

Geotraverses through Higher and Tethyan zones of Lahaul and Spiti sector of N-W Himachal and adjoining part of Ladakh Himalaya

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Systematic geological cross-sections along traverses of Manali-Leh Highway, Satluj River section, Spiti River section and Pin and Parahio River sections have been sketched in course of expeditional work. An attempt has been made to illustrate the real ground picture visible in the field, keeping as far as possible in mind the vertical and horizontal scales and directional orientation. The extrapolation has been avoided. The profile along the Manali-Leh Highway presents the picture of tectonic contact between central crystalline unit of Vaikrita and thick sedimentary sequence of Phanerozoic with Haimanta Group at the base. Unique features of inverted Mesozoic synform and younger granitic intrusion along the deep fracture have been illustrated. Along the profile of Satluj Valley the Rampur antiform with Precambrian volcanics is succeeded by Vaikrita crystalline of high grade metamorphism ending up with tectonic contact with Tethyan sediments at Khab, sense of movement and intrusive granitic rock-types suggest the nature of visible thrust contact. The profiles along Spiti, Pin and Parahio rivers are very illustrative to confirm the missing carboniferous zone -- the conjectural flexure of Hercynian orogenic phase. Profuse disharmonic folding with Triassic horizon and thrust structures with limited displacements within the formations have also been noticed. Structural profiles indubitably confirms the tectonic contacts on either side of the Tethyan sedimentary sequence. Low amplitude thrusting and recumbent folds are sometimes indicative of vivid tectonic phenomenon within the thick pile of deformed Tethyan sequence.

Key words— Geotraverses, Tectonics, Lahaul-Spiti Sector, Ladakh Himalaya.

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सारांश

उत्तर पश्चिमी हिमाचल के लाहौल एवं स्पीति सेक्टर तथा लद्दाख हिमालय से जुड़े भागों के उच्चतर एवं टिथियन प्रखण्ड का भूगर्भीय पथअंकन

