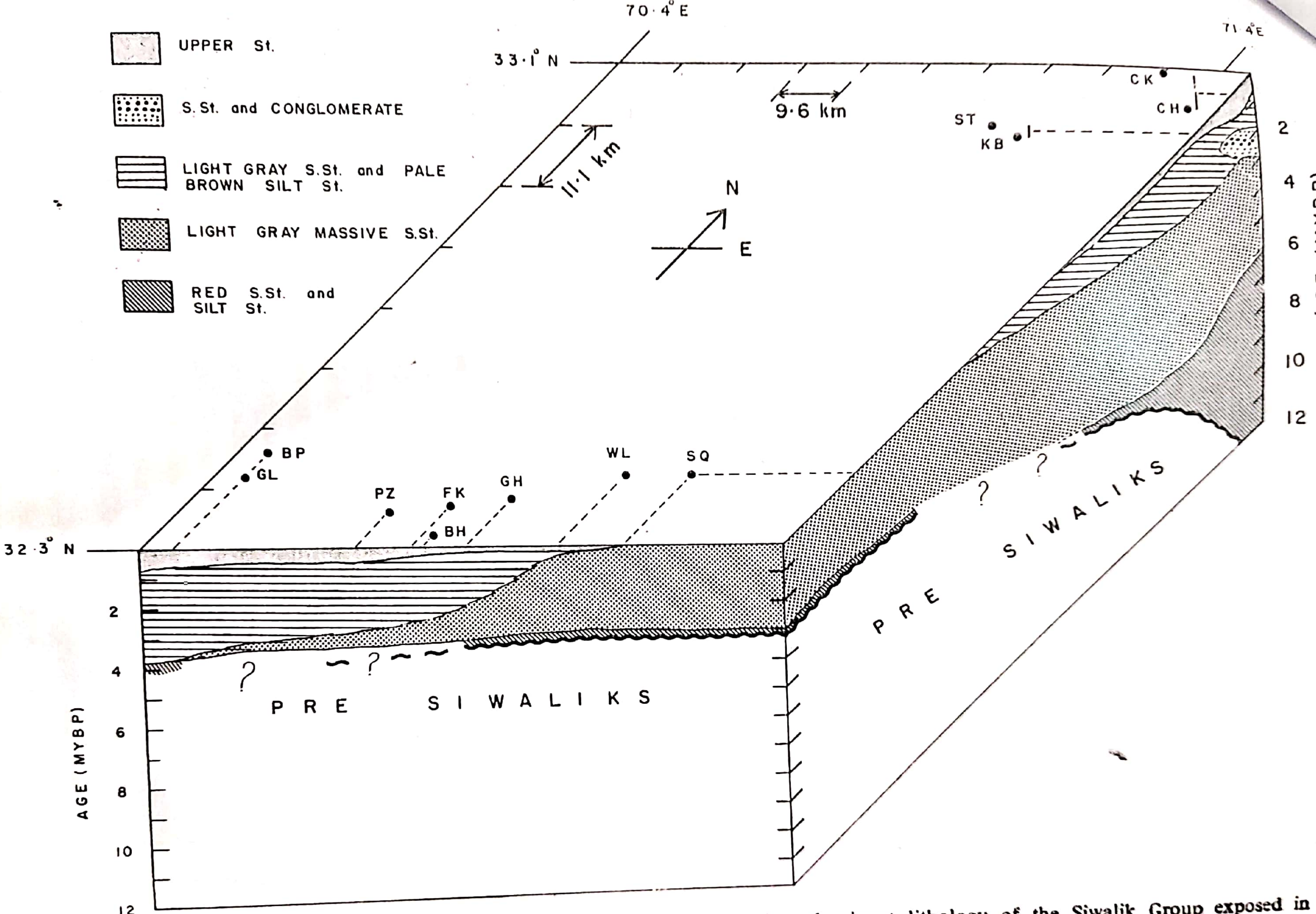


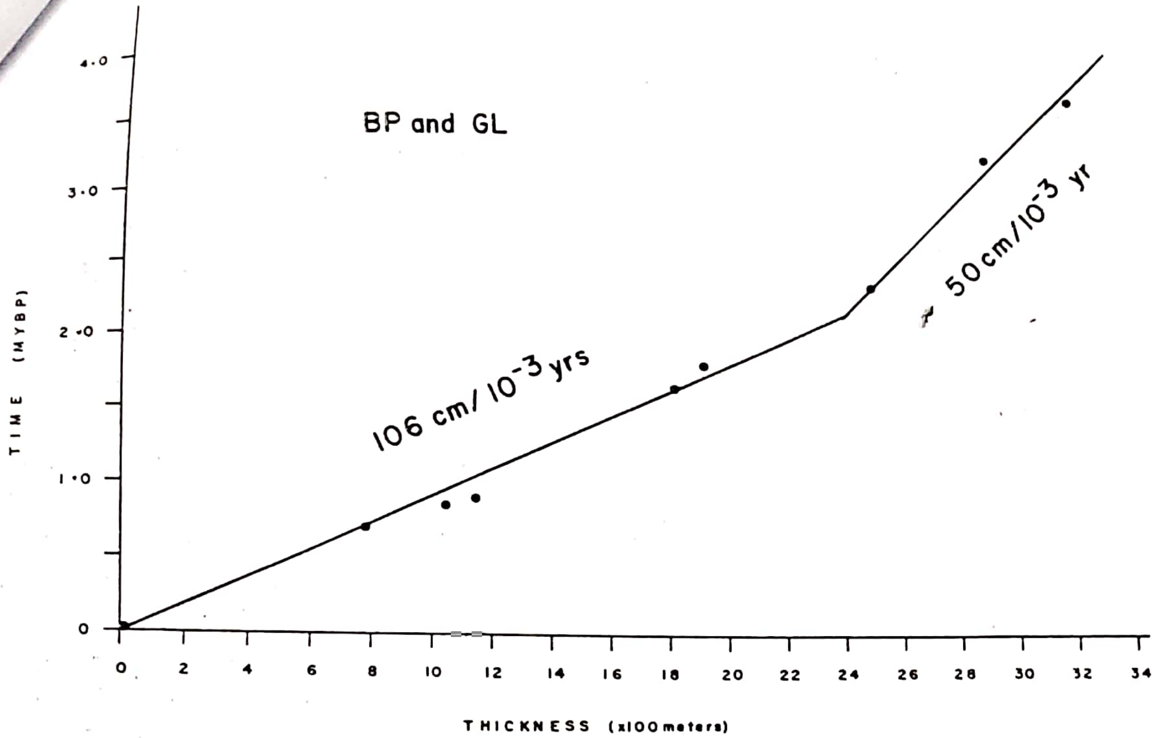
Fig. 3. Block diagram based on the age (after Khan, 1983) plotted against dominant lithology of the Siwalik Group exposed in the Trans-Indus Salt Range. Explanations same as in Fig. 2.

These observation suggest that the ancestral river system deposited channel sediments and associated overbank sediments in the Potwar Plateau prior to 15 Ma, whereas the Trans-Indus area was not yet undergoing subsidence. with the passage of time, this ancestral river migrated towards the west and, by about 12 Ma, reached into the Trans-Indus area. From 12 Ma to about 6 Ma, the areas now occupied by the Surghar and Shinghar Ranges were under the influence of a constantly migrating river channel. It was during this time that the basal red bed zone, consisting of a sequence of alternating sandstones and siltstones, was deposited. This was followed by a 3–4 million year period during which most of the Trans-Indus area — particularly the area now occupied by the Surghar and Shinghar Ranges, was in the recurring axial zone of river channel. The Bhittani area was within the range of the migraitng river channel, but mostly remained away from the recurring axial zone of river channels until the culmination of Siwalik deposition about 50,000 years ago. During the period 2–0.5 Ma, the areas of the Spin Qammar and Walewal sections, and part of the Makarwal Anticline area, were repeatedly occupied by the axial zone of river channels. It was during this time period that conglomeratic units were deposited in the northern parts of the Surghar and Shinghar Ranges. This suggests an increase in the gradient which might coincide with the onset of Pleistocene tectonics (uplifting) in this area. This phase of tectonics resulted in the folding of Siwalik sediments previously deposited. This also resulted in the braiding of the river channel. The coarsening-upward sequence of braided river channel is particularly evident in the Bhittani Range and the Makarwal Anticline where the top of the stratigraphic sequence is often represented by loose conglomerates.

