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Autor: Bürgisser, Heinz M. / Gansser, Augusto / Pika, Jii

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Late Glacial lake sediments of the Indus valley area, northwestern Himalayas

By HEINZ M. BÜRGISSER, AUGUSTO GANSSER and JIŘI PIKA[1])

ABSTRACT

Late Glacial lake sediments are widespread in the western Himalayas. Dammed by side glaciers, moraines and landslides the lakes were rather shortlived, emptied rapidly and produced fanglomeratic floods.

The investigated lake sediments south of Leh (Ladakh) follow above fluviatile deposits. They are laminated silts showing a locally high carbonate content reflecting a more distant source followed by silts from a nearby granitic environment.

ZUSAMMENFASSUNG

Spätglaziale Seesedimente haben eine weite Verbreitung im westlichen Himalaja. Sie wurden nach dem Rückzug der grossen Talgletscher in gestauten Seen durch Seitengletscher, Moränen und Bergstürze gebildet.

Diese Seen hatten eine kurze Lebensdauer, brachen häufig aus und waren verantwortlich für die Bildung grosser Terrassen fanglomeratischer Zusammensetzung.

Untersucht wurden Seesedimente südlich von Leh (Ladakh). Sie umfassen laminierte Silte, die auf zyklisch abgelagerte fluviatile Schichten folgen. Auffallend ist der lokale hohe Karbonatgehalt der lakustrinen Ablagerungen, der von den südlich liegenden Zanskar-Kalkketten stammt, während die oberen Siltlagen das nähere Granitgebiet widerspiegeln.

Introduction and description of the lake sediments

Along the upper courses of the larger Himalayan rivers, Late Glacial lake sediments are widespread but have received little attention by the visiting scientists. This preliminary note is intended to awake the necessary interest for this neglected topic. As they are covered by younger, mostly small lateral moraines, as well as by extensive fluvioglacial sediments and local fans, they are difficult to recognize and their original extent remains practically unknown.

These lakes must have formed after the retreat of the largest valley glaciers belonging to the third glacial stage. They were dammed by end moraines, and more frequently by landslides and active lateral glaciers which are well displayed today in the Shaksgam valley (Landsat photos and DESIO 1980). Landslides have often been overprinted by glacial activity and are not always clearly separated from terminal moraines. A good example is the landslide to the west of Skardu which has dammed the Skardu lake and has been overridden by an active lateral glacier coming from

[1]) Geologisches Institut, ETH-Zentrum, CH-8092 Zürich.