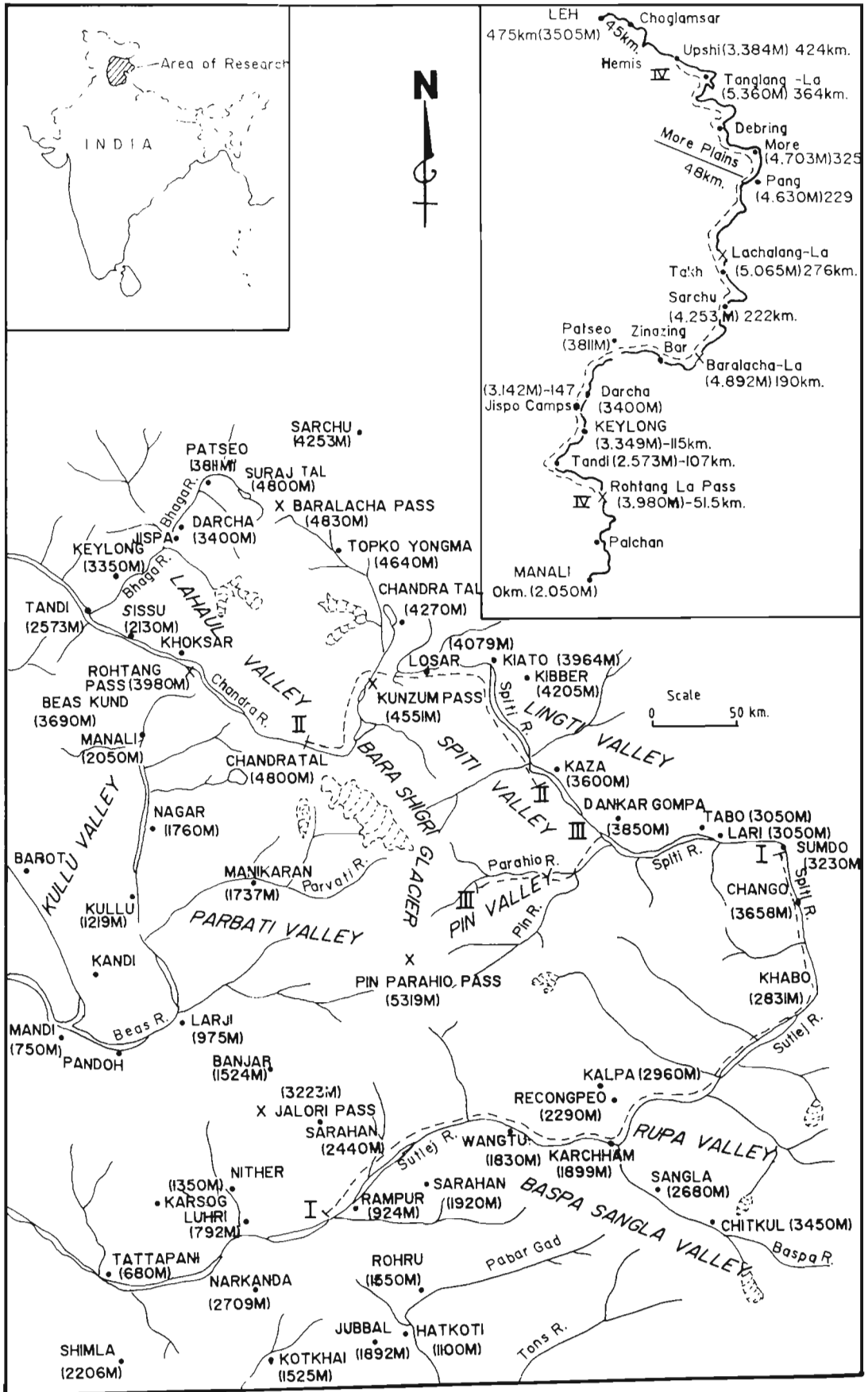
अंशुकुमार सिन्हा

खोज अभियान के दौरान मनाली-लेह राजमार्ग, सतलज नदी प्रखण्ड, स्पीति नदी प्रखंड तथा पिन एवं पराहियो नदी प्रखंड के एक छोर से दूसरे छोर तक व्यवस्थित भौगोलिक अनुप्रस्थ परिच्छेद खींचे गए। ऊर्ध्व एवं क्षैतिज पैमाने तथा दिशीय स्थिति को यथासम्भव ध्यान में रखते हुए क्षेत्र में दर्शित वास्तविक भू-चित्रों को यथार्थ रूप में अंकित करने का प्रयत्न किया गया, जिसमें बहिर्वेशन से बचा गया। मनाली-लेह राजमार्ग के एक छोर से दूसरे छोर तक के अभिलक्षण वैक्रीता एकांश की केन्द्रीय क्रिस्टलता तथा आधार तल पर हेमन्ता वर्ग के साथ फैनरोजोइक की मोटी अवसादी श्रेणियों के बीच विवर्तनिक संस्पर्श प्रस्तुत करते हैं। इनमें गहन शैल विभंग के साथ व्युत्क्रमित मीसोजोइक अभिनतरूप (सिनफार्म) एवं अपेक्षाकृत नए ग्रेनाइट अन्तर्वेदन के कुछ विशिष्ट अभिलक्षण भी अंकित किए गए हैं। सतलज घाटी के अभिलक्षणों का अवलोकन करने पर यह ज्ञात हुआ कि रामपुर अपनतिरूप (एन्टिफार्म) जिनमें पूर्व कैम्ब्रियुगीन ज्वालामुखी चट्टानें थीं, के ऊपर कायान्तरित क्रिस्टलीकृत वैक्रीता चट्टानें हैं, जो खाब स्थित टिथियन अवसादों के साथ विवर्तनिक सहसम्बन्ध दर्शाती हैं। इनमें प्राप्त गतिसंवेदन तथा अन्तर्वेधी ग्रेनाइट चट्टानों के प्रकार दृश्य क्षेपण संपर्क की प्रकृति को प्रस्तावित करते हैं। स्पीति, पिन तथा पराहियो नदियों के अभिलक्षण अत्यधिक सुस्पष्ट हैं, जिनसे कार्बोनीफेरस संस्तर (हर्सीनियन पर्वतन अवस्था के आनुमानित आनमन) की अनुपस्थिति की पुष्टि होती है। शैल-समूहों में ट्रायसिक संस्तर स्थिति के साथ विविधरूपी वलन की बहुलता तथा सूक्ष्म विस्थापन के साथ क्षेपण संरचना भी अंकित की गई है। टिथियन अवसादी श्रेणियों के दोनों ओर अंकित संरचनात्मक अभिलक्षण विवर्तनिक संस्पर्श की निश्चित रूप से पुष्टि करते हैं। मोटी टिथियन श्रेणियों के विरूपित रूपों में कभी-कभी निम्न आयामी क्षेपण एवं शयान वलन मिलते हैं, जिनसे विवर्तन की अवधारणा का स्पष्ट संकेत मिलता है।

WE have been concentrating to systematically undertake the geotraverses in the higher region of northwestern Himalaya covering the higher zone of Himalayan region of Himachal Pradesh and partly the Ladakh region of Jammu and Kashmir. For this the following geotraverses were taken to cover the maximum topographical and

geological informations.

Geotraverse I. Along the deep gorge of Satluj Valley : Rampur Jeori Bhabanagar Wangtu-Akpa-Pooh-Khab; along Spiti River up to Khab-Chango/Sumdo (Text-figure 1 & 2) (Plate 1).



Text-figure 1-Location map of the area of research and the ground positions of geotraverses I, II, III & IV as described in the text in the NW Himalayas of Himachal Pradesh & Ladakh.

