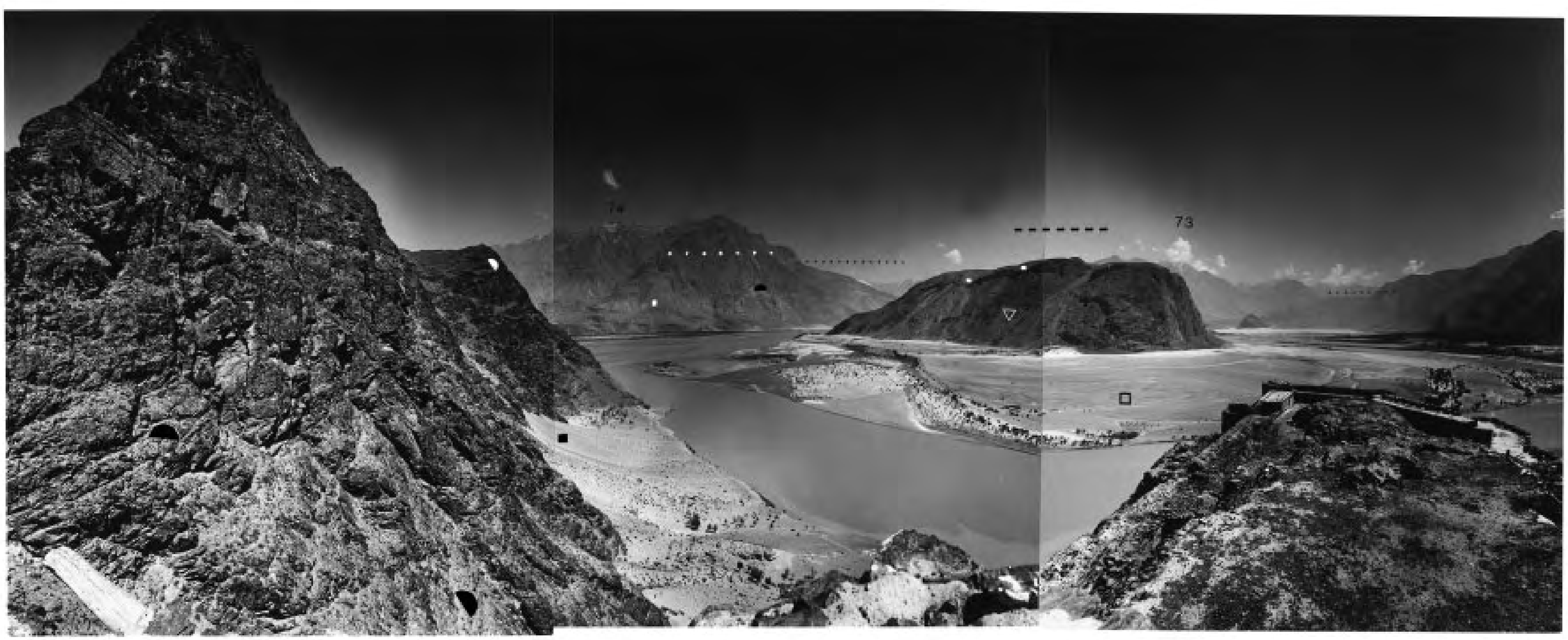
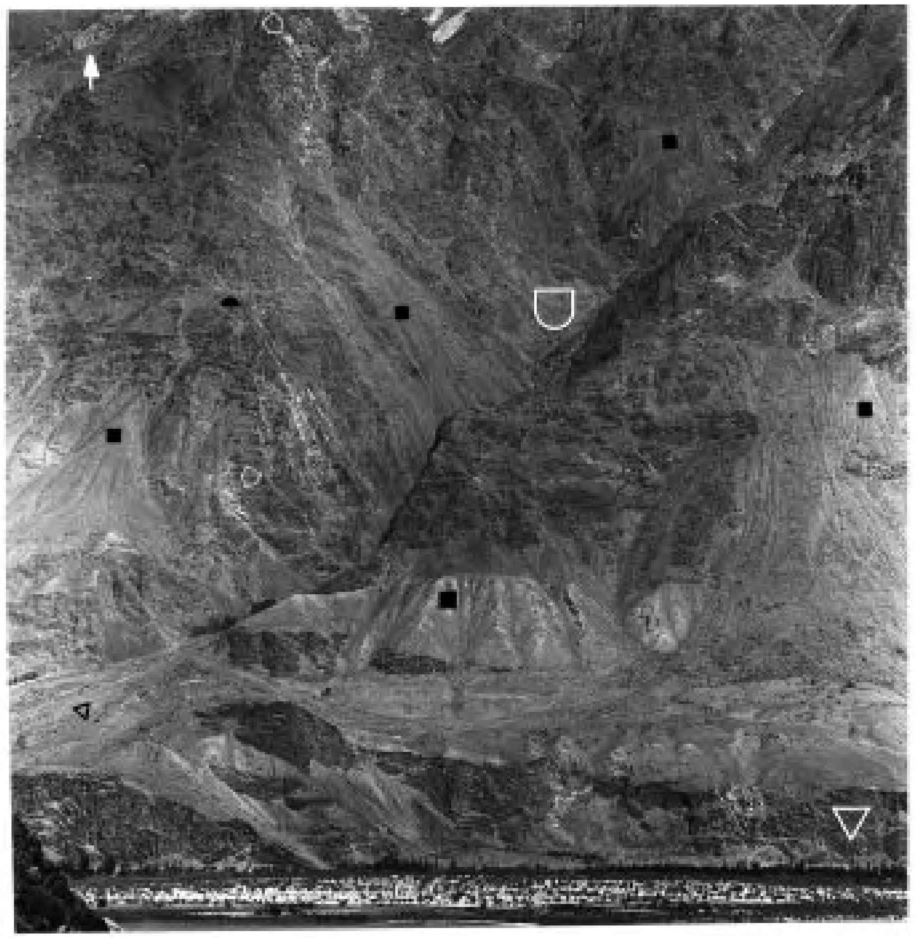
→ *Photo 150.* Viewpoint situated only 500 m further E than that of Photo 149 (35°18′ 10″ N/75°38′ 30″ E, 2230 m asl) facing WNW looking to the Karpochi, the western "riegel" (barrier mountain) in the Skardu Basin; on the left the wall of the small fortress (cf. Photo 149 on the right). (◓) are glacigenic polishings, preserved as unambiguously identifiable prehistorically abraded rock parts. (■) is the metres- to decametres-thick ground moraine (cf. Photo 146 ■ below No.76 seen from afar) with erratic granite boulders up to the size of a hut (↓) which overlies the outcropping phyllite rocks at c. 2400-2600 m asl, i.e. 240-440 m above the Indus valley bottom. Photo M.Kuhle, 31.7.2000.





