Geol. Bull. Univ. Peshawar, 1985, Vol. 18, pp. 153–161

TECTONIC GEOMORPHOLOGY BETWEEN THAKOT AND MANSEHRA, NORTHERN PAKISTAN

ROBERT D. LAWRENCE[1] & JOHN F. SHRODER, JR[2]
[1]Oregon State University, Corvallis, OR 97331 USA
[2]University of Nebraska at Omaha., NE 68182 USA

ABSTRACT

Geomorphic features between Thakot and Mansehra include (1) bedrock terraces and an associated knickpoint on Nandihar Khwar, an Indus tributary, (2) deeply weathered residual soils on a relict upland surface called the Chattar plain, (3) an escarpment developed at the edge of headward erosion into this upland surface, and (4) an incised intermontane sedimentary basin north of Mansehra. Together these features provide new data to be used in reconstructing the history of recent uplift of the Himalaya in Pakistan. They reflect a period of relative tectonic stability during tropical soil development on a surface of rolling hills between about 25 and 5 m.y..ago followed by uplift and erosion of that surface. These residual soils may be an important sediment source for the young intermontane basins developed in association with foreland thrust fault motion during the last 5 m.y.

INTRODUCTION

The uplift of the Himalaya has been studied using the record of unroofing occurring in the Siwalik sediments (e.g., Johnson and others, 1979), using modern seismicity (e.g., Seeber and Armbruster, 1979), and using structural features of the bedrock (Calkins and others, 1975; Fernandez, 1983; Yeats and Lawrence, 1984). Because the uplift of the Himalaya is young and ongoing, much additional information is contained in the geomorphology of the mountains themselves (Seeber and Gornitz, 1983; Gornitz and Seeber, 1981). Few geomorphological studies oriented towards analyzing tectonism have been conducted in the mountains of Pakistan as yet. This reconnaissance study of the area between Thakot and Mansehra reveals some tectonically significant features and suggests some avenues for valuable future research.

The area of interest (Fig. 1) extends from Thakot on the Indus River up Nandihar Khwar to a pass at about 1800 m, then across the Chattar Plain to an escarpment where the land drops down to the Mansehra Basin, and ends at Mansehra. Much of this region is a relict landscape that is temporarily preserved bet-