- Geotraverse II. Chota Shigri-Kunzum La-Kaja (along Chandra & Spiti rivers) higher Himachal Himalaya in Lahaul and Spiti (Text-figure 1 & 3), (Pl. 1 & 2).
- Geotraverse III. Geotraverse along Pin and Parahio valleys in Spiti region of higher Himachal Himalaya (Text-figure 1 & 4), (Pl. 1 & 2).
- Geotraverse IV. Geological Cross-section along Manali-Leh highway (covering the higher Himachal Himalaya of Rohtang Pass (3980 m) across Chandra and Bhaga Valley through Keylong-Jispa-Baralacha Pass- Larchung La Pass-Taglang La-Upshi-Leh (Text-figure 1 & 5(i) & (ii) (Pl. 1, 2 & 3).

Geological description of these areas have been given by several workers like Stoliczka (1865), Hayden (1904), Berthelsen (1951, 1953), Fuchs (1982), Srikantia (1981), Bhargava (1987), Bhargava and Bassi (1985, 1986), Herren (1987), Gaetani *et al.* (1990), Gaetani and Garzanti (1991), Garzanti (1991, 1993), Garzanti and Frethe (1991), Spring and Blanc (1992), Spring (1993), Spring *et al.* (1993), Steck *et al.* (1993), Vannay (1993), Vannay and Steck (1995), Harris *et al.* (1993), Fuchs and Linner (1995, 1996), Rao *et al.* (1982), Powell and Conaghan (1973), Bhat and Le Fort (1992), Thakur (1992), Sinha (1989, 1992, 1997), Sinha and Upadhyay (1997), Sinha and Mishra (1997). The detail information of the above geotraverses are as follows:

Geotraverse I.

Along Satluj River Gorge and upstream along its tributary Spiti River (Text figures 1 & 2).

Crossing the Shali-tectonic window, we come across the klippe of Chail Formation in the Nirth synform. Here the gorge of Satluj River becomes narrower and as we traverse upstream the Rampur

window of basic rock (Bhat & Le Fort, 1992), the gneiss and mylonites are exposed up to the Bhabanagar Hydel project site. These rocks are intruded by younger leucogranite of Himalayan age (Sharma *et al.*, 1993). If we compare the crystalline of Jutogh Formation in the Shimla hills, it looks in the root zone of Chail and Jutogh tectonic units. Further upstream of the Satluj gorge at the right bank of Wangtu Project, there are intrusions of profuse leucogranite apophyses and about 300 m from the bed of the river adjacent to the Bhabeh Hydro-electric project tunnel. Further, as we come across the blue blades of kyanite and sillimanite bearing horizons the rocks here are of very high grade. There are also amphibolitic sills visible within the gneissic rocks. As we proceed towards the Karcham upstream along the Satluj gorge, massive intrusives of granitic bodies along with amphibolite sills start appearing. Between Wangtu and Karcham, there is a clear-cut evidence of shear zones at the village Tapri. The crystallines of Vaikrita (Griesbach, 1891; Sinha, 1989) zone are gneisses and mica schist horizons and massive quartzitic zone between Karcham and Pawari villages. The crushing of the rock type before Pawari is indicative of a shear zone of thrust along the west bank of Satluj River. The interspersed zone of quartzitic and gneissic rocks in the vicinity of Kalpa township, the capital of Kinnaur and the hamlet of Pio Rest House, produces very good soil for the healthy growth of apple and grape orchards of high altitude variety. Further upstream traverses encounter a huge crushed Akpa granitic zones. These leucogranites (Sharma *et al.*, 1993) indicate a very strong evidence of emplacement of granitic bodies of the younger Himalayan Tertiary age along the axial zones of high grade higher Himalayan crystallines (Vannay & Grasemann, 1997; Walker *et al.*, 1997; Weinburg, 1997).

Proceeding further upstream across the Moorang village, there appears a tectonized zone near Spilo village and a low grade metamorphic zone of Haimanta Group sequence. These

horizons, composed of low grade metamorphic phyllites and quartzitic sandstone continue up to Pooh. Beyond Pooh, again the high grade crystalline appears and at Dabling a symmetrical anticlinal structure is exposed in the west bank of Satluj gorge. The zone between Dabling and Khab looks to be highly disturbed and magmatically intruded by young granites (Kwatra *et al.*, 1993). There also appears a typical appearance of dykes swarms of leucogranitic intrusives evading the country rock. At Khab, the Satluj enters in the Tibetan territory in the north-east region and the Spiti River joins with Satluj. Along the left bank of Spiti River there is a marked tectonic break with the intruding leucogranites. The line of dislocation is clearly visible along the right bank of Spiti and Lipak rivers near Yang Thang Rest House at Maling Village. The tectonization and crushing of the rock continue up to Chango Village with the constant falling of boulders. Earlier in 1904 in Hayden's map this fault was clearly mapped, and at 1.31 p.m. IST on 19th January, 1975 it has been reactivated triggering an earthquake of magnitude 7 on Richter scale (Singh *et al.*, 1975). Visibly this is the zone of active fault with constant falling of big boulders on the road making impossible to drive and therefore it also becomes difficult to maintain the road in good condition. Interestingly, at the Leo Village in the right bank of Spiti River, an exposure of the limestone of Garbyang Formation (Sinha, 1989) was observed which appear similar to the limestone horizons of Malla Johar. The comparative study of the Haimanta and Martoli of Spiti and Malla Johar (Sinha, 1989) makes us to