← *Photo 151.* At 2200 m asl, seen from the middle of the Skardu Basin facing N into the orographic right flank of the Indus valley (◓: 35°22′ N/75°38′ E). (▢) is a 6 km-long side valley, the Marshakala Lungma (Photo 149 below No.74), leading down from the 5153 m-high Marshakala, an ESE tributary summit of the 5242 m-peak (Photo 149 No.74), to 2160 m. Despite its steepness the valley has been widened to a trough and glacigenically polished. The Indus and its in part thinly wooded gravel floor (□) is at 2160 m asl. Its outer bank has undercut the phyllite rocks of the valley flank (▽ white). The outcropping and very resistent metamorphic rocks are glacigenically abraded (◓) over the entire flank area depicted in this photo. (⇩) are small-scale damage to these polishings caused by postglacial to recent crumblings; the youngest crumblings can be diagnosed by its lighter colour (the ferromanganese incrustation is lacking). This applies also to the fresh tracks of the falls below (below ⇩). (■) are remnants of ground moraine on the slopes of the main- and side valleys. Since deglaciation they have been partly furrowed and partly removed (e.g. on the right and left of ■ on the very left). Here, a classic transitional glacial debris accumulation after Iturrizaga 1998, 1999 is concerned. (↑) is a highest remnant of ground moraine at 3430 m asl, 1270 m above the valley bottom. (▽ black) is ground moraine material, surficially displaced and buried by mudflow activities at the exit of the Marshkala Lungma (▢). Photo M.Kuhle, 15.8.1997.

→ *Photo 152.* Looking from the bottom of the Indus valley, from the SE margin of the settlement of Skardu, into the orographic left slopes facing SE (2230 m asl; 35°16′ 50″ N/75°39′ 30″ E). (■) are remnants of ground moraine preserved in niches on the upper slope as far as a height of 3350 m (■ somewhat below – – and on the very right), reaching significant thicknesses of over 100 m (■ large) on the middle- and lower slope, c. 200-500 m above the valley bottom. (– –) is the LGM glacier level about 3400 m asl, identifiable according to a polish band (◓) with an upper abrasion limit, which truncates the granite bedrock. (■ on the left below) is a ground moraine accumulation mediating with a trough-shaped profile line between the valley ground and the valley flank. At the exit of steep single-ended, i.e. flank valleys it has been selectively dissected and removed by rill rinsing and linear erosion (▼). According to the cirque-like form (○) situated in a NE-exposition below the 4969 m-peak, a N-satellite of the 5321 m-peak (No.77; Fig.2/1; not visible in this photo, but in Photo 153), a prehistoric cirque glacier has to be suggested. After the LGM-glacier level had dropped, the tongue of this cirque glacier, which previously flowed into the Indus glacier, has pushed the ground moraine cover of the main glacier down-slope. Thus, the former ground moraine has been pushed as a pedestal moraine of the cirque- and hanging glacier against the lowered margin of the main glacier (■ large). Owing to this, a classic ground moraine ramp (▽) is concerned (Kuhle 1982a p 84; 1983a p 238), pressed into the gap between valley flank and main glacier which had been widened by the melting-down, so that the locally very important thickness of the ground moraine (see above) becomes understandable (■ large). (▽) is the flat ground moraine ramp on which the hanging glacier was situated. (□) are irrigated fields between which grow walnut- and apricot trees but also willows and poplars. Photo M.Kuhle, 15.8.1997.

↑ *Photo 153.* Panorama from the Karpochi, the western 2698 m-high "riegel" (barrier mountain) (right margin) of the two central "riegels" of the Skardu Basin, taken from the small fortress at 2270 m asl (35°18′ 10″ N/75°38′ 30″ E): from facing SSE with the massif of the 5321 m-peak (No.77) via the massif of the 5339 m-peak (No.78) towards the SSW, with the massif of the 5322 m-peak (No.75) and the 5343 m-high Garsinge (No.76) in the WSW up to W with the 5204 m-high Phara (No.79) looking into the orographic left flank of the Indus valley (cf. Photo 146 No.75 and 76). (■ below No.77) are remnants of ground moraine in the orographic right flank of the Satpare Lungma leading down from the Deosai plateau, above the Satpara (or Satpura) Tsho (lake). (■ from below No.78 up to the right margin) are ground moraine covers, attaining maximum heights of c. 3400 m (■ below No.76), i.e. they lie as far as c. 1300 m above the Indus valley bottom. Four types of ground moraine accumulations have to be differentiated: 1. the flat covers reaching up the highest (■ on the right below No.78 and No.76), which partly are heaped up by a thinly scattered debris of crumblings; 2. ramps as parts of a trough profile in the transition from the lower slope to the valley bottom (■ below No.75 and on the very right). Owing to their dissection they are only preserved in remnants; 3. the up to 600 m-high, decametres- to far over 100 m-thick accumulations of ground moraine, marginally dispersed into rills and earth pyramids, which lie at the exit of the 'Biansah Lungma' (valley in which the settlement of Biansah is situated) (■ on the left below ◓ below No.75) and finally 4. the up to 400 m-high and at least 300 m-thick ground moraine ramps (■ white) on which the settlement of Tindschus is situated with its irrigation fields at the exits of the three steep valleys leading down from the over 5300 m-high, still glaciated mountains (No.75 and 76). (△) are polygenetic fan features mainly built up of mudflow- and alluvial debris which for a large part consists of displaced High-(LGM)- to Late Glacial moraine material (Stage 0-IV). They overlie the bottom of the entire Skardu Basin as far as the Indus and are largely covered by wood- and bushland but also by irrigated areas with fields and fruit-trees. The fans, coming down from steep valleys, are connected with the talweg dissecting the moraines. The irrigation channels are also linked with the valley exits (e.g. below No.75 between ■ and △). (□) is a postglacial accumulation of rock avalanche from the orographic right flank of the Satpare Lungma, damming up the Satpara Tsho (lake) (cf. Hewitt 1999:222 and 230 Fig.7). (⇩) are break-out scars developed by quite important postglacial crumblings, which according to their dimensions have to be classified as rock avalanches; (▼) mark active tali made up of the fine debris of the crumblings from those break-out scars. (◓) are glacigenic flank abrasions, the roundings of which contrast with the crumbling edges and rough faces of the break-out scars (⇩). They reach up to 3400 m asl, so that this ought to have been the LGM-glacier surface (— —). (○) are cirques, which still today show snow fields or glaciers. The cirques and cirque glaciers of the 5204 m-high Phara (No.79) situated in a NE-exposition (○ below No.79) are evidence of a current orographic ELA at 4800 m asl. Photo M.Kuhle, 15.8.1997.