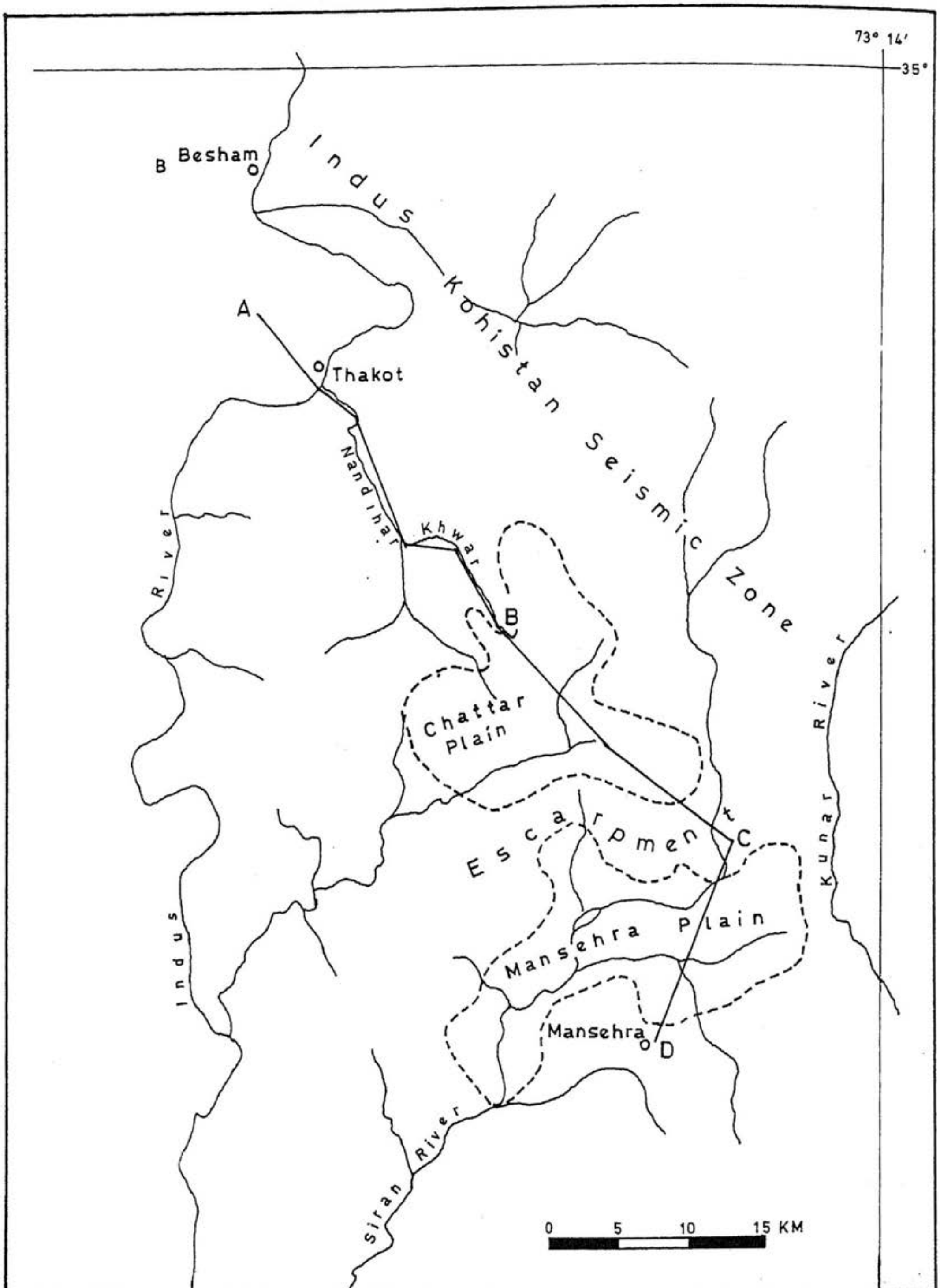

Fig. 1. Location map of study area and line of profile A—B—C—D of fig. 2.

ween the deeply entrenched and rapidly downcutting Indus River to the west and the Kunar River to the east. The Chattar Plain is an old landscape remnant, whereas the Mansehra Basin is younger and records a separate episode in the history of the mountains. A two-stage history recorded in Nandihar Khwar provides additional information. In this brief note we discuss the available data on these landscape elements and the probable significance of these observations for the uplift history of the Himalaya.

The area as a whole is underlain by Mansehra granite and remnant inliers of quartzose metasediments (Shams, 1969, 1983; Calkins and others, 1975). Two main intrusive granite types are present: coarse feldspar-porphyry granite and younger silicic tourmaline granite. A Rb–Sr isochron of 516 ± 16 m.y. (Le Fort and others, 1980) indicates that these are pre-Himalayan intrusions. They provide relatively uniform weathering characteristics and erosion resistance on bedrock underlying the area. The granitic rocks have a well developed orthogonal joint system that is important to the weathering pattern of the rocks