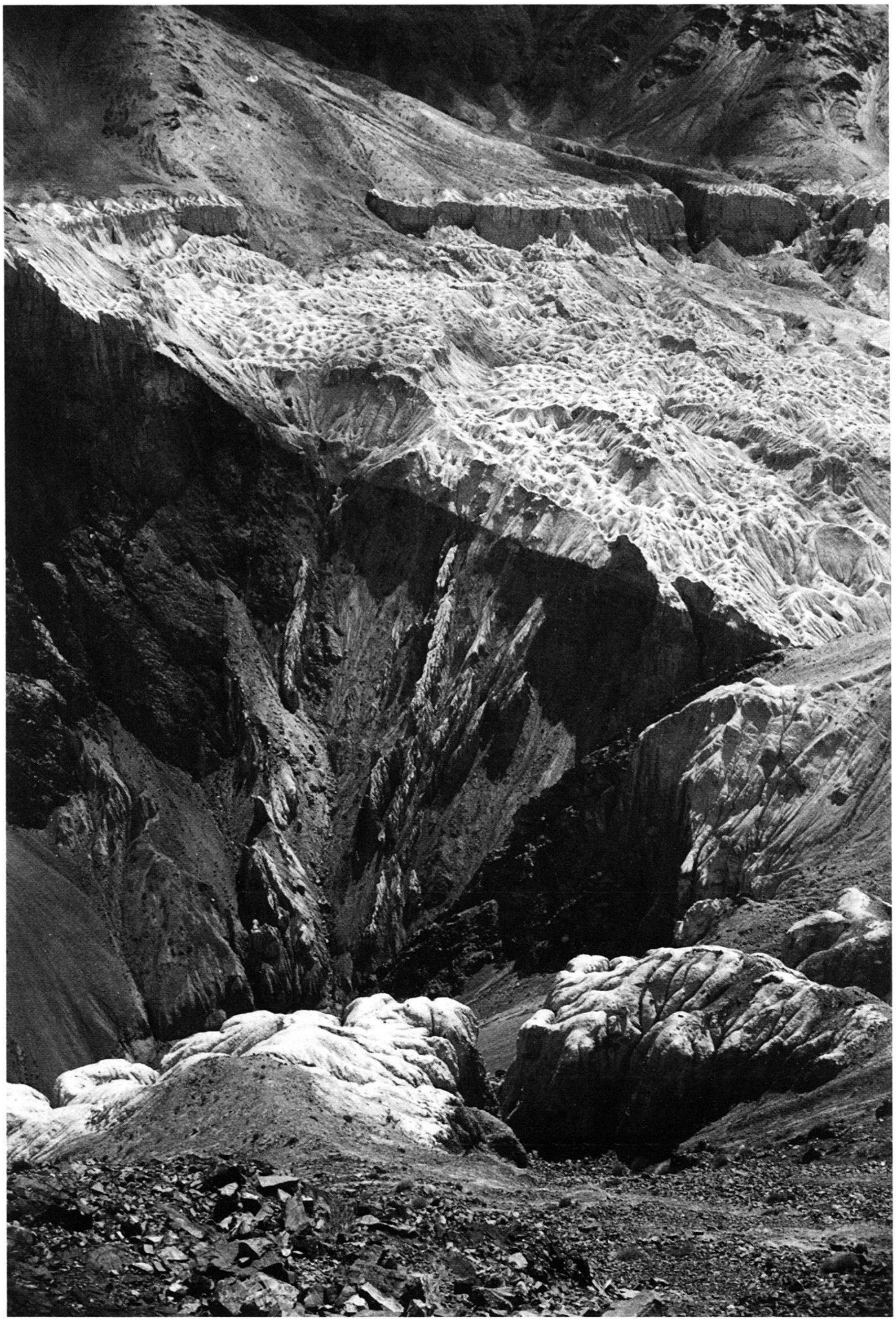

Fig. 1. The Lamayuru lake sediments seen towards southwest. They transgress the steeply folded Triassic Lamayuru flysch and are marginally covered by local fans. Note the deep erosion towards left. (Phot. A. Gansser.)

the southern side. It has been taken as a terminal moraine by DAINELLI who has investigated the Skardu area in detail (1922).

Remnants of the lake sediments in the western Himalayas have been recognized already by the first explorers of these regions (mentioned in DAINELLI 1922). Outstanding in this respect are the lake sediments of Lamayuru, a spectacular remnant at 3600 m altitude, drained today by a side river of the Indus, forming a deep gorge 600 m deeper (Fig. 1). This spectacular erosion must have happened after the last glaciation. The old history of the famous Lamayuru monastery just west of these lake sediments is actually based on a mystic lake. During the time of Sakyamuni Buddha the Lamayuru valley was supposed to have been a clear lake and an abode of the bad Naga spirits. Once a famous Lama landed on a small island in this lake and prophesied the establishment of a monastery and made offerings of grains of barley to appease the Nagas. After this ritual he threw the grains into the lake and "with his spiritual powers caused the lake to flow in one direction". After his departure the grains sprouted on the dried lake in the form of a beautiful swastika (PANDEY 1975). Lakes play an important role in the Buddhistic history of the Himalayas. Unique is the rare presentation of boats in the midst of bodhisattvas in the hall of Alchi monastery, the famous and oldest temple of the Ladakh region (Fig. 2). The rapid draining of the Lamayuru lake mentioned in this mystic story may actually be a fact, relevant for most of the Late Glacial lakes of the Himalayas. This probably frequent catastrophic event is witnessed by some of the extraordinarily high terraces of a wild fanglomeratic composition. The cause, the timing and the

Fig. 2. Presentation of boats on an old wall painting in the hall of Alchi monastery, the oldest buddhistic temple of Ladakh. (Phot. K. Riklin.)