→ *Photo 154.* Panorama from the orographic left side of the Indus valley, taken in the lower area, i.e. at the NW-exit of the Skardu Basin (2160 m asl; 35°40′ 45″ N/75°27′ 30″ E) looking up the Indus: from facing SE (left margin) with the orographic right flank of the Indus valley, via SSE (centre) with the left valley flank, up to S (right margin) seen into an orographic left tributary valley, which drains the northern foothills of the 5204 m-high Pahra massif. (□) is a gravel bank in the Indus river bed; (○) are limnic sediments the accumulation of which is due to the damming-up of the Indus to a lake. This damming-up was caused by a rock avalanche described by Hewitt (1999, p 223-228, Fig.4-6) as "Kazarah rock avalanche", which originated from the orographic right Bragardo Lungma (cf. Photo 170) damming-up the Indus valley bottom. (▽) are the metres-sized, edged boulders of the rock avalanche on its SE margin, undercut by an outer slope of the Indus. Godwin-Austen (1864), Dainelli (1922) and finally Owen (1988a, Fig.2) have misinterpreted the rock avalanche as a moraine. (■) are accumulations of ground moraine reaching a height of c. 2850 m (■ white), 700 m above the Indus river bed (□). (▼ left) is secondarily replaced debris with moraine material beneath, which, at least on its surface, has joined the dynamic force of a mudflow. (◁ on the right) is the debris of crumblings, perhaps with a minor component of dislocated moraine, on a sloping denudation terrace in the bedrock. (⇓) mark irrigation fields with walnut-, apricot -, willow- as well as poplar trees in the Koneore settlement. (– –) are the minimum heights of the Ice Age glacier level at c. 3300 m (– – on the left) and 3100 m asl (– – on the right) estimated according to ground moraines (■), glacigenic roundings and abrasion forms (◓). Photo M.Kuhle, 11.7.2000.

→ *Photo 155.* At 2490 m asl, panorama from the orographic left margin of the Skardu Basin (Indus valley) in the area of the Mantal locality, in the junction area of the Satparu Lungma (□ above) and the Indus valley (Skardu Basin) (35°16′ N/ 75°38′ 23″ E), from facing S to the Satparu Lungma (left margin) via WSW into the flank of the mountain spur in the exit of the side valley (centre) as far as N into the Skardu Basin and down toward the 5242 m-peak beyond the Indus valley (No.74). The viewpoint is on the edge of the alluvial debris fan terrace (○) on the orographic left, c. 70 m above the Satparu river (▼). (□) are deposits of rock avalanches with megaclasts of the "Satparu Lake-Skardu rock avalanche(s)" as described by Hewitt (1999:228-231). (□ on the very left) is the highest surf-rampart of this accumulation of rock avalanches damming-up the Satparu (Satpara) Lake. These rock avalanches were multi-phased (ibid.). (The two large ■ black) are glacial remnants of ground moraine which have partly been buried by the rock avalanches, i.e. which, lying under their material, come to the surface. (■ white on the left) is also LGM-ground moraine in a higher position. It is surficially covered by crumblings in the form of debris cones and -tali (△) over large areas. (◓) are glacigenic rock abrasions, which have not yet splintered away and roughened by breakages. (– – white) is the LGM glacier level reconstructed according to the glacigenically rounded mountain spur (below – – white), which is 3200 m-high on the right and 3500 m-high on the left; it was situated at c. 3400 m asl (– – white). (■ white on the right) is the erratics-bearing ground moraine on the "Karpochi" (riegel) on the distal margin of the mudflow fan (torrential fan), discharged from the Satparu Lungma into the Skardu Basin. (■ black, small) mark deposits of ground moraine in the area of the Kuardu locality on the right flank of the Indus valley; (– – black) is the corresponding prehistoric glacier level c. 1200 m above the bottom of the Skardu Basin. Photo: M.Kuhle, 3.8.2000.

↑ *Photo 156.* In the region of the "Satparu Lake-Skardu rock avalanche(s)" at the exit of the Satpare Lungma (35°14′ 30″ N/ 75°38′ 38″ E; 2670 m asl) view towards the N down the Satparu river (⇓). (△) are the edged, coarse boulders of the rock avalanches, which, cleared of the fine material matrix by flushing, accumulate in the talweg. The river (⇓), which has been - and still is - dammed-up by the rock avalanches, so that the Satparu Tso (lake) exists down-valley at 2678 m, cuts into the rock avalanche material (□) and removes the fine material. Accordingly, the coarse boulders (△) have been compacted in the talweg. The dissection of the rock avalanche material has initially taken place as a result of the over-spill of a prehistoric Satparu Tso which was far more extended. This over-spill is still in the process of development. (◀ black) is an active talus of debris along which mainly rock avalanche material (□ on the right) slides down to the talweg (⇓). (■) marks an Ice Age ground moraine cover at 3100 m, down-slope torn away by the rock avalanches and still gradually breaking-off (▲ white). Owing to this, rounded and facetted moraine boulders occur in the rock avalanche material, even though in small portions. (◓) are glacigenic rock abrasions, further above reshaped by postglacial crumblings and rock rills (⇩). (— —) is the LGM-surface-level of the Satparu tributary glacier at c. 3500 m asl. Photo: M.Kuhle, 6.10.1997.

↑ *Photo 157.* Panorama from the orographic right flank of the Satpare Lungma (35°11′ N/75°37′ 30″ E; 2820 m asl) near the Satparu settlement, up-valley of the lowest junction of two (a left and a right) side valleys (▷ large and △ white): from facing W (left margin of the photo) via NW to the left valley flank behind the junction of the orographic left side valley (centre) and N down the Satparu Lungma with the Satparu Tso (above ▢), up to NNE into the orographic right side valley junction (right margin). (▢) is the glacigenic trough valley Satpare Lungma, basally filled by a fluvial alluvial debris bottom (□ black), with a mountain river and a lake which has been dammed-up by a rock avalanche ("Satparu Lake-Skardu rock avalanche(s)") at the valley exit (▲ black). (△ large and △ white) are alluvial debris fans discharged from the side valleys and heaped up on the main valley floor. They are used as field terraces. (□ white) is either a remnant of ground moraine or these are the remains of a rock avalanche accumulation not yet completely removed, which, as its polymict, partly round-edged and facetted large boulders suggest, also contains displaced moraine, as is usual for postglacial rock avalanches in prehistoric glacial valleys. (■) are up to decametres-thick (third ■ from the right) ground moraine covers on both main- and side valley flanks, lying up to an altitude at c. 3800 m (■ on the very right and fourth from the right) (Fig.47). In places this moraine material is preserved in situ (first and second ■ from the left and second from the right), in places it has been buried down-slope (first ■ from the right) or dislocated (third ■ from the right). (The third ■ from the right, II-III) is ground moraine displaced kame-like and accumulated against a Satpare Lungma glacier which has already melted down (accordingly it was a Late Glacial glacier, perhaps of the Stages II-III; Tab 1). (▼ white) indicates a mudflow cone which also contains displaced ground moraine at the slope foot. (– –) is the position of the LGM-glacier surface (Stage 0), partly reconstructed with the help of glacigenic flank abrasions (◓). (△ black, small) shows the body of a glaciofluvial gravel floor terrace, left behind by the glacier meltwater of the Satpare Lungma glacier melting back as far as the valley head during Stage IV (Tab 1). Besides older ground moraine and glaciofluvial gravels, this terrace body also contains rock avalanche material. (○) are cirques formed by their High- to Late Glacial glaciation (Stage 0 to IV, Tab 1). Photo M.Kuhle, 6.10.1997.