Nandihar Khwar has a tectonically disturbed drainage system. Profile A–D (Fig. 2) illustrates this in segment A–B. This profile has been constructed to follow the drainage lines (Fig. 1) in order to approximately portray stream profiles. A strong knickpoint occurs in the stream profile below Batgram. The lower segment of the stream has been rejuvenated by lowering of its base level as a result of rapid downcutting by the Indus River. This stream segment has a steep gradient (ca. 16 m/km) and a narrow V–shaped valley. The upper part of the valley has a broad bottom, gentle side slopes, and a low gradient (ca. 8 m/km). Below Batgram a series of paired bedrock terraces record the continuation of the previous valley floor that has been incised due to down-cutting initiated at the mouth of the stream. The upper valley segment has deep residual soils of the same type as are better preserved on the Chattar Plain. A valley with a knickpoint like this may record regional uplift, increased discharge in the master stream through climate change, or drastic reduction in available bed load. In this case we can eliminate the idea of increased discharge because the Indus flow has decreased since the last Pleistocene glacial period. Although the bedload volume of that time was certainly greater than at present, sufficient quantities are being carried relative to present discharge to indicate that this is not the cause of the knickpoint. Furthermore, the well-documented active uplift of this general area (Zeitler and others, 1982) clearly shows a direct relation to active stream incision. As downcutting proceeds then, the more competent major stream adjusts by rapid downcutting to a new graded profile, and slower downcutting by side stream is initiated at their mouths and works headward. The knickpoint records how far the regarding process has travelled up the stream. Profiles with knickpoints are typical of the side streams of this portion of the Indus River valley. Projecting the upper valley profile of Nandihar Khwar and its terraces to the Indus River suggests an uplift of about 300–400 m in the episode recorded here.

The Chattar Plain occurs at the drainage divide between Nandihar Khwar which flows north-northwest straight to the Indus and longer, more easterly

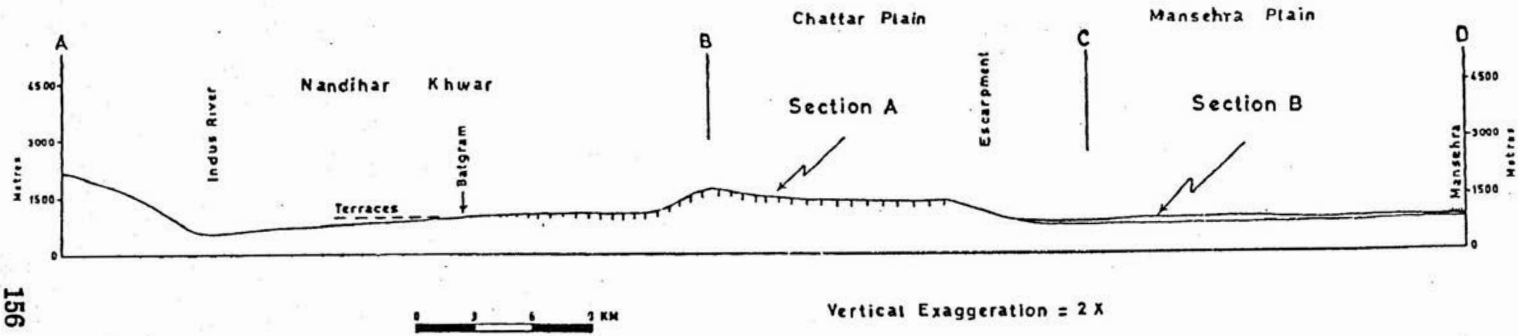

Fig. 2. **Topographic profile A—B—C—D from Indus River valley** to Mansehra along line **indicated in fig. 1. Sections A & B are shown in fig. 3.**

streams that flow south for some distance before turning southwest to join the Indus. The upper reaches of these streams flow down a tectonically uplifted and tilted land-scape. These stream segments will be disrupted by stream piracy and the drainage reoriented toward the Indus and Kunar rivers in the near geologic future if the landscape remains undisturbed by renewed tectonic activity. The Chattar Plain is a relict fragment of this uplifted and tilted landscape. It is covered by thick (4–10 m) residual soils that locally preserve china clay deposits of some economic potential. The upper part of this soil is a thick clay-rich saprolite that commonly preserves granitic textural features. At depth, core stones occur in the saprolite, and these pass downward or laterally into disintegrating, jointed granite (Figs. 2 & 3). A deep soil of this sort requires development over a prolonged period of tropical weathering on a terrain of relatively low relief. We now see only a small, rather fortuitously preserved remnant of what once must