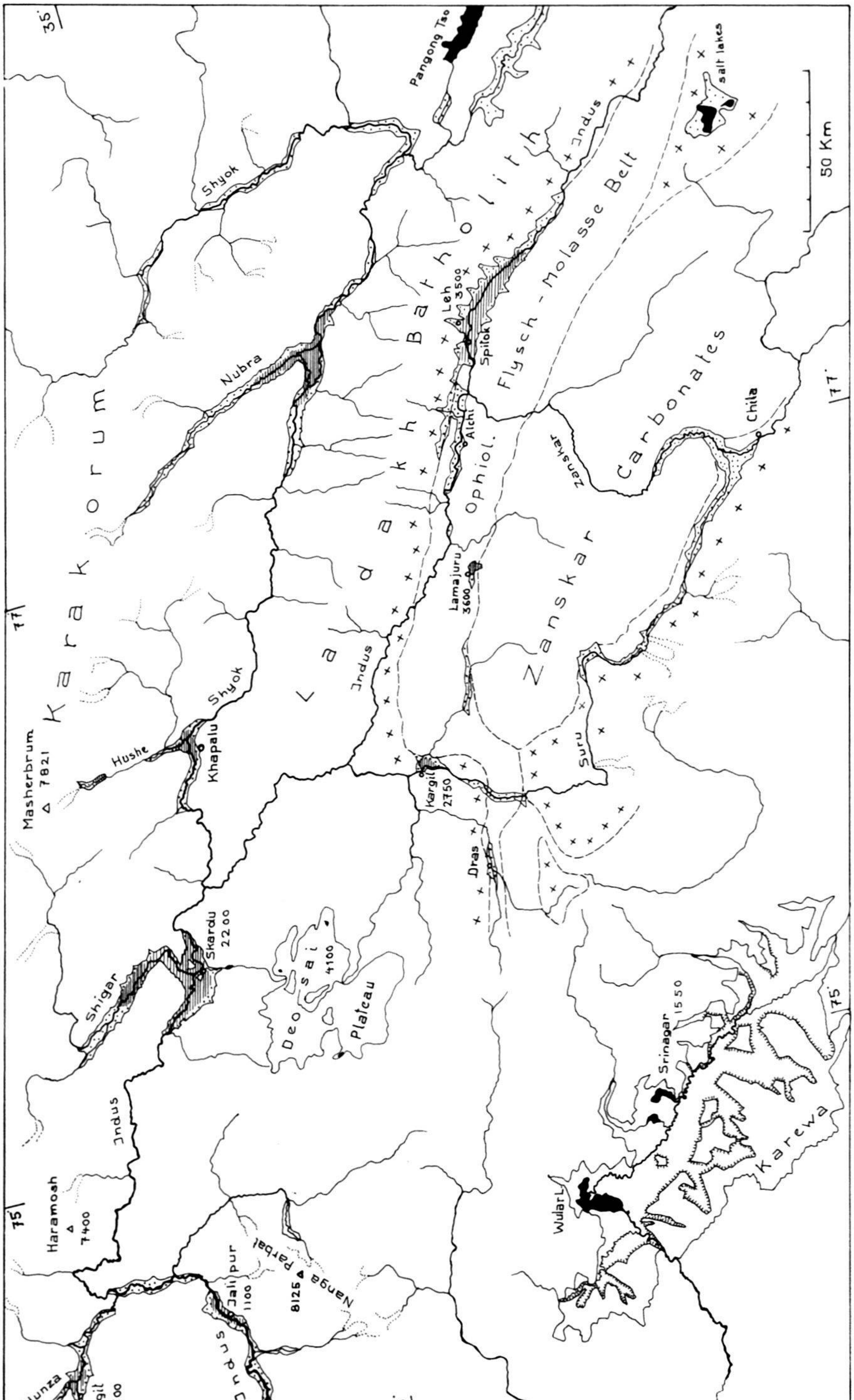

Fig. 3. Late Glacial lake sediments in the Indus area (northwestern Himalaya and Karakorum). Compiled from Landsat photos, field work and all other available information by A. Gansser. Dots = fluvioglacial sediments, horizontal lines = lake sediments and assumed extension of lakes, fine dots = glaciers, black = present lakes, heights in meters.

general effect of such events is still unknown and certainly presents an important research topic in Himalayan morphology. Practically still unknown are the detailed sedimentology and geochemistry of the Himalayan lake sediments. The present paper is just a preliminary attempt to draw attention to this rather neglected topic.

Ascertained and assumed lake sediments are indicated on Figure 3 covering the northwestern Himalayas along the upper Indus drainage area. This map also includes the well-known Karewa lake sediments of Kashmir. The latter cover a much larger area and are partly older than the Late Glacial lakes. They reportedly straddle the Pliocene/Pleistocene boundary, with the Lower Karewas being unconformably transgressed by the Upper Karewas (Roy 1975). They also occur at a considerably lower level (1500 m) but have been subsequently tilted up to over 3000 m. An excellent account is given by De Terra & Patterson (1939).

In the central Himalayas Late Glacial lake sediments have been reported from the Garbyang region (border area of west Nepal) by Heim & Gansser (1939). They have been formed after the retreat of the main Kali valley glacier and dammed by a combination of moraines and landslides at Budhi (Fig. 4), not unlike the large lake of Skardu region at the Indus (see below). In the middle part of this lake, slumped lake sediments are involved in lateral moraines from the Tinkar valley (Fig. 5). It shows the influence of the last glaciation, particularly of side-valley glaciers, on the lake sediments. Other Late Glacial lake sediments have been reported from the Kali Gandaki section of central Nepal (Fort 1974) and were observed during the excursion related to the Tibet Symposium in southern Tibet between the Himalayas and Transhimalayas along the Tsangpo river and its tributaries (Academia Sinica 1980a). Loess sedimentation plays here an important role. It has also influenced the corresponding lakes of the upper Indus. The southern Tibetan lakes lead to the widespread and spectacular lakes covering the whole of Tibet which, surprisingly, are still little known except for some spotty chemical investigations by Chinese scientists (Academia Sinica 1980b). The sedimentology of these lakes is practically unknown.