→ *Photo 159.* Panorama taken from 3200 m asl in the middle Satpare Lungma (35°08′ 45″ N/75°37′ 01″ E) looking up-valley facing S into the orographic right valley flank (left margin) via W into the orographic left flank (centre of the panorama) up to NW down- valley (right margin). (■ black) are ground moraines on the valley slopes. In places they attain decametres in thickness (the two■ from the right). These important ground moraines forming the inner slope of an orographic left lateral moraine (■ black on the very right with III) belong to the late Late Glacial (Stage III). They contain far-travelled and accordingly round-edged granite boulders. (■ white) is a Late Glacial end moraine (Stage IV, Sirkung Stage, see Tab 1) in a valley-blocking position, which, among other things, consists of edged (□ white) and round-edged (○ white) up to rounded (○ black) granite boulders in a fine matrix (see Fig.22 and Fig.6 No.16). (□ black) marks the current gravel bed of the Satpare river in which moraine, undercut by lateral erosion (e.g. ■ on the very left) has been - and still is being - reworked. Additionally, the gravel bed receives a supply of already re-arranged ground moraine from the mudflow cones- and fans (△) in many places. (◓) are glacigenic flank abrasions- and polishings which have been roughened - even though not completely destroyed - by postglacial reworking. Their upper limit - a more or less clear polish line - allows an approximate reconstruction of an early Late Glacial (Stage I) to LGM-glacier level (Stage 0, cf. Tab 1) (– –). The then glacier surface ran at c. 3900 m. Photo M.Kuhle, 3.8.2000.

↑ *Photo 158.* Panorama from the orographic right flank of the Satpare Lungma (35°10′ 59″ N/75°37′ 31″ E; c. 2820 m asl) looking up-valley: from facing SE (left margin of the panorama) with the orographic left flank, via NNW (centre) up to via WNW (right margin) into the lowest orographic left side valley in the area of the Satparu settlement. (□) are ground moraine remnants in the two valley flanks; below rock fractures (⇩) they are surficially covered by debris overlays (▼ white) at some places. It has been observed that these debris covers also occasionally contain displaced ground moraine material (△ white) from the upper slopes. (▼ black) is a mudflow cone consisting - at least in part - of ground moraine which has been transported down-slope. (The two first ■ from the left with II-III) are remnants of a Late Glacial ground moraine pedestal (Stage II or III, Tab 1) upthrust against the Satpare Lungma glacier from the small, steep orographic right side valley leading down from a 5032 m-high summit named Tschalsi. At that time the main glacier was probably still superimposed upon by the side glacier. This remainder of a moraine pedestal, i.e. of its upper edge (above the two first ■ from the left with II-III) is situated c. 500 m above the current gravel floor of the main valley (□). In the moraine remnant marked (■ white), a ground moraine remnant of the Satpare Lungma glacier (main valley glacier) can be recognized, in which a small remainder of the then glacigenic trough-shape of the bottom has been preserved in the loose rock. In an appropriate thickness and altitude above the main valley gravel floor (□) a moraine remnant (below ■ black small, panorama centre) has survived at the exit of an orographic left side valley. Both the ground moraine remnants show a relative height of c. 50 to 60 m. They prove that the Satpare Lungma glacier, too, has flowed on a ground moraine pedestal which has been extensively removed (with the exception of these two remnants) by the Satpare river (□). (■ small, panorama centre) shows furrowed ground moraine from which earth pyramids develop on the orographic left slope. (■ second from the right) is a further basal ground moraine remnant at 500 to 700 m above the valley bottom (□). (△ black) mark a glaciofluvial gravel floor terrace into which late Late Glacial (Holocene) rock avalanches have also been locally incorporated. Terraced irrigation fields are situated upon it. This terrace body has been accumulated by the last late Late Glacial (at the end of Stage IV, Tab 1) glacier meltwater and since then becomes dissected. (◓ black) are glacigenic flank abrasions even reaching up to 3700 m-high spur summits (◓ white). (– –) are glacier levels. (– – 0) is the LGM (= Stage 0) glacier level at 3800 m asl: ice thickness c. 1000 m. Photo M.Kuhle, 6.10.1997.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← *Photo 161.* At 4150 m asl from the Deosai plateau (35°40′ N/ 75°31′ E) facing SE (left margin) via S (centre) up to WSW (right margin) looking over a glacial landscape. No.80 is the massif of a 5375 m-high summit. (■ white) marks (Fig.48) an undulating ground moraine face extending over kilometres, which, as the arrangement of its positions suggests, is built-up by a ground moraine cover metres- to decametres-thick. (○) are round-edged and facetted polymict erratic boulders of granite and quartzite. Among them are also edged, i.e. partly edged boulders of sedimentary rock (□) already showing stronger traces of weathering, i.e. splintered post-sedimentarily. The boulders are in size up to 4 x 2.8 x 2 m. (■ black in the foreground) is the clay-containing matrix (boulder clay); (■ black in the background) are faces of ground moraine, which - only little reworked - lie up the slopes of roches moutonnées (◓ on the left) and glacially streamlined hills (first to third ◓ from the right). Near the culminations of the glacial abrasion forms, faces of rock polishing emerge from the ground moraine covers (e.g. ◓ on the left). The development of fluvial rills, which took place after the deglaciation, is only insignificant, so that the glacial forms must be young. (– –) is the LGM glacier level between c. 5000 (– – fine on the left) and 4700 m (– – bold, middle; Fig.48) reconstructed according to these glacial features. Photo M.Kuhle, 3.8.2000.

→ *Photo 164.* At 3930 m asl, from the centre of the Deosai plateau (35°00′ 32″ N/75°24′ E) looking to the SE; No.84 is the 5193 m- massif in the SSE. The large névé patches there and the small avalanche-fed glaciers on the N-exposed wall feet (below No.84) prove a current ELA about 4700 to 4800 m asl. From the foreground up to the 5193 m-massif extends a classic prehistoric glacial landscape with ground moraines (■) on which a scatter of polymict, up to over 2 m-long, round-edged, far-travelled boulders (○) can be seen, pierced by abraded glacial erosion forms (◓) as e.g. roches moutonnées (◓ on the left). (◓ on the right) is the glacigenically triangle-shaped face of a “truncated spur”. The boulders consist of metamorphic sedimentary rocks (phyllites); (◁) is a debris flow fan accumulated from dislocated moraine at the exit of a flat low ground valley after the deglaciation, i.e. during postglacial times. It is distally undercut by the present-day river in the talweg (below △). The LGM-ice-level (– –) ran between an altitude of 4800 (Fig.49) and 4900 m. Photo M.Kuhle, 3.8.2000.