SEDIMENTATION RATE

Sediment accumulation rates were calculated for each section using the age data of Khan (1983) and stratigraphic thicknesses. However, sedimentation rates for the parts of the sequence devoid of overbank deposits could not be calculated due to the lack of time constraints. The plots of age versus thickness for each stction are shown in Figure 4, and calculated rates are given in Table 1. It is important to note that average sediment accumulation rates are lowest for stratigraphic sequences composed of reddish-brown siltstone and sandstone couplets. The sequences with pale brown siltstone units show moderate accumulation rates, whereas the upper parts of sequences in the Bhittani, Khasor, and Shinghar Ranges, which are dominated by thick sandstones, show the highest accumulation rates. In light of these data, it is most likely that thick sandstone units of the Marwat and Makarwal Anticlines were also deposited at a rate of 1.0–1.5 m/1000 **yrs.**

The sediment accumulation rates calculated for the Siwalik Group of the Trans-Indus Salt Range are mostly higher than those calculated for the Siwalik Group in the Potwar Plateau as calculated by Opdyke *et al.* (1979) and Johnson *et al.* (1982). This suggests that, although Siwalik sedimentation in the Trans-



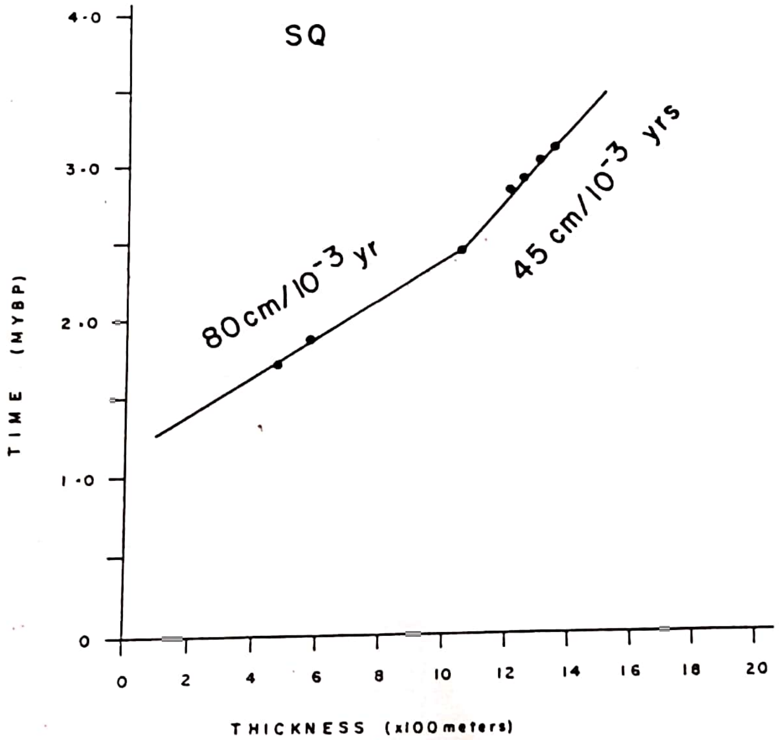


Figure 4 ....continued

Indus area started later than in the Potwar Plateau, the depocentre was repidly subsiding. Lack of a hiatus in the entire stratigraphic sequence of the Siwalik Group in the Trans-Indus area indicates rapid erosion of the source area, keeping pace with the subsiding basin and providing detrital material without any break.