In Figure 3 we have shown the major lake sediments of the Indus drainage area, but realized that many more localities exist which have not yet been reported or studied. In the west we note lake sediments at Jalipur outcropping under large Indus terraces, together with the somewhat older molasse-type Jalipur sediments which have been steeply folded (Gansser 1980). They are located at an altitude of 1100 m, within the deep Indus gorge, at only 21 km distance from the 8125 m high Nanga Parbat.

The flood plain of Gilgit also exposes lake sediments, which are again covered by the fluvioglacial terraces of the Hunza river. More spectacular are the lake sediments in the Skardu basin, at the confluence of the Indus with the Shigar river. Dainelli (1922) has investigated them without, however, giving any sedimentological data. As already mentioned, the Skardu lake was dammed by a conspicuous landslide subsequently overworked by a lateral moraine related to a glacial advance from the left side. This fact was verified by one of us (A.G.) during regional geological investigations in 1978. The Skardu lake sediments have a wide extent and are about 70 m above the present Indus river level. Yellow grey silts and fine laminated sands alternate frequently and in the upper part of the section expose intricate folds

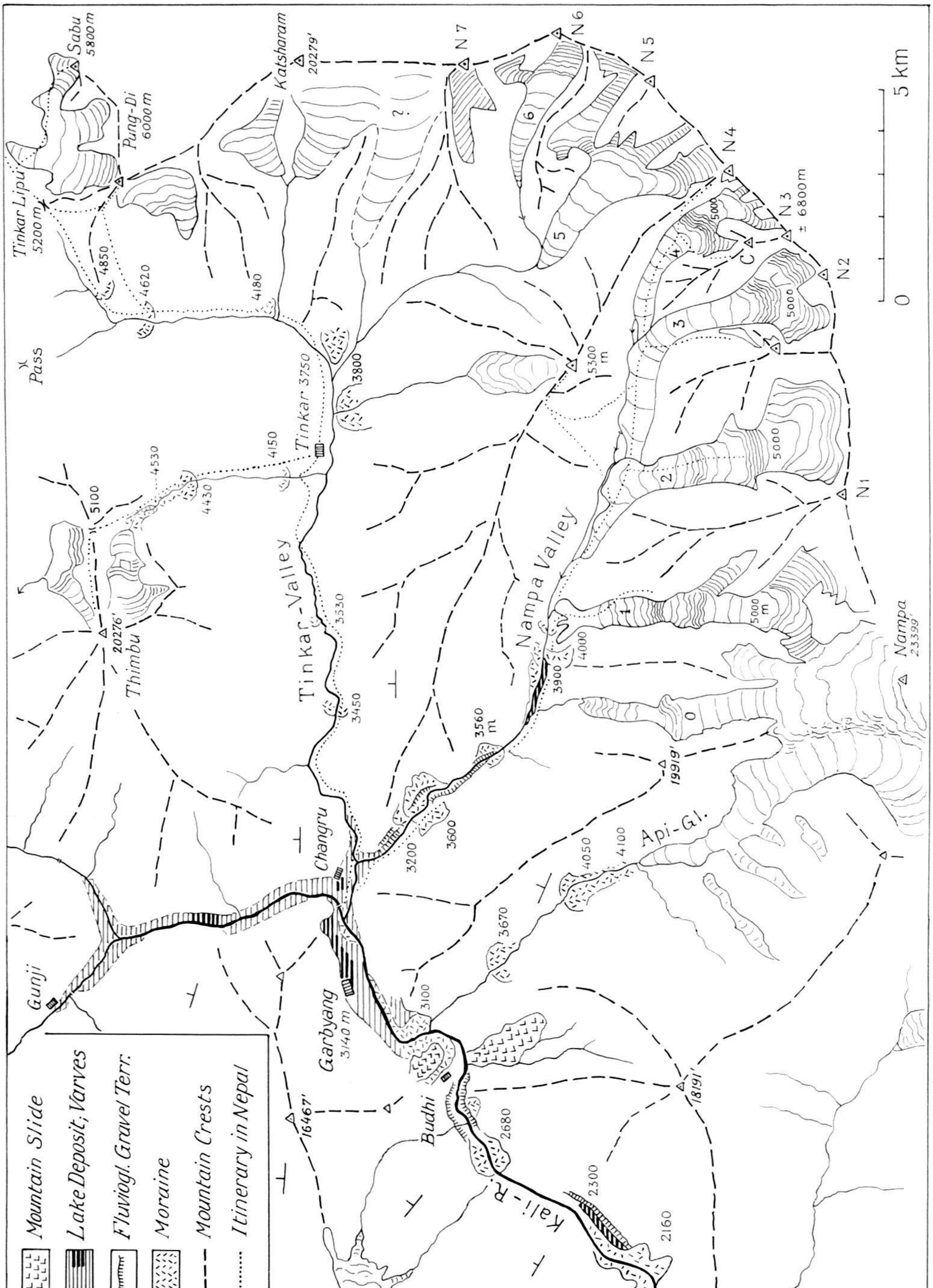

Fig. 4. Sketch map of the glaciation in northwestern Nepal (mainly by A. Gansser). (From HEIM & GANSSER 1939.)