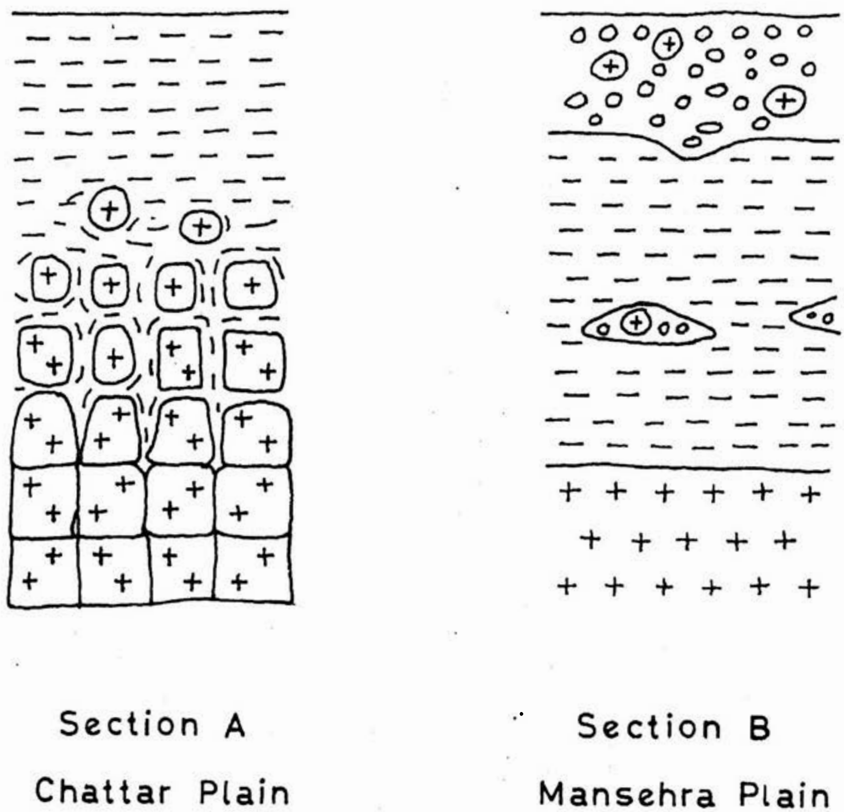

Fig. 3. Diagrammatic sections of sediment above bedrock. SECTION A — Chattar Plain — residual weathered clay-rich saprolite and core stones above bedrock. SECTION B —Mansehra Plain — fine clastics deposited above bedrock that are interbedded and overlain by lenses and sheets of coarse clastics presumably derived from sequential erosion and redeposition of saprolites and then core stone fragments similar to section A.

have been a widely developed, deep residual soil over much of Swat, Hazara, southern Kohistan, Kashmir, and perhaps the Lesser Himalaya. Relict deep saprolitic weathering is also present on the granite porphyry, gneiss, and amphibolite of Swat (Moosvi, Haque and Muslim, 1974; P.S. Rosenberg & I. Khan, personal communication, 1983). The valleys of Swat are choked with very large granitic boulders derived from the core stones of its ancient soils. Relict soils 10 to 15 meters deep development on the Panjal Traps were also generated over a long period of time that ended around 4 to 5 m.y. ago (D.W. Burbank, written communication, 1985).

The soils of the Chattar Plain are commonly subject to numerous landslides of the slow earth flow and debris flow type. Deep weathering of granitic rocks in the tropical highlands of Africa, followed by rapid uplift and erosion, is generally accompanied by extensive landsliding in the uplands which brings fine-grained saprolites quickly into fluvial transport. Landsliding and consequent dissection is repetitive at the same site, and provides exposure of the deeper coarse clastics for their later movement into the transport and depositional system (Shroder, 1973, 1976). This same process is well advanced in the uplands of the Chattar, especially, where accelerated by the rapid modern deforestation. The highway is repeatedly disturbed by massive slow landslides that choke the rivers with debris.