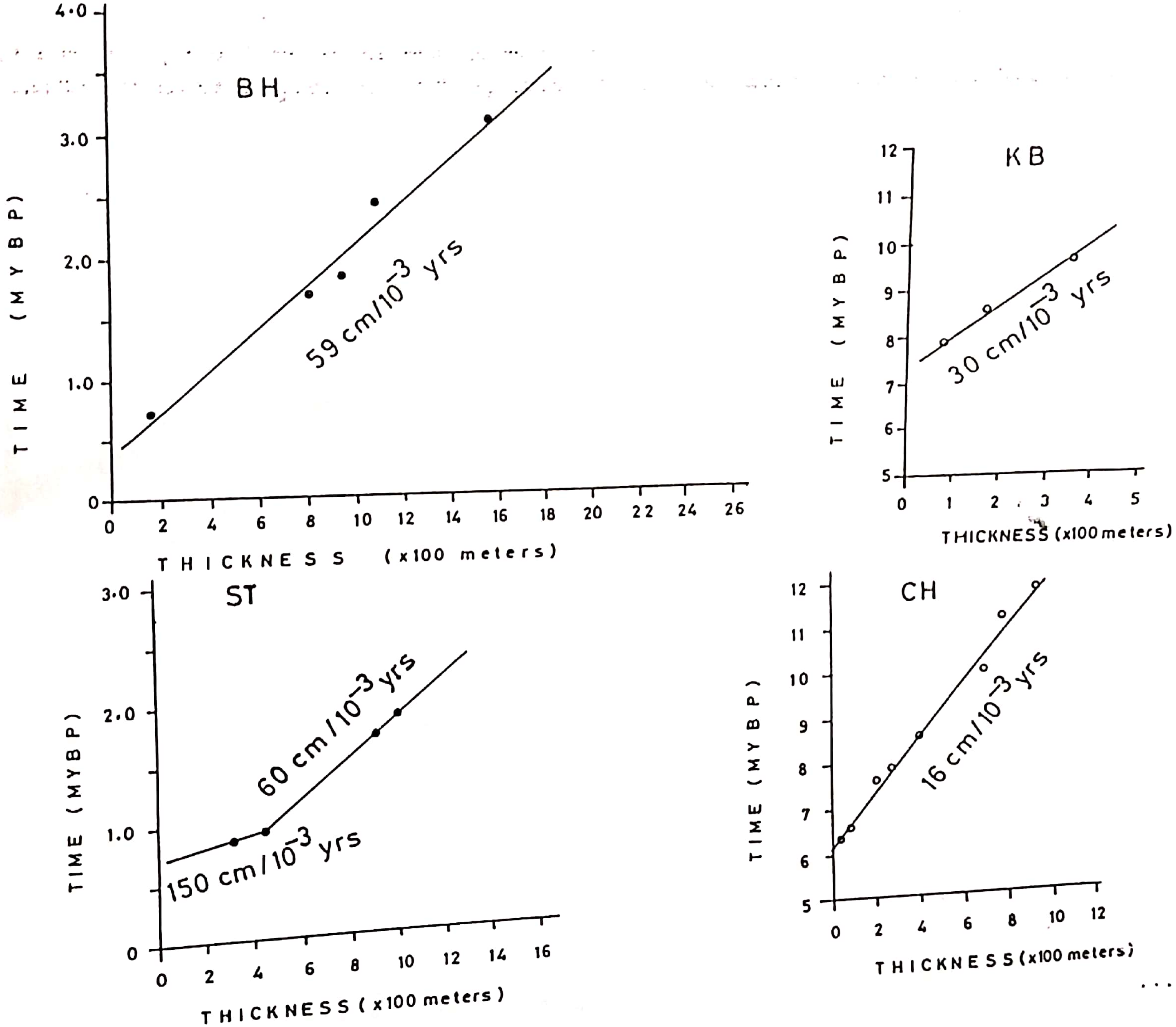


Figure 4

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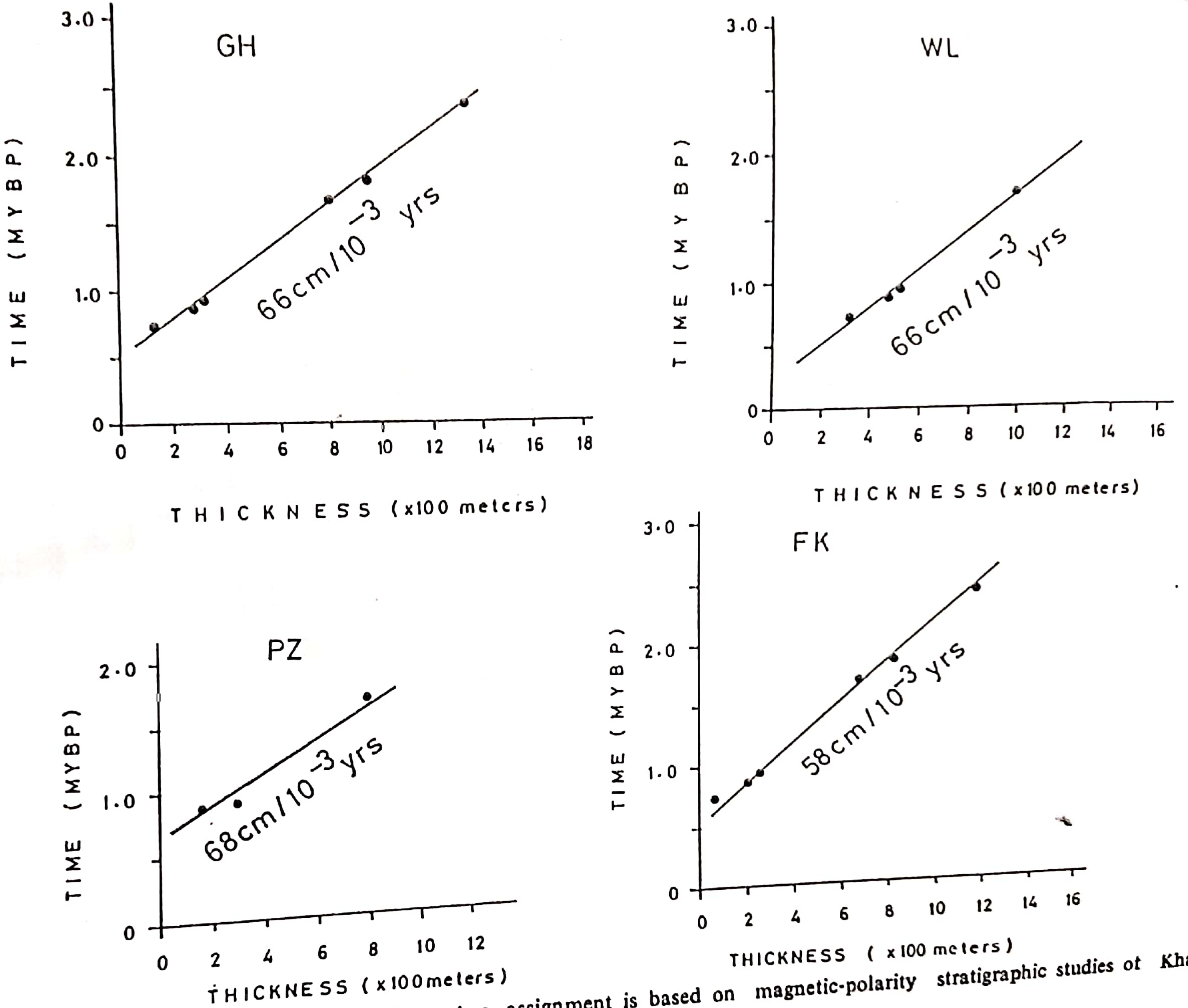