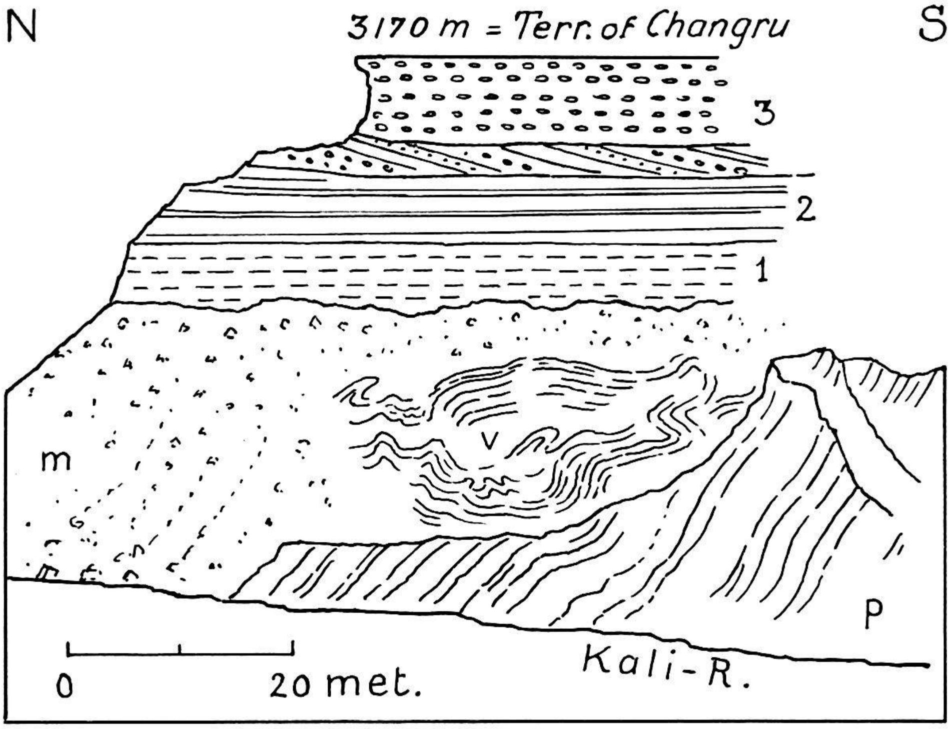

Fig. 5. A relic of the lake deposits at Kaua Talla, Kali gorge above Garbyang. P = phyllite (Cambrian); m = moraine mixed with talus, enclosing V = varves crumpled by subaquatic sliding or glacial pressure; 1 = compact loam; 2 = varved loam; 3 = gravel, lower part with foreset bedding. (From Heim & Gansser 1939.)

(Fig. 6). The folds can be large-scale, with amplitude of tens of metres, or can occur within single silty horizons of less than 1 m thickness. This latter type often resembles the convolute folding which we have observed in the famous Lisan Formation in the Dead Sea valley (Begin et al. 1974). Some of the larger, irregular folds may be related to ice-pressure resulting from lateral glaciers of the fourth glacial stage. They came down from the ice cap that must have covered the peculiar Deosai high plateau. For the intraformational, convolute-type folding an explanation is here equally difficult as for the Lisan folded beds.

East of the Skardu basin we meet the large basin of Khapalu, along the Shyok river. Here lake sediments are mostly eroded by a strong fluvial activity. Fluviatile sedimentation has filled the basin mostly from the north. Some floods may have been caused by the breakthrough of a lake dammed by landslide and moraine material in the upper Hushe valley at the foot of the Masherbrum. Here, well-bedded, silty to fine sandy lacustrine sediments are well preserved just behind the broken landslide (Gansser 1980). A large basin exists further up the Shyok river at the confluence with the Nubra. The only reports of lacustrine sediments in this region come from old travellers, such as Thomson (1852) and Nieve (1913), and indicate that these sediments are rather widespread. Recent investigations by Indian geologists do not deal with Quaternary deposits. A large Quaternary basin has been formed in the middle Zanskar river near Chila. It may have been occupied by a larger lake but, since no information is available, only fluvioglacial sediments have been shown on our map (Fig. 3).