The chronology of Cenozoic events in the Hazara-Swat area receives an additional datum from the Chattar Plain residual soils. Because the soils are developed on the Mansehra-Swat granites, these rocks must have been exposed prior to this period of weathering. Metamorphism of the granites and overlying sediments reached a peak prior to 30 m.y. (Kazmi and others, 1984; Maluski, 1983) and uplift of the area is dated by fission-track ages at 18–20 m.y. (Zeitler and others, 1982). These dates appear to record an early episode of thrust faulting that emplaced the granites and metasediments over little metamorphosed Precambrian and Paleozoic strata of southern Hazara and Swat. Development of the Chattar soil began as soon as a surface of low relief developed over these structures. Just north of the Chattar Plain is the Indus Kohistan Seismic Zone (IKSZ of Seeber and Armbruster, 1979) and northeast of this is a northwest-trending topographic step along which the terrain to the northeast rises to peaks over 8000 m (Gornitz and Seeber, 1981). This line is considered to overlie a blind ramp fault in the Himalayan sole thrust and is perhaps an extension of the faults of the Pir Panjal Range. The uplift of this range and of the area north of the IKSZ is dated at 4–5 m.y. by a change in the source of paleomagnetically dated Siwalik sediments (Raynolds, 1981) and by the similarly dated initiation of Karewa sedimentation (Burbank and Johnson, 1982 and 1983). Tilting, uplift and erosion of the extended Chattar weathering surface was probably initiated at this time and continues to the present. Very rapid uplift of the Pir Panjal and IKSZ began about 350,000 years ago (Burbank an Raynolds, 1984). Thus a tentative chronology suggests that prolonged weathering between 20 to 5 m.y. ago developed the residual soils which were intermittently eroded during tectonism of the last 5 m.y. and then rapidly dissected in the last 350,000 years.

The soils of the Chattar Plain, and presumably those of similar but now denuded nearby areas, are an important sediment source that contributed to the intermontane basin and young molasse sediments of the Himalayan foreland trough. It is likely that Tertiary tropical weathering of the rocks of the rising Himalayan mountain chains contributed an important clay fraction to these foreland sediments. Such clays can be expected to be dominantly kaolinitic, although diagenetic changes may alter their structure later. Highly weathered core stones and bedrock would have provided clastics to the sediments. Tracing the older Murree and Siwalik sediments back to their upland provenance is difficult because the original saprolites and geomorphology are gone, nevertheless some speculation is possible. The fine grained Murree Formation at the base of the molasse probably records erosion of old upland soils on earlier surfaces much like the Chattar Plain that developed during intervals of relative tectonic quiessence and does not necessarily require long distance transport from another tropical provenance to the south as has been traditionally asserted (Wadia, 1975, p. 331, and Krishnan, 1968, p. 466).

The Mansehra Basin is an area of sediment infilling north of Mansehra town. It is separated from the Chattar Plain by a relatively steep escarpment (C on Fig. 2) and a drainage divide controlled by a low bedrock high. Sediment from the Chattar Plain does not feed into the Mansehra Basin, but headward erosion is rapidly working into the divide and drainage will soon be diverted in this direction. The Mansehra Basin is probably similar in origin to the Haro, Campbellpur, and Peshawar Basins (Burbank, 1983), although it is a smaller feature. The sedimentary infilling is mostly fluvial in origin, but may have local lake deposits. The bottom of the sedimentary section is fine grained and is preusmably derived from the saprolitic soils of an easterly extension of the Chattar Plain. Lenses of channel gravel occur high in the section, and the top is an extensive gravel sheet. These gravels are probably derived from the core stones and rare bedrock exposed by erosion of the residual soils. Thus the residual soils profile with fine-grained saprolite above and core stones below is inverted by sequential erosion and redeposition into the Mansehra Basin where the reworked saprolite forms the base and the core-stone fragments form the top of the section (Figs. 2 & 3). In general, uplift in the Plio-Pleistocene initiated final erosion of the Chattar and other upland saprolites and they may be the source of much sediment in the Peshawar, Campbellpur, Haro, and Mansehra intermontane basins.