← *Photo 160.* 360°-panorama taken at 3950 m from the valley head of the Satpare Lungma on the NNE-margin of the Deosai plateau (left half of the panorama) (35°05′ 25″ N/75°33′ E) from facing S up-valley (↗) via WNW onto a 4430 m-high rock head (◓ white centre) via N down-valley (▽) up to E into the orographic right valley flank (◓ white on the very right and left) with its 4580 m-high culmination (below 0 – –). (■) are ground moraine covers and -remnants preserved in many places. They can be diagnosed on the Deosai plateau (second ■ from the left) as well as in separate positions on ledges of the valley flanks (the left ■ below – – fine on the right) and on the bottom of a hanging valley (the right ■ below – – fine on the right) as far as altitudes of 4000 to 4400 m. At some other places on the slopes the ground moraines are overlain by postglacial local debris of crumblings (▽). (■ on the very left) is ground moraine marginally dissected by down-slope removal; its fine material matrix has been flushed out more heavily (⇓). Owing to this, the remnant of ground moraine cover in between emerges as a segment of a stretched slope with an edged lateral boundary (■ between the two ⇓). (◓) are glacigenic abrasions and -roundings in the metamorphic sedimentary rocks and schists (phyllites) outcropping here, which have been strongly roughened by physical weathering since deglaciation. This results in a picture of a prehistoric erosive glacial landform as can be met in the European Alpes at the St. Bernhard Pass (San Bernardino) or in the Norwegian mountains at Sulitielma (near Fauske). (◓ second from the left, black) marks a glacigenically rounded rock threshold ; (↗↖) are two ravine-like talwegs through which the Satpare river flows down and which have been cut by subglacial meltwater erosion into the rock threshold. This can be suggested because of ravine forms sharply inset into the bedrock, which are set off in an upward direction with their working edges against the round abrasion forms. In addition, the two talwegs, from which the orographic right (↗ on the left) sets in several metres higher, argue in favour of a subglacial development, because meltwater tunnels in the ice make this difference in height possible. Terminal moraines and dumped end moraines are lacking in this large-scale, very clean landscape which is poor in accumulations. The latter are absent, because the ice which flowed down from the Deosai plateau had no surface moraine cover; there were no conditions for its development, i.e. the supply with ice avalanches as a result of the steep relief, usually the norm for the Karakorum, was lacking. (– –) is the minimum height of the Ice Age (LGM = Stage 0) glacier level between c. 4500 and 4850 m. Here, in its upper reaches, the Satpare Lungma accordingly was completely filled with ice. Photo M.Kuhle, 3.8.2000.

← *Photo 163*. At 3930 m asl in the centre of the Deosai plateau (35°00′ 32″ N/75°24′ E) from facing NNW (left margin) via NNE (on the right of No.75 = 5322 m-peak) up to ENE (No.77 = 5321 m-peak). No.78 is the 5339 m-peak massif, the 5205 m-high NE satellite of which is visible here. (– –) marks the LGM glacier level about 4800 m asl (Fig.48) reconstructed with the help of the hill landscape showing an uninterrupted glacigenic abrasion (◓: glacially streamlined hills) with ground moraine covers on the slopes (■ background). (■ foreground) depicts this ground moraine in detail: it concerns boulder clay consisting of facetted to rather well-rounded boulders, in size up to 2.2 m (○) which, isolated from each other, "float" in a clay-containing matrix (■). They are made up of metamorphic silt-stones and quartzites; in part they have iron manganese crusts. On boulder surfaces of this type, traces of erosion as e.g. desquamation (←) do occur. Photo M.Kuhle, 3.8.2000.

← *Photo 162.* Panorama across the Deosai plateau, taken at 4000 m asl from the gravel plain (□ black) of a mountain river flowing down from the north-eastern marginal chains of the plateau (No.75 = 5322 m-peak) to the S (35°04′ 20″ N/75°29′ 30″ E): from facing SW with the 4812 m-high Asmor (No.81) and the 4608 m-peak (No.82) via W with the 4969 m-high Barsri (No.83) and NW with the 5339 m-peak, the 5205 m-high NE satellite of which is visible here (No.78), as far as N (right margin). This is a high plateau landscape on which a low mountain range is set, showing a vertical distance of 600 to 1300 m. (○) is a trough-shaped, cirque-like valley head belonging to a valley bottom which is adjusted to the high plateau. For the last time it has been formed after the LGM, i.e. during the Late Glacial Stages III and IV, when the glacier cover had already heavily melted-down (cf. Tab 1). (▽) are trough-shaped, i.e. typically glacigenic cross-profiles of high valleys. (◓) mark glacigenically abraded and partly polished mountain ridges (◓ on the very left) as well as glacially streamlined hills. They are covered with ground moraine over large areas (■); this consists of polymict, in many places erratic, i.e. far-travelled, round-edged, and hence facetted boulders (see Photo 163). A few quartzite boulders, the size of a fist up to a head, are striated. Figures 23 and 6 (No.17) provide evidence of the glacigenic character of their matrix. Ground moraines (■) and abrasion forms (◓) testify to a thickness of the plateau ice of 600 to 800 m on average (Fig. 48-50); the corresponding LGM-glacier level (– –) ran about 4800 m asl. (□ white 2) is the highest, up to 15 m-high glaciofluvial terrace body (gravel field Dhampu Stage No.2; Tab.1); (● 1) is the next younger, at most 5 m-high, and also still Late Glacial terrace body (gravel field Sirkung Stage No.1), (□ black -0 to -8) is the Holocene gravel floor body from the Neoglacial (Nauri Stage V) up to the present (Stage XII) (see Tab 1). These gravel fields have been made up from dislocated and at the same time outwashed Ice Age to Late Glacial moraine. Photo M.Kuhle, 3.8.2000.

↓ *Photo 166.* Panorama at 4070 m asl from the western central region of the Deosai plateau (34°59′ 30″ N/75°19′ 05″ E) from facing E (left margin) via N (middle) up to W (right margin). No.84 is the 5193 m-peak, No.81 the Asmor (at 4812 m it is four metres higher than Mt. Blanc) and No.82 the 4608 m-peak. A hill landscape with glacially streamlined hills (the two ◓ on the left), roches moutonnées and glacigenic polish thresholds (the two ◓ on the right), nearly completely covered by ground moraine (■) with large, partly erratic (granite) boulders (e.g. ▲) lying on the surface, extends from the fore- to the background. (Below ⌒) a further polish threshold occurs, over which the High Glacial ice transfluence into the W-adjacent valley system of the Khilin Gah has taken place. The streamlined hills tower a good 300 (◓ on the left) up to c. 560 m (◓ white) above the level of the corresponding neighbouring high valley bottom. The ground moraine on their slopes, which further down has been deposited at a greater thickness, is dissected by flat flushing rills (▽ white) up to a depth of several metres. At their lower ends small alluvial fans (△ black) provide evidence of the minor masses of fluvial material which at the same time has been fluvially removed. (0 – –) is the LGM (Stage 0, Tab.1) glacier level about 4800 m asl, locally reconstructed with the help of ground moraines with and without erratics and abrasion features (cf. Fig.50). Photo M.Kuhle, 3.8.2000.