Fig. 6. Intricate folding in lake sediments of Skardu. View towards up valley. The outcrop of banded silts and fine sands is about 15 m high. (Phot. A. Gansser.)

The Quaternary basin of Kargil has been investigated by DE TERRA (1935). Striking here are the large, Late to Postglacial terraces which dominate the basin. DE TERRA mentions argillaceous, well-bedded lacustrine horizons just above some gravel beds which cover the bedrock in the deepest gorges. These beds have a sharp lower contact which suggests sudden damming (landslide below Kargil). DE TERRA places these sediments after the second glaciation and thinks that the third glacial advance only partly covered the Kargil area. The glacial history of the Kargil basin is still little known but it seems most likely that the lake was formed after the strong erosion following the third glaciation. This would conform to the general situation of most of the glacial lakes in the wider area.

Better known are the lake sediments of the basin south of Leh, well exposed opposite Spitok monastery (Fig. 3). They are the remnants of a lake of considerable size, which were covered by surprisingly large alluvial fans (Fig. 7) coming from the Molasse belt to the south (FRANK et al. 1977). It was only in 1979 that we sampled the base of these sediments near Spitok. Though the section is limited, the following sedimentological results may give some valuable information about the composition of the Late Glacial lake sediments of the wider Indus area.

On the road opposite Spitok, the young sediments overlie the Ladakh Intrusives. The composite section (Fig. 8) shows a clear division into an inhomogeneous, conglomeratic-sandy-silty lower part, and a more uniform, silty-clayey upper part.

The lower sequence is thinly bedded. A few erosional bedding planes divide the sequence into six cycles all of which have a more or less clearly developed fining-

Fig. 7. The western edge of the Leh lake basin with flat alluvial fans derived from tonalites of the Ladakh batholith, outcropping in the fore- and background. (Phot. A. Gansser.)

upward trend but different facies successions. A basal pebble conglomerate usually overlies each erosional surface and is followed by sandstone units which commonly show horizontal bedding or are massive. The sandy fill of a 0.9 m deep incised channel is cross-bedded. Convolution occurs in the top part of a sandstone bed. Greyish yellow siltstone is present at the top of two cycles.

Some of these clastic beds show an unexpected composition. Most conglomerates are extraformational and composed of angular to subangular granite pebbles derived from the nearby hinterland. However, an intraformational conglomerate stringer, only 1.3 m above the base of the section, is composed of cm-sized pebbles of calcareous siltstone. Similarly, the fine siltstone higher up in the same cycle is very calcareous; X-ray diffractometer analysis showed 70% calcite and only 29% quartz + feldspar + clay minerals (Fig. 8).

The upper sequence is more uniform. Greyish yellow, faintly to distinctly laminated rocks with mean grain size in the silt grade form thick intervals. 1–6 cm thick bands of yellowish grey, indistinctly laminated, coarse siltstone are intercalated at irregular intervals. Towards the top, where the bulk of the siltstone is yellowish grey in color, many thin bands of fine sandstone are intercalated. The yellowish coloration is due to limonite grains. Horizontal lamination is the dominant bedding of these siltstones. Micro-channelling was once observed, and in another thin bed the lamination was strongly contorted. Thick folded intervals between undeformed beds, as described from the Skardu lake beds (DAINELLI 1922), were not observed.