Deposition in the Mansehra Basin was apparently controlled by a bedrock ridge that extends east-west in the area of Mansehra town. Sediment in-filled valleys of the same type are present in the Ambella-Jowar area of southern Swat. In the larger Plio-Pleistocene basins to the south, similar bedrock ridges formed barriers that favoured lake and river deposition. There bedrock is uplifted to form ridges along ramp structures of thrust faults of the foreland fold and thrust system. It seems probable that the bedrock ridge around Mansehra may have a similar origin. The escarpment between the Chattar Plain and Mansehra

Basin may also be structurally controlled, but it is more probable that it simply records the distance to which headward erosion has worked into the uplifted surface.

The recognition of a widespread residual soil in Hazara and Swat, and that it has been the source of much fine-grained basin fill, suggests that the extensive Potwar silts, of the northern Potwar Plateau which have been considered to be loess need careful re-examination. Indeed, Yeats (personal communication, 1985) considers the Potwar silt to have been deposited in an intermontane basin developed behind the rising Salt Range. The fine-grained sediments of the Chattar Plain residual soils and the Mansehra Basin stand readily in steep cliffs like those which characterize loess deposits, and are only distinguished from loess by the presence of fluvial and lacustrine bedding, and by proximity to the residual soils as a source. Careful field and laboratory re-examination of the Plio-Pleistocene basin fills to distinguish clay minerals typical of tropical weathering, from Indus valley loess, and from fresher, more unweathered Pleistocene glacial rock flour promises to provide important new insight into the development of these areas. We further suggest that Siwalik and Murree units be re-evaluated in terms of erosion of residual soils and bedrock from northern or northwestern areas. In order to further elucidate the suggestions presented here, systematic sampling of upland residual soils and proximal and distal depositional by-products needs to be done. Granulometry, clay mineral determination, and electron microscopy of surface textures, and paleocurrent directions should provide maximum information.

In conclusion we have reported evidence for a prolonged period of deep tropical weathering on a surface now reduced to rolling hills of exposed rubble and bedrock. This occurred after metamorphism, deformation, and thrust faulting of the crystalline rocks of southern Swat and Hazara. Major uplift of this region probably occurred before soil development and recent uplift has been less than 1500 m, probably much less. These residual soils have played an important part in providing sediment to the intermontane basins south of the mountains. Remnants of this old weathering surface are now being destroyed by mass movement, downcutting and headward erosion along rejuvenated river systems.

Acknowledgements. Partial support for this study by USA NSF grant INT 81–18403 is gratefully acknowledged. This work was conducted while Shroder was a Fulbright lecturer at Peshawar University. Field assistance by A.A.K. Ghauri and M. Saqib Khan and support by Vice Chancellor R.A.K. Tahirkheli of Peshawar University and B. Lohaf of the U.S. Education Foundation of Pakistan is much appreciated.

REFERENCES

Burbank, D.W., 1983. The chronology of intermontane-basin development in the northwest Himalaya and the evolution of the northwest syntaxis. Earth Planet. Sci. Letters 64, 77—92.

—— & Johnson. G.D., 1982. Intermontane-basin development in the past 4 Myr in the north-west Himalaya: Nature 298, 432—436.

——— & ———., 1983. The late Cenozoic chronologic and stratigraphic development of the Kashmir intermontane basin, northwest Himalaya: Paleogeography, Paleoclimatology, Paleoecology 43, 205—235.

——— & Raynolds, R.G.H., 1984. Sequential late Cenozoic structural disruption of the northern Himalayan foredeep: Nature 311, 114—118.

Calkins, J.A., Offield, T.W., Ablullah, S.K.M. & Tayyab, Ali S., 1975. Geology of the southern Himalaya in Hazara, Pakistan, and adjacent areas. U.S. Geologicl Survey Prof. Paper 716C, 29 p.