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← *Photo 165.* Panorama taken at 4050 m asl from the centre of the Deosai plateau (35°00′ 30″ N/75°20′ 45″ E) looking from facing S (left margin) via WSW down-valley (⌃), toward NNW up-valley (half right) up to NNE (right margin). No.78 is the 5205 m-peak of the 5339 m-massif. (○) are erratic boulders, among them far-travelled granite blocks with longitudinal extensions of 2 to 3 m (e.g. the first and second ○ from the left). These boulders are facetted, i.e. round-edged; the smaller ones are even rounded, but, owing to radial cracks, they are partly broken in situ, i.e. post-sedimentarily (second ○ from the left). Sedimentary rocks, as e.g. schists, outcrop in the underground. (■) are ground moraines on which these large boulders lie, whilst the smaller ones, which are fist- to head-sized, are increasingly embedded in the fine matrix as moraine boulders, isolated from each other. (As a rule, the large boulders are increasingly forced out of the material formation and thus come to the surface. See Kuhle 1991b:128-130). The 400 to 600 m-high low mountain relief here - which is similar to a Scandinavian fjell-landform - is completely covered by ground moraines (■) with a thickness of metres to decametres. Where the thickness of the covers decreases, i.e. in the direction of the hill-tops, glacigenic abrasions are evident (◓). (□) marks the valley bottom from glaciofluvial gravels and boulders which have been residually washed out of the ground moraine since the Late Glacial deglaciation, i.e. at postglacial times, and so have been cleared of the moraine matrix in situ and condensed on the spot. (0 – – and – –) is the large-scale reconstructed LGM-glacier-surface at c. 4800 m asl (cf. Fig.49 and 50). (⌃) was a then ice transfluence over the W edge of the Deosai plateau into the orographic right (E) source branch of the Das Khilin Gah and thus to the Astor valley system and the Nanga Parbat-massif. Photo M.Kuhle, 3.8.2000.

← *Photo 167.* This panorama was taken from the W-margin of the Deosai plateau at 4180 m asl, looking over the Scheosar Tso (lake) (34°59′ 58″ N/75°14′ 22″ E) from facing ESE (left margin) via SSW (middle) up to WNW (right margin). No.84 is the 5193 m-peak. Rock thresholds and classic roches moutonnées (◓) fringe the lake basin as a classic polish depression. The high valley in the background shows a glacigenic trough-shape (▽). (■) are parts of a ground moraine cover, displaced near to the surface and dependent on the slope by solifluction processes on the roches moutonnées. The ground moraine contains erratic gneiss- and granite boulders (○), which because of their round-edged to rounded forms cannot be mistaken for slope debris weathered in situ; the matrix is unambigously glacigenic (Fig.24 and Fig.6 No.18) The LGM-thickness of the ice has decreased from E to W in the direction of the 4266 m-high transfluence pass (⌃) leading over to the Das Khilin Gah, because beyond its transfluence the ice flowed down steeply toward the WNW. Accordingly, the ice level (– –) has undergone a loss in height from c. 4750 m on the left (cf. Fig.50) to c. 4450 m asl on the right (– – ⌃). The roche moutonnée at the pass (◓ white) has forced the overflowing glacier ground upwards to c. 4320 m asl, so that crevasses might have been developed there; potholes, however, have not been found. Photo M.Kuhle, 3.8.2000.

← *Photo 169.* At 3300 m asl, panorama taken from the orographic right flank of the Das Khilin Gah (main valley) (35°03′ 20″ N/ 75°05′ 10″ E), 2.4 km down-valley of the Jidim settlement, looking from facing SE (left margin) up-valley, via SW into the left valley flank (middle) up to WSW (right margin) into a left trough-shaped side valley (▽). Fig.51 shows the same valley cross-profile. No.81 indicates the position of the 4812 m-peak and No.82 that of the 4608 m-peak (cf. Fig.2/1); the peaks themselves, however, are not visible from here. The viewpoint is on an orographic right ground moraine body (■ on the very left and right below) which contains facetted, polymict boulders up to several metres in length (above ■ on the right below). (□ on the left) is the river, which in postglacial times (since the deglaciation) has condensed the ground moraine on the bottom so that a valley floor has been made up with a surface rich in boulders and gravels (□ right); the matrix is silty-sandy. In some places the ground moraine has been dislocated by mudflow dynamics to form small mudflow fans (▷ black). (◁ white) is a debris cone the surface of which is covered by rock crumblings; its core, however, consists of buried ground moraine. (○) mark Late Glacial cirque-, i.e. nivation depressions. The orographic left moraine ledge (second ■ from the left) has partly been dissected and removed by their meltwaters (▼); (■ white and black on its right side) are ground moraine remnants in situ, in parts characteristically patterned by gully washing (↑ ↑) since the deglaciation. In an upward direction this ground moraine slope peters out into a Late Glacial lateral moraine terrace (III) of the Dhampu Stage (III, see Tab 1). (◓) are relics of the High Glacial abrasion which are relatively well-preserved in the form of roundings of the rock shoulders (◓ white and black on the right). (– – black and – – white 0) is the corresponding LGM-ice-level at 3900 m (on the left) and 3700 m (cf. Fig.51). Photo M.Kuhle, 3.8.2000.