believe that the stratigraphic horizons discovered by Griesbach (1891) and Hayden (1904) are remarkably homotaxial. Further upstream along the Spiti River, there is a clear stratigraphic horizon of Permo-Carboniferous rocks with the lithology of light and dark shales and sandstones.

Further upstream of Spiti River from the Chango-Shalker Village, we continued along horizons of Permo-Carboniferous belts till Thabo Monastery (Pl. 2, fig. 2). From this locality, Birbal Sahni and Gothan (1937), Høeg *et al.* (1957) and the author (AKS, 1985) discovered the Lower Gondwana flora. From the collection made during the year 1985 from the same horizon of Po Series near Thabo Monastery Gothan and Sahni (1937) reported for the first time some fossils of (Pl. 4 & 5) *Rhacopteris*. From the author's collection Maithy (Birbal Sahni Institute of Palaeobotany, Lucknow) identified the following species, viz., *Rhacopteris ovata* (McCoy) Walkom and *Triphylopteris lecuriana* Jongmann which reconfirm them to be of Lower Carboniferous age (Pl. 4 & 5).

Geotraverse II.

Chota-Shigri-Kunzum-La-Kaja higher Himachal Himalaya in Lahaul and Spiti (Text-figures 1 & 3) (Plates 1 & 2).

A few traverses were taken along the right bank of Chandrabhaga River after crossing Rohtang Pass (3980 m) (Pl. 1, fig. 1; Pl. 2, fig. 3). The Chota Shigri Glacier comes down from the high reaches of Central crystalline consisting of high grade metamorphic of Vaikrita Formation and the snout with heavy morain against the

PLATE 1



1. Bird-eye view of Kulu Valley looking from South; in the background the Rohtang Pass (3980 m) snow capped high grade metamorphic Central Crystalline *Vaikrita* High Himalaya Range. The monsoon clouds are intercepted by this range and causing the northern part of Higher Himalaya, a highland desert.
2. Monsoon clouds looming low over the Rohtang Pass (3980 m) area and blooming high altitude flora in the foreground.
3. Contorted and ptygmatically folded high grade metamorphic rocks at Rohtang Pass area.
4. Tectonised zone of initial Tethyan Thrust and subsequent South Tibet Detachment (STD) between pile of Phanerozoic sediments.
5. Exposure of Haimanta group of low grade metamorphic at the base of sedimentary pile of Phanerozoic sediments.
6. Wide open valley of Spiti River with the exposure of Mesozoic sediments on either side of the river bank.



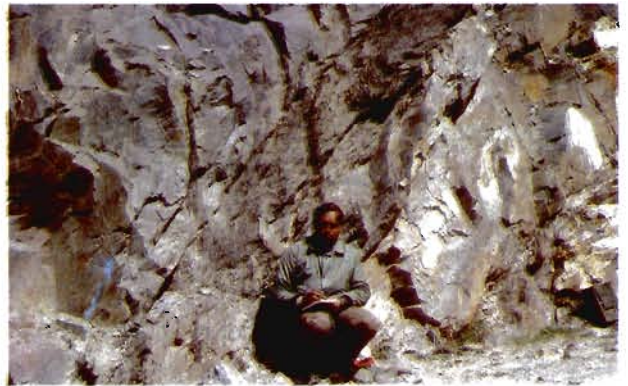
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Chhatru Rest House situated on the right bank of Chandra River. Since the Project work in the Chota Shigri glacier is far away stream of Chandra Valley hence, there is a suspension rope way crossing line temporarily erected across the high torrent stream of Chandra River. Before Batal Rest House, there is a marked tectonic contact between the high grade Vaikrita crystalline rocks and the low grade Haimanta Formation (Pl. 1, fig. 5). The shear zone shows the sense of movement from north to south followed by gravity slump of subsequent tectonic and orogenic movement. The shear zone (Pl. 1, fig. 4), visible over a distance of about 2 km, is also intruded by younger granitic bodies. Moving up on the road from Batal Rest House, the Lower Palaeozoic sedimentary sequences are continuously exposed from the Kunzum La project across Chandra River up to Kunzum La Pass (4520 m). This is an interesting section where one can try to search for the Precambrian-Cambrian boundary; the uninterrupted section of Lower Palaeozoic encompasses Ordovician, Silurian and Devonian rocks. It is interesting to note that here we also came across the algal limestone of reefal origin of Upper-Ordovician and Lower Silurian Period. This horizon is comparable with the younger limestone of Malla Johar area (Sinha, 1989; Sinha *et al.*, 1996). The variegated nature of the Silurian is very prominent in the multi-colour of rocks. The Devonian is very typical correlatable with the both quartzite of Kashmir and Kumaun. The Spiti river which starts from the Kunzum La Pass flows down to Takche where a prominent tributary Kabjima Nala joins with the main-stream of Spiti. The valley of Spiti River becomes