Fig. 4. Plots of stratigraphic thickness versus time. Age assignment is based on magnetic-polarity stratigraphic studies of Khan (1983). Abbreviations of section names are same as in Fig. 2.

TABLE 1. SEDIMENT ACCUMULATION RATES OF THE VARIOUS SECTIONS FROM THE TRANS-INDUS SALT RANGE.

Stratigraphic section	Sediment accumulation rate (cm/Kyr.)	
Bain Pass and Garhi Landa.	50	(from upper Gilbert Chron to lower Matuyama Chron.)
	106	(from lower Matuyama Chron to upper Brunhes Chron.)
Pezu Pass.	68	
Faqir Kille.	58	
Gharangai.	66	
Walewal.	66	
Bhandara.	59	
Spin Qammar.	45	(during Gilbert Chron.)
	80	(during Matuyama Chron.)
Spalmai Tangi.	60	(from lower to upper Matuyama Chron.)
	150	(upper most Matuyama Chron.)
Khora Baroch.	30	
Chichali.	16	

TECTONICS

Another important feature of the Siwalik Group in the Trans-Indus area is that a stratigraphic sequence as young as the post—Jaramillo Subchron and the early Brunhes Chron has been folded and tilted at 10°–70°. This shows that, except for the gradual subsidence, the Trans-Indus area did not undergo orogeny since the onset of Siwalik sedimentation, until about the late Matuyama/early Brunhes Chron. The abundance of conglomerate units in the northwestern part of the Makarwal Anticline suggests of this area to a recently uplifted area in the north. In the Makarwal Anticline area, sediments of the late Matuyama Chron, which form the top of the stratigraphic sequence, have been folded. These observations indicate that the earlier effects of tectonism were felt during the late Matuyama Chron (about 1 Ma), in areas now forming the northwestern parts of the Makarwal Anticline, and the Bhittani, Marwat and probably the Khasor Ranges underwent tectonic effects as late as early to middle Brunhes Chron (about 500,000 years age). This demonstrates the youthfulness of the tectonics in this area and substantiates the recent study of Zeitler *et al.* (1982) which has shown that the Himalayan orogeny is still an active process. Very recent effects of uplifting in the Trans-Indus area are also provided by the uplifted alluvial terrace deposits.

CONCLUSIONS

Sediment accumulation rates were calculated for each of the stratigraphic sections using plots of stratigraphic thickness against age (based on the magnetostratigraphic studies). These accumulation rates are generally higher than those of the Siwalik Group sediments of the Potwar Plateau. Also the entire stratigraphic sequence covering the time span of 12 MYBP to 0.5 MYBP is conformable. These factors suggest that the area now occupied to the Potwar Plateau area, and except for the general subsidence of the basin of depsition there was no tectonic activity until folding began about 500,000 yrs. BP. At this time, the entire area was uplifted during the Pleistocene phase of the Himalayan orogeny and Siwalik sedimentation was brought to a halt. The uplifted terraces of recent alluvial deposits in this area, show that uplift is still active.

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