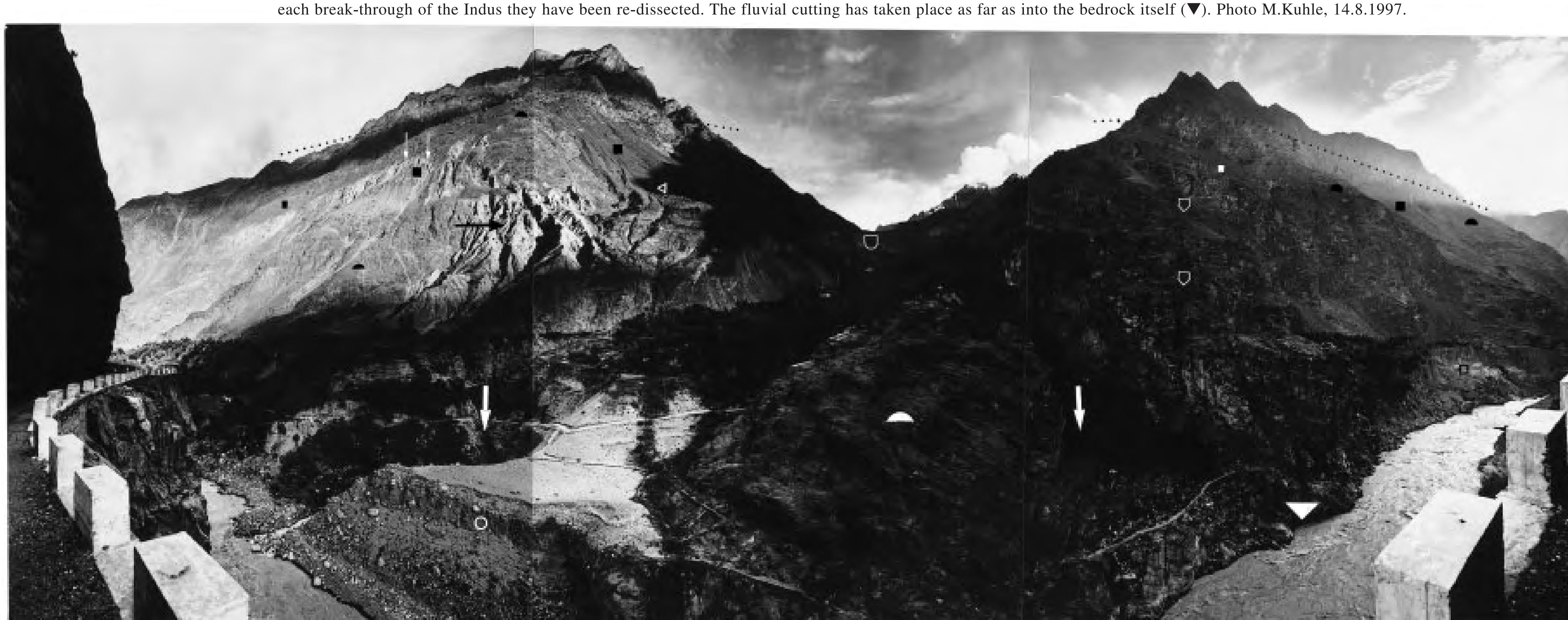
← *Photo 168.* Panorama taken at 3880 m from the orographic right (E) source branch of the Das Khilin Gah (valley), c. 9 km up-valley of the Jidim settlement, from the orographic right valley flank (35°00′ 55″ N/75°12′ E) looking from facing ENE (left margin) up-valley, via S into the left flank (⇩) up to NW into the right flank down-valley (right margin). No.81 indicates the position of the 4812 m-peak, No.82 that of the 4608 m-peak, No.86 that of the 4843 m-peak and No.85 marks the position of the 4848 m-peak (cf. Fig.2/1); the four peaks themselves are not visible from here. (◓) are glacigenic abrasion roundings and polishings locally crumbled away (⇩). (■) are two types of moraine accumulations: a.) ground moraines which have also survived in higher slope positions (■ on the right, below ▽ , ■ on the very right, above) and b.) Late Glacial lateral- (■ IV = Sirkung Stage, see Tab.1) and end moraines (■ on the left of the right ▢). The moraines are made up from a boulder clay with large (up to 2.5 m-long) polymict, edged to round-edged boulders (○); the granite boulders are the largest. Gullies (▽), developed by the seasonal snow-meltwater, dissect the ground moraine on the slopes; more or less intensive slides also occur in it (↓). (▲) is a “tor”, i.e. a c. 15 m-high rock-tower of granite, carved out of the valley ground as a sharp “riegel” (barrier mountain) and preserved despite the glacigenic ground scouring. (▢) mark valley cross-profiles with a clearly glacigenic trough character. (– –) is the minimum height of the Ice Age (LGM = Stage 0) glacier level between c. 4450 m (– – fine, half-left) and 3900 m (– – half-right, down-valley), reconstructed with the help of the abrasion forms (◓). (0 – – and – – above ▽ and on the very right) are locally higher prehistoric glacier levels above mountain ridges. Ice influx has taken place through a transfluence over the western marginal threshold of the Deosai plateau (Photo 167) at (⌃). Photo M.Kuhle, 3.8.2000.

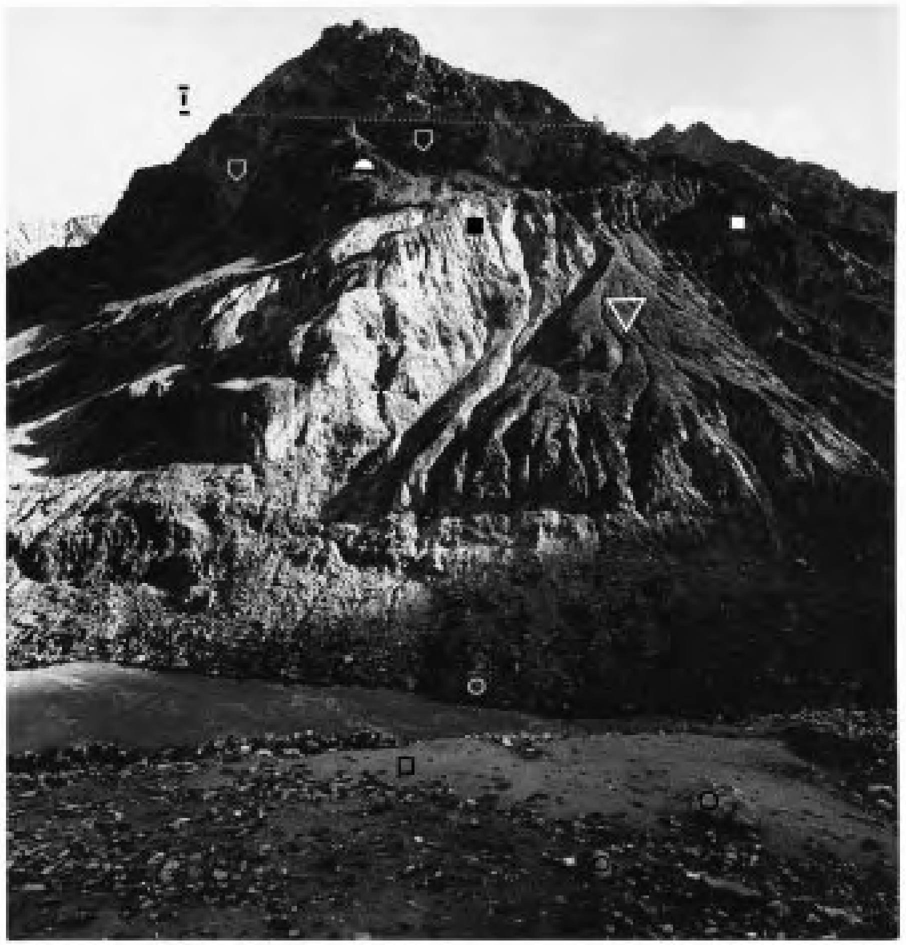
← *Photo 171.* Panorama taken at c. 2200 m asl looking down the Indus valley, just 300 m above the Indus (◇), from the orographic right valley flank (35°35′ 16″ N/75°20′ 24″ E) between the Tungas (Tamas) settlement in the E and Dasu (▽ white) in the W near the police station at Thowar Rondu: from facing SW (No.88 = 5450 m-peak) into the left Indus valley flank, via W (centre) down-valley as far as NW (right margin) with the terraced irrigation fields of the Dasu settlement (▽) and the exit of the Tormik Lungma. The orographic left side valley joining from the right below No.88 is the Trik Lungma from the 5450 m-peak N-flank, the valley head of which currently is still glaciated; its mouth shows a trough cross-profile (between the second – – and third – – from the left). (▢) is the glacigenic trough profile of the Indus valley depicted in Fig.53. (■ large) is the ground moraine on the valley bottom being at least 50-60 m-thick; in places it even reaches over 100 m (■ large, middle). At some places steep furrows have dispersed it into pre-forms of earth pyramids (▼ white). Obviously, the Last Glacial (LGM- to early Late Glacial Stage I-) glacier (cf. Tab 1) has also overridden the material of interglacial rock avalanches, so that it has been covered by ground moraine (■ large on the left). (■ small) are the highest ground moraines reaching up to 3150 m asl, c. 1250 m above the valley ground. Fig.53 (right side of the Indus valley) represents the moraine material on the orographic right valley flank (■ small on the right). (▲ black) are further furrows and pre-stages of earth pyramids. Here, too, the involvement of rock avalanche material cannot be excluded. (▷ black) are debris tali deriving from the rock wall above, which has been crumbling away since the deglaciation. (◓) mark rock forms, which have been glacigenically abraded through ground scouring and shaped like roche-moutonnées (◓ on the left and right; especially ◓ on the right), as well as flank polishings (◓ centre), the upper line of which indicates the polish limit of the LGM glacier level at 3150 m asl (– –), so that a thickness of the Indus glacier of c. 1200 m could be reconstructed here. (▽ white) can be interpreted as a ground moraine pedestal of the orographic right side glacier from the Tormik Lungma; a corresponding ground moraine pedestal on the orographic left is situated in the junction of the Trik Lungma (on the left above ▢). Photo M.Kuhle, 11.7.2000.