very wide (Pl. 1, fig. 6, Pl. 2, fig. 1) due to the fluvio-glacial action. In the Kabjima Nala flowing down SW to join Spiti, there is a very interesting exposure of Permo-Carboniferous rocks with the flexural deformation (Text-figure 3) showing an apparent disconformity but without any distinct tectonic deformation. This horizon is important in Himalaya which has been identified as the Hercynian gap with the missing Carboniferous rocks. It is represented by black slates and changing lithology with conglomerates having silicious and argillite clasts in the argillaceous matrix. At Losar down stream in the Spiti Valley (Pl. 1 & 2), a thick horizon of Triassic rocks represented by alternating shale, silt and limestone layers (Balini & Krystyn, 1997; Garzanti, 1993; Bagati, 1990) is exposed. The river occupies a gorgeous nature further down stream to Kaja near Hansa onwards through Kioto Village. The massive Jurassic horizons (Krishna *et al.*, 1997) occupy the higher gorge with distinct litho-stratigraphic character and Megalodon bearing fossils (Pl. 2, fig. 5). The name of Kioto limestone is derived after village Kioto (Hayden, 1904). Traversing down stream from Kioto Village, before the village Pangma, it has been distinctly observed that the fold pattern in the Triassic horizon is disharmonic (Pl. 2, figs 1 & 3). There are also younger folds disturbing both the Jurassic and Triassic horizons before reaching Pangma, the contact between incompetent Triassic and the massive rocks; competent Jurassic rocks show a tectonic contact. It is apparent that this movement must be along the stratigraphic contact but mobilized during the Himalayan orogenic movement. In the left bank of Spiti River, before

PLATE 2



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| <ol style="list-style-type: none"> 1. Wide open valley of Spiti River with the exposure of Triassic and Jurassic rocks. Photo view looking towards east. 2. The famous village of Thabo with monastery and in the background the Upper Palaeozoic rocks are exposed from where the Lower Carboniferous plant fossils were first recovered and described by Gothan & Sahni (1937). 3. The crossing of Parahio River by rope-bridge. The exposures are of | <ol style="list-style-type: none"> Triassic sediments. 4. Camp-site in Parahio River Valley with the exposure of Lower Palaeozoic rocks in the background. 5. Exposure of massive pyramid like thick carbonate sequence of Jurassic rocks with Megalodon fossils. 6. The intraformational conglomerate formed with Ordovician and Silurian fragments of algal limestones. |
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Ki Monastery, the Cretaceous fossils appear at various higher reaches near Kibber and Chikim (Singh *et al.*, 1995). The magnificent disharmonic folding is also possible all along the left bank of Spiti River leading to Kaja. The Kaja is the township and the capital of Spiti region having the Government offices. Further down stream along Spiti River, about 10 km at Attargoo the Pin River joins the Spiti River. In the next geotraverse (Text-figure 4) description we shall describe our next geotraverses from this upstream along Pin River towards Bhabeh Pass and tributary of Parahio River upstream towards Thango near the junction of Sumna Nala.

Geotraverse III.

Geotraverses along Pin and Parahio valleys in Spiti region high Himachal Himalaya (Text-figures 1 & 4) (Plate 2)

Down the Pin valley from the Bhabeh Pass the Vaikrita high crystalline zone is succeeded by the Haimanta low grade metamorphics. It has been cited in the literature that there is a gradual passage of metamorphic gap from Vaikrita to Haimanta (Hayden, 1904; Berthelsen, 1953). But the recent work along the Rohtang Pass (Text-figure 1) (Pl. 1, 2 & 3) sector and the Satluj-Spiti rivers cross-sections have shown that there is a distinct tectonic break with the sense of first movement from N-S followed by subsequent normal gravity slump known as the South Tibet Detachment (Pl. 1, fig. 5) (STD) (Herren, 1987) from Zanskar area. As we go down along the Pin Valley towards Sagnam (Pl. 2, figs 3 & 4) where Pin River joins the Parahio River (Sinha, *et al.*, 1997, (see Text-figure 1 & 2), there is a marked Lower Palaeozoic exposure including the upper

part of Cambrian conglomeratic horizons between conglomeratic and upper Ordovician Silurian limestone shales (Pl. 2, fig. 6). The siltstones are white quartzite of Devonian ending up with the occurrence of Carboniferous and Permian Kuling beds (Fuchs, 1981). Pin River, between Baldar and Sagnam, flows along a white valley with considerable Quaternary debris on the either sides on the banks. Mud Village has been the type area of Muth quartzite of Spiti since early days research in this area (Hayden, 1904; Goel & Nair, 1977). In new topo-sheet it has been shown that the Permian horizons of Kuling shale are exposed in the Kuling Village, nevertheless it is advisable that we should stick to the earlier nomenclature described in the literature, viz., Muth and Kuling (Berthelsen, 1953).