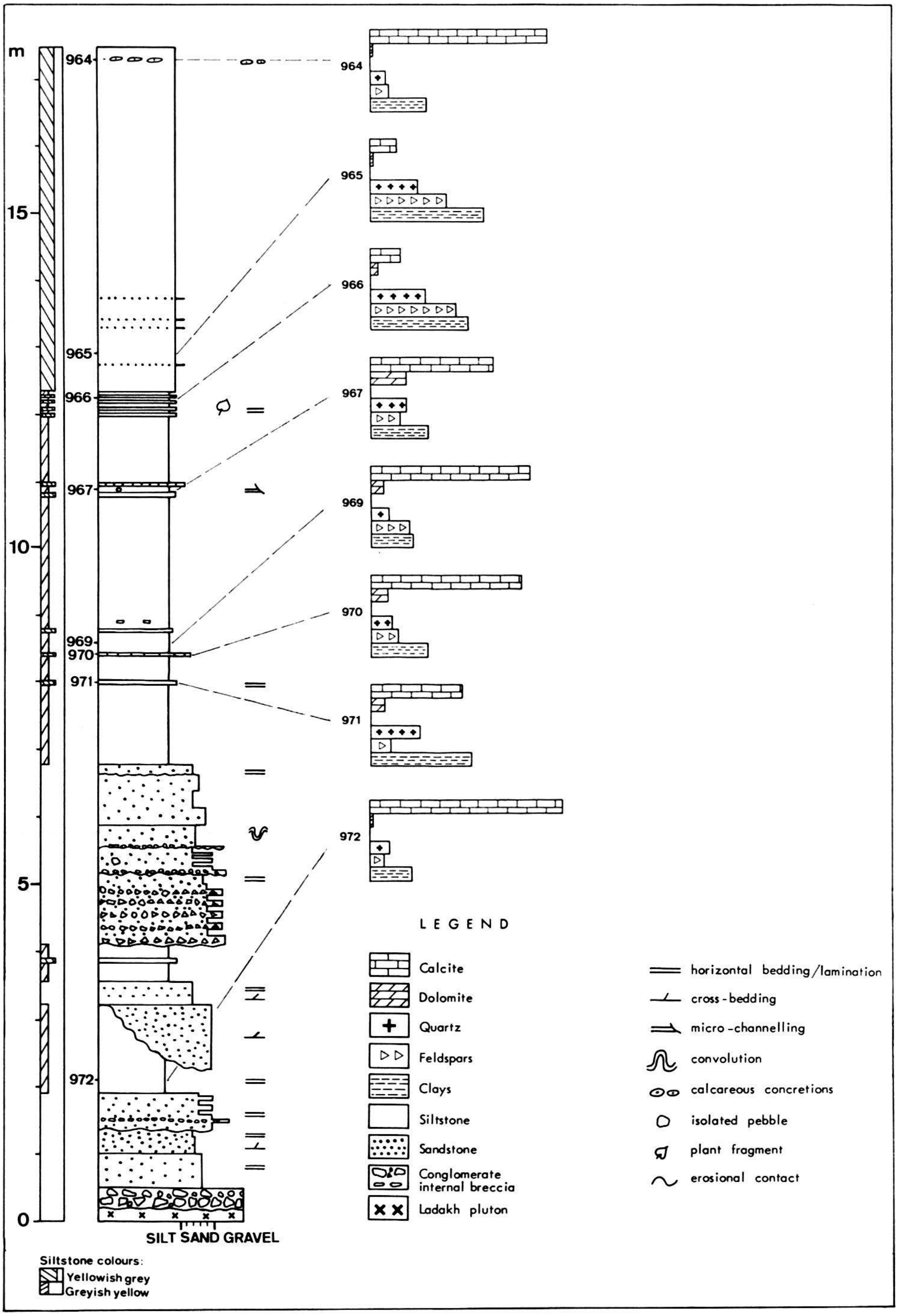

Fig. 8. Profile through lacustrine sediments opposite Spitok monastery, Leh basin (Ladakh), and their mineralogical composition (histograms).

The only identifiable fossil was a reed-like plant fragment in a yellowish grey layer. Spherical black spots (0.5–1 mm in diameter) are frequent in the greyish yellow siltstone. Rare, small (< 5 mm long) coaly coatings could be leaf fragments.

The mineralogical composition of these siltstones again deviates from that expected in a granitic terrain. In the lower part, carbonates make up 35–70% of the siltstone, with calcite predominating over dolomite (Fig. 8). In a layer of laminated clayey sandstone (sample 970), the lighter lamina has twice as much carbonate than the coarser-grained darker lamina (Fig. 9a). The overall composition is about the same as the adjacent greyish yellow siltstone (samples 967, 969). In sample 971, a slightly reddish interval has the same bulk mineralogy as the normal greyish yellow part (Fig. 9b).

Higher up in the profile the carbonate content of the siltstones decreases appreciably, and the composition approaches the expected values for a fine-grained rock derived from a close granite source (clay minerals > feldspar > quartz) (Fig. 8). Disc-