Fernandez, A., 1983. Strain analysis of a typical granite belt: The Mansehra pluton, northern Pakistan. *In* : Granites of the Himalayas, Karakorum, and Hindu Kush (F.A. Shams, ed.) Inst. Geol. Punjab Univ., Lahore, p. 183—199.

Gornitz, V. & Seeber, L., 1981. Morphotectonic analysis of the Hazara arc region of the Himalayas, north Pakistan and northwest India. Tectonophysics 74, 263—282.

Johnson, G.D., Johnson, N.M., Opdyke, N.D. & Tahirkheli, R.A.K., 1979. Magnetic reversal stratigraphy and sedimentary tectonic history of the upper Siwalik Group, eastern Salt Range and southwestern Kashmir. *In* : Geodynamics of Pakistan (A. Farah and K.A. DeJong, eds.) Geol. Surv. Pakistan, p. 149—165.

Kazmi, A.K., Lawrence, R.D., Anwar, J., Snee, L.W. & Hussain, S.S., 1984. Geology of the Indus suture zone in the Mingora-Shangla area of Swat. Geol. Bull. Univ. Peshawar 17, 127—144.

Krishnan, M.S., 1968. Geology of India and Burma, 5th edition. Higginbothams, Ltd., Madras, 536 p.

Le Fort, P., Debron, F. & Sonet, J., 1980. The "Lesser Himalayan" cordierite granite belt: topology and age of the pluton of Mansehra (Pakistan). Geol. Bull. Univ. Peshawar 13, 51—61.

Maluski, H. & Matte, P., 1984. Ages of alpine tectonometamorphic events in the northwestern Himalaya (northern Pakistan) by $^{39}Ar/^{40}Ar$ method. Tectonics 3, 1—18.

Moosvi, A.T., Haque, S.M. & Muslim, M., 1974. Geology and China clay deposits Shah Dheri (Swat) N.W.F.P. Pakistan. Records Geol. Surv. Pakistan 26, 28 p.

Raynolds, R.G.H., 1981. Did the ancestral Indus flow into the Ganges drainage ? Geol. Bull. Univ. Peshawar 14, 141—150.

Seeber, L. & Armbruster, J., 1979. Seismicity of the Hazara arc in northern Pakistan: decollement versus basement faulting: *In* : Geodynamics of Pakistan (A. Farah and K.A. DeJong, eds.) Geol. Surv. Pakistan, p. 131—142.

Seeber, L. & Gornitz, V., 1983. River profiles along the Himalayan arc as indicators of active tectonics. Tectonophysics 92, 335—367.

Shams, F.A., 1969. Geology of the Mansehra-Amb state area, Northern West Pakistan. Geol. Bull. Punjab Univ. 8, 1—31.

———, 1983. Granites of the NW Himalaya in Pakistan. *In* : Granites of the Himalaya, Karakorum and Hindu Kush (F.A. Shams, ed.) Inst. Geol. Punjab Univ., Lahore, p. 75—121.

Shroder, J.F., Jr., 1973. Erosional remnants near the Rift edge in Malawi. Zeit. Geomorph. S. 18, p. 121—143.

———, 1976. Mass movement on Nyika Plateau, Malawi. Zeit. Geomorph., B. 2, p. 56—77.

Wadia, D.N., 1975. Geology of India, 4th edition. Tata-McGraw Hill, New Delhi, 508 p.

Yeats, R.S. & Lawrence, R.D., 1984. Tectonics of the Himalayan thrust belt in northern Pakistan. *In* : Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan (B.U. Haq and J.D. Milliman, eds.) Van Nostrand Reinhold, p. 177—198.

Zeitler, P.K., Tahirkheli, R.A.K., Naeser, C.W. & Johnson, N.M., 1982. Unroofing history of a suture zone in the Himalaya of Pakistan by means of fission-track annealing ages. Earth Planet. Sci. Letters 57, 227—240.