Coming down from the Thango of Parahio River (Text-figure 4) the classical and angular unconformity of Cambrian and Ordovician rocks can be seen at the cross-section of Sumna nala (described by Hayden, 1904). This is the classical unconformity established in the Tethyan realm of Himalaya which could be compared with the type area of Cambrian and Ordovician in the Atlantic coast of Wales, U.K. (author's observation during 1991 field work of IGCP project 319) (Parcha, 1996). Here in Parahio Valley, the Cambrian-Ordovician is basically represented by greenish siltstone and shaly horizons. There are same horizons of Malla Johar young limestone of reefal origin (Sinha, 1989). The Silurian horizons are basically represented by the intra-formational conglomerate at the base succeeded by fine grain limestone, siltstone and shale essentially of deep red colour. Going along the Parahio River stream on the left bank near

PLATE 3



1. A bird eyeview of Ladakh mountain range looking towards north-west. The Indus gorge is in the foreground.
2. Quaternary recent lake sediments in the Lamayuru area.
3. The Indus River flowing from east to west having molassic sediments of Miocene age on the left bank. Indus River marks the subduction zone of Indian and Eurasian plates.
4. A view of Chitkan Nala in Ladakh Himalaya having exposures of ophiolitic melange in the background. View looking towards S-E.
5. Another exposure of ophiolitic melange in the Indus gorge.
6. The exotic blocks in the Lamayura Flysch sediments near Mulbek Village (Krishna *et al.*, 1997).



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the Gechang Village (Pl. 2, fig. 4), white sugary quartzite of Muth of Devonian age is exposed dipping NE 45°. Over the quartzite a black shale horizon of Kuling is present. At this point due to the steep slope, the Carboniferous horizon could not be located. Overlain by the silty beds the Triassic horizon appears with the massive zone of disharmonically folded layers of limestone, black shale sandstone and siltstone all along the west bank of Parahio River down to Sagnam Village (Pl. 2, fig. 3) and Pokching and Mekin at the junction of the Pin Parahio rivers at Mekin Village on the left bank of Parahio River. Muth white sugary quartzite is exposed in the core and anticlinal structure having Permian black Kuling shale and Lipak Formation of Lower Carboniferous (Fuchs, 1982). At the exposure, the Triassic horizon overlies the Permian Kuling shale. The lower most part of the terrace shows the algal stromatolitic growth which could not be identified as definite form for the determination of age of this rock. The tectonic breaks of local nature between Kuling and Chhidang-Tokbo villages may also be seen. These faults locally disturbed the Triassic horizons and near the camp site of Chhidang Village, there appears the massive *Megalodon* limestone of Kioto Formation. The Kioto limestone and the Triassic horizons are imbricately folded and faulted as we proceed down stream along the west bank of Pin River. At Attargoo (3375 m) Pin River finally meets the Spiti River and the massive limestone horizons of Kioto-Jurassic Formation crosses towards NE over the Dankar Gompa (3850 m) and possibly the Cretaceous horizons on the top of the cliff in NW (5720 m) which marks the northern end of the geotraverse (Text-figure 4).

It is interesting to note that due to strong permafrost action and the highland desert condition, formation of soil is very meagre resulting poor vegetation growth and plantation activity. Recently, the Forest Department of Himachal Pradesh has taken up a programme to plant some special species in this area with partial success.

Geotraverse IV.

Geotraverse along Manali-Upshi-Leh highway through Higher Himachal and Ladakh Himalaya (Text-figures 1 & 5(i) & (ii)), (Plate 3).