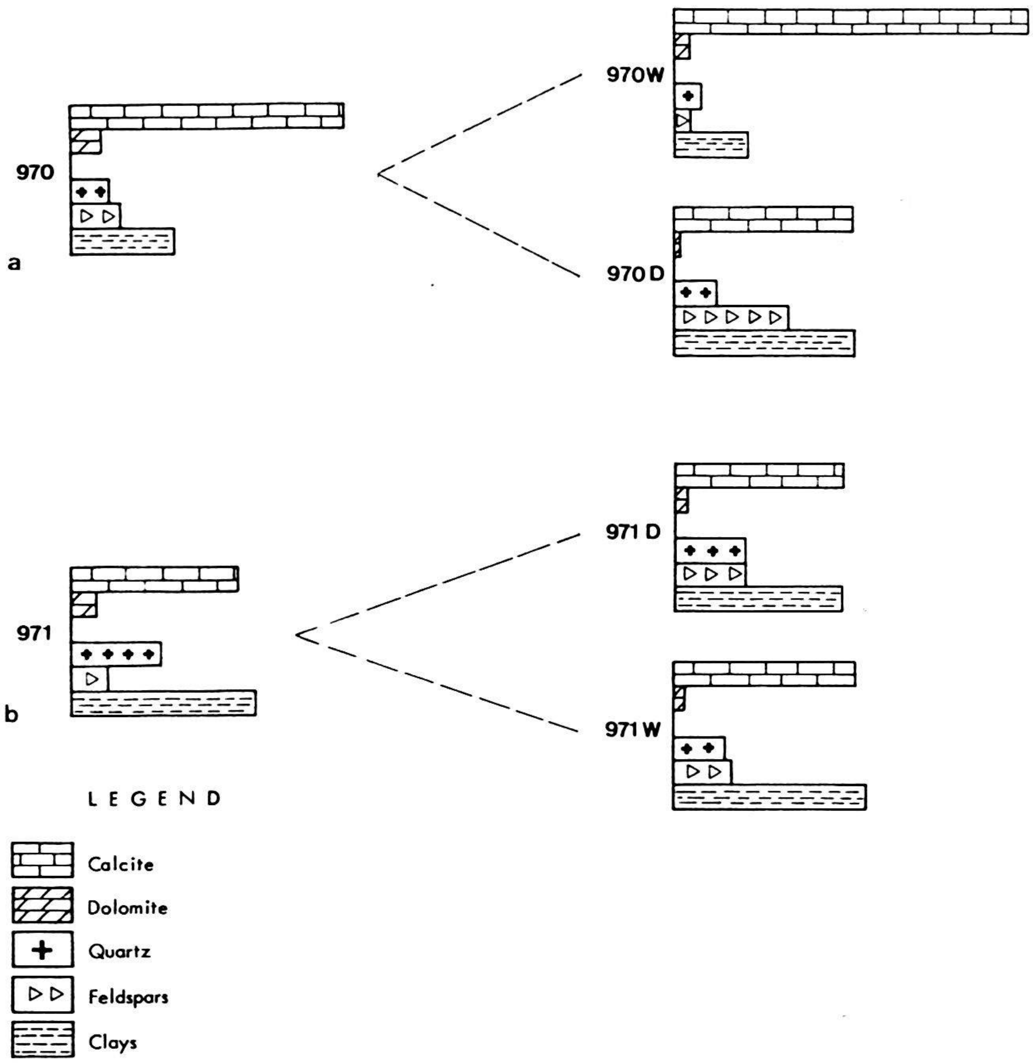

Fig. 9. Weight percent histograms of the main mineral components in (a) the sample 970, lighter lamina 970W has twice as much carbonate as the darker lamina 970D; (b) the sample 971: the reddish interval 971D has the same bulk mineralogy as the normal greyish yellow part 971W.

shaped calcite concretions occur in the siltstone at the top of the measured section. The better cementation is due to minute (1-2 μm) crystals of calcite. The overall composition is very similar to that of the lowest siltstone in the section (sample 972). The influence of loess may have contributed to some extent to the lake sediments, but it was not possible to find any direct evidence.

Discussion

A fluvial depositional environment is suggested for the lower sequence on the basis of the fining-upward cycles, channelling, cross-bedding and the stratigraphic position (immediately overlying granitic basement).

For the upper sequence, a deeper lacustrine depositional environment is more likely than an overbank floodplain environment because of the homogeneous grain size, the lack of bioturbation and the fine parallel layering resembling detrital varves. Many similarities exist with the distal glacio-lacustrine, parallel-laminated facies of SHAW (1975) and the "laminated basal beds" in a recent Norwegian glacial lake (THEAKSTONE 1976). They include main grain size, bedding and such details as thin layers of sand and some local deformation of the parallel bedding, associated with beds which include fine sand. This facies has been deposited from suspension in distal parts of the glacial lake, in water depth of several tens of metres.

Coarser laminated lake sediments reflect stronger currents, as observed in lake of Walenstadt (LAMBERT 1978, LAMBERT & HSÜ 1979) or in lake Thun (STURM & MATTER 1972) or in the vanished lake of Einsiedeln (PIKA 1982). Particularly during an early period of deposition, substantial amounts of material from the south side of the Indus valley, e.g. from the carbonates of the Zanskar Ranges (Fig. 3), reached the site. The increased calcite content (up to 70%) matches well with characteristic high calcite content of the Upper Karewa lake beds (72%, DE TERRA 1939).

Due to the breaching of a dam, the lake level dropped, leading to a rapid drainage and erosion of the lake bed. A similar termination occurred in the glacial lake Hitchcock (ASHLEY 1975).

The preliminary character of this note precludes more detailed interpretations, but stresses the importance of glacial lake sediments in the western Himalayas.

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