→ *Photo 173.* At c. 1670 m asl, NW down-valley of the Changmachhu locality, 2.5 km up-valley of the valley cross-profile Fig.54 (35°41′ 40″ N/74°54′ 28″ E), looking up the Indus valley: from facing NE (left margin) into the junction of the orographic right side valley (⛉) with the 5090 m-peak (No.89), the N-crest of which mediates to the 6050 m-peak (on the left outside the panorama), via SE (centre) up the Indus as far as S and SSW (right margin) looking into the left Indus valley flank. (■) has been approached as a ground moraine ledge, i.e. a High- (LGM) to Late Glacial ground moraine body, fluvially undercut by the main- and side valley talweg, i.e. worn down or displaced by landslides and debris flows (△ black) during the postglacial period. Indications as to an alternative approach as rock avalanche have not been found. The roots of earth pyramids (←) have, however, also been observed in sediments of rock avalanches. 300 to 400 m above the Indus river, the ground moraine (■) which, according to its increase in thickness towards the talweg shows the characteristics of a pedestal moraine, clings to the polished rock slopes above (◓ black, small). Owing to this, trough cross-profiles (⛉) have been developed, which are especially clear in the side valley. (⇩ black) is a mountain spur, which has been polished back, i.e. a glacigenically triangular-shaped slope, showing fresh crumblings. (⇩ white) is a cleft-dependent crumbling rill in the gneiss bedrock (◓ white on the right), which, adjacent to it, has been glacigenically abraded (◓ white on the right). (△ white) marks an active debris cone with a mantling of the debris of crumblings; (◓ on the very left) are relatively intact abrasion faces. (◓ on the right margin) is a roche moutonnée undercut by the Indus. (□) show fluvial sands, pebbles and gravels. The classically glacigenic polish bands (◓ black, small) reach their polish line (– –) at somewhat over 3100 m. (▼) are flat, subglacial meltwater rills of a cirque glacier (situated in the area of – – on the left), which have reshaped the High Glacial polish ground (◓ on the left below ▼) during the Late Glacial. Photo M.Kuhle, 14.8.1997.

← *Photo 170.* At 2150 m asl, panorama taken from the orographic right river side of the Indus (5 m above its high-water level), 2 km WNW of the lower end of the Skardu Basin, i.e. the Indus bridge near the Bragardo settlement, at the upper start of the Indus gorge stretch (35°27′ 43″ N/75°26′ 30″ E), down-valley of the rock avalanche (□), which Hewitt (1999, pp 223-228, Fig.4-6) has described as "Kazarah rock avalanche" (cf. Photo 154): from facing E (left margin) up-valley, via SW (centre) with the mountain ridge (⇩) rising from the left, from 3886 m, to the right up to 4727 m, diagonally down the Indus, as far as WNW into the orographic right flank of the Indus valley (right margin). (◓ black on the left) is the orographic right, glacigenically abraded flank of the Skardu Basin from Bragardo up the Indus (near the left margin in Photo 154); (◓ white) are further glacigenically rounded and smoothed massive-crystalline rocks on the orographic right Indus valley flank; (◓ black on the right) show corresponding abrasions on the opposite valley flank, reaching up to (– – I) and, even more heavily roughened, up to (– – 0); (– – on the left and – – 0) is the LGM-glacier-level about 3300 m; (– – I) is that of the Late Glacial Ghasa Stage (I, Tab 1) about 2900 m asl. (⇩) marks a rock wall, which, in dependence on the clefts, has heavily crumbled away since the deglaciation; (△ white small on the right) are the pertinent debris cones derived from rock fall, which probably contain ground moraine remnants which they have carried along and which cover the ground moraine lying beneath. (□) shows the rock avalanche ("Kazarah rock avalanche" see above) emerging from the orographic right Bragardo Lungma, which has dammed-up the Indus valley bottom. The Indus river, flowing here with a water volume of c. 500 m^3/sec on average (at the time when the picture was taken it flowed an extreme summer-high-water after heavy rainfall during the night to August 1st, 2000), has already cut the rock avalanche by an over-spill of c. 50 (□ black) to 120 m (□ white) in depth, and at the same time has removed its fine material and compacted the coarse boulders, so that a terrace has been developed (▼). (■) is ground moraine the matrix of which is rich in clay, with polymict, partly rounded boulders in the erosion shadow of the half-eroded remnant of a roche moutonnée (◓ on the very right); (▽ white on the left and ▽ large) is moraine, dislocated downslope through debris flows from the here a good 3000 m-high right Indus valley flank, which stretches steeply up to the currently still glaciated 5220 m-peak, a SE-satellite of the 5770 m-peak (Fig.2/1 No.72). (▽ white, large) shows a debris flow, which had moved down 35 minutes before the photo was taken. Here, between the Skardu Basin and the inflow of the Gilgit river, 28 debris flows have moved down into the Indus valley during this night, blocking the road for ten days. This is an example of the extremely active postglacial displacement of moraine material. (○ foreground) marks a well-rounded granite boulder; (◇) is a practically unmoved, edged gneiss boulder and (○ middleground) are round-edged gneiss-, i.e. granite boulders - a mixture of dislocated rock fall-, moraine- and finally also debris flow material which is representative of the steep relief. Photo M.Kuhle, 1.8.2000 at 7 o'clock in the morning.

↓ *Photo 172.* Panorama at c. 1800 m, 110 m above the Indus, from the orographic right Indus valley flank (35°35′ 58″ N/75°04′ 28″ E) opposite the Tulu settlement (above ↓ white large, on the left), below the junction of the orographic left side- and hanging valley, a trough valley ('Tulu Lungma') leading down from the 5524 m-peak to the N, the valley head of which is currently still glaciated (⛉). Taken from facing SSE (left margin) up the Indus valley, via SSW to the hanging trough valley (⛉) up to NNW down the main valley (right margin). (◓) are orographic left glacigenic flank abrasions, part of which occurs on banking edges (◓ right half of the panorama). Due to crumblings they have been roughened more strongly there (⇩) since the deglaciation. In an upward direction the abrasions (◓) peter out into a classic polish line about 3150 m asl, c. 1400 m above the current valley ground (– –). In many places these