Climbing up from Manali towards Rohtang Pass (3980 m) a continuous metamorphic rock sequence is visible changing in grade from chlorite-biotite schist to granito-gneissic and biotite schist, there is a marked change in the metamorphic grade ranging up to kyanite-sillimanite (Pl. 1, fig. 3) grade near the Kothi Village where the Rohalla *Nala* flows down demarcating geomorphological change in the trend of rocks. Moving upwards further towards Rohtang Pass, there is a huge magmatic intrusion of Tertiary Leuco granite (Pl. 1, fig. 4) as well as Lower Palaeozoic granite of about 500 m.y. Besides downwards from the Rohtang Pass an inverted sequence (Wyss, 1997) of marbolized limestone is exposed along the left bank of Chandra River having stratigraphic contact with the low metamorphic grade Haimanta rocks (See Text-figure 5). In literature, this limestone has been referred as Mesozoic having ammonoid fossils (Powell & Conaghan, 1973; Steck *et al.*, 1993). Chandra and Bhaga rivers ultimately meet together and called as Chandrabhaga River. This river flowing further NW received water from various tributaries and

PLATE 4

The photographs are all from untouched negatives.
The original specimens are preserved at the Geological Survey of India, Calcutta.

1, 2 *Rhacopteris ovata* McCoy Walkom (= *Rh. inaequilatera* Fstm. non Goepf.). From a bed with marine fossils (Fenestella shales), ½ mile N. N.E. of Po, Spiti. Fig. 1, nat. size; Fig. 2 x 2. K3/294 (Page 196).

3, 4 *Rhacopteris ovata* McCoy Walkom (= *Rh. inaequilatera* Fstm. non Goepf.). Thabo stage, ¼ miles S.W. of Thabo. Spiti. Fig. 3, nat. size; Fig. 4 x 2. K3/293 (Page 198).



2. ($\times 2$).



1.



3.



4. ($\times 2$).

is named as Chenab River. Traversing along the Bhaga River beyond Keylong at Jispa in the low grade metamorphics of the Haimanta Formation, a profuse intrusion of 500 m granites as well as Tertiary granites are present. These granitic bodies are definite intrusives in the Precambrian and Lower Palaeozoic Tethyan realm. Upstream Bhaga River, at Sumdo Village, there is a pronounced tectonic dislocation marking the extension feature fault of post-orogenic regime. From Darcha Village to Patseo Rest House, fine grade siltstone and shaly rocks of visibly Ordovician character are exposed. Before reaching Ordovician character from camp site Zingzing bar (4883 m) the red colour sedimentary horizons of Silurian age starts appearing. At the contact of Ordovician and Silurian rocks on the way of Baralacha La (5606 m) there appears reefal limestone of Caradocian. At the Baralacha, there is a huge lake called Suraj Tal towards the source of Bhaga River, whereas from the adjoining area of Chandra Tal, the Chandra River originates and as described earlier they meet at Tandi Village making the prominent River called Chenab which flows down through Jammu area to Pakistan making a tributary to Satluj and Indus River System (Text-figure 1). The traverse then follows along Yunam River down the stream from Kenlung Village (4531 m). The Yunam River meets with the Tsarap River near Tingting Khur Village. The tectonics between Baralacha La and Sarchu and Sarchu plain are highly complicated because of local overthrusting phenomena of Devonian quartzite and black slate of Permo-Carboniferous age. The Devonian Muth quartzite forms a huge recumbent fold (Text-figure 5(i)). There is an exposure of conglomeratic horizon between Baralacha Pass and Kenlung camp-site (4531 m) which perhaps belongs to the Silurian

or Lower Palaeozoic age (Fuchs & Linner, 1995). At the junction of Sarchu plain with the Tsarap River, the folded rocks give a very interesting picture of gravity folds and thrust slides. There also appears a huge recumbent fold in the NW side of the road demarcating the massive fossiliferous rocks of Jurassic age (Text-figure 5(ii)). The narrow gorge ends up at Pang camping site. From there onwards, a wide stretch of more than 10 km of More Plain starts where one can drive as one wishes without following the road track. The majestic outcrops of Palaeozoic limestone and shaly horizon appear in the northwestern flang up to Taglang La Pass. The Permian horizons with limestones are exposed below 5203 m high peak. Climbing up Taglang La Pass it is obviously visible that the Lower Palaeozoics are metamorphosed because there is no metamorphic break at this point. Fuchs and Linner (1995, 1996) have predicted that here the rocks are part of Palaeozoic Tethyan sequence (Pl. 3, fig. 6). Going further down towards Gaya and Lata villages (Pl. 3, figs 1 & 3), there is an exposure of Palaeozoic rock sequence which is truncated by a sharp fault zone at Lata comprising monotonous sequences of Indus Flysch or trench sediment horizons (Pl. 3, figs 1-5). This sequence is highly disharmonically folded till Upshi where the Indus flows coming across the intrusive Ladakh granites. Then the typical trench of subduction zone of the Indian and Eurasian plates starts (Pl. 3, fig. 3). The traverse then turns towards Leh along the right bank of Indus River and all along the river the Ladakh granite and molasse sediments are exposed (Pl. 3).

If one takes further geotraverse towards north (Pl. 1, fig. 1) from Leh (Weinberg, 1997) one has to cross the Khardung La Pass (5569 m) situated on the granitic and andesitic magmatic rocks; there onwards starts new orogenic cycles of Karakoram

PLATE 5

The photographs are all from untouched negatives.

The original specimens are preserved at the Geological Survey of India, Calcutta.

1, 2 *Rhacopteris ovata* McCoy Walkom (= *Rh. inaequilatera* Fstm. non Goepp.). From a bed with marine fossils (Fenestella shales), ½ mile N. N.E. of Po, Spiti. Fig. 1, nat. size; Fig. 2 x 2. K.3/294 (Page 196).

3, 4 *Rhacopteris ovata* McCoy Walkom (= *Rh. inaequilatera* Fstm. non Goepp.). Thabo stage, ¼ miles S.W. of Thabo. Spiti. Fig. 3, nat. size; Fig. 4 x 2. K.3/293 (Page 198).

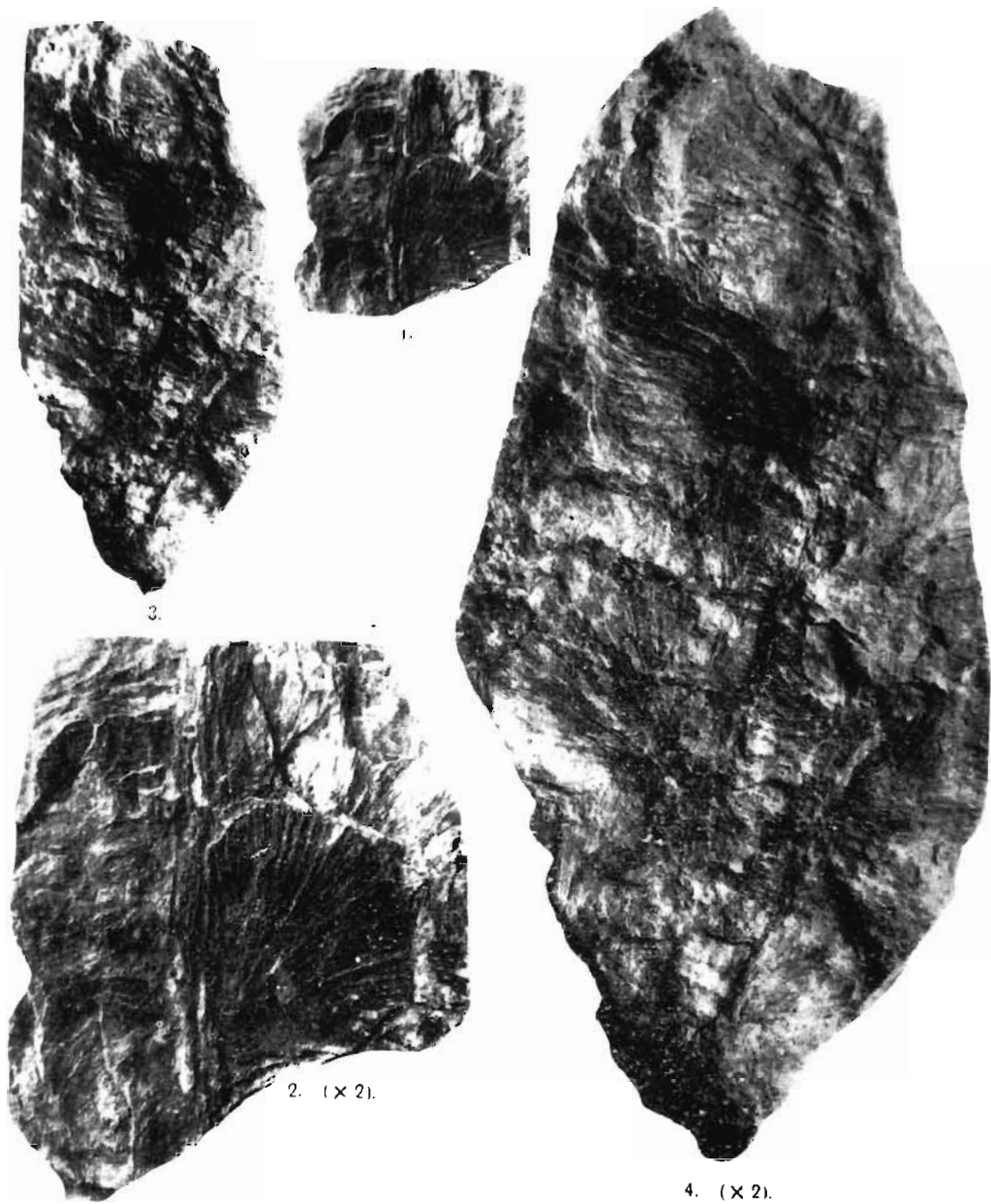


PLATE 5

mountain. Part of the sequence between Leh and Khalsar belongs to the back-arc sequences pertaining to the Karakoram mountain range are described. (Sinha *et al.*, 1997; Sinha *et al.* 1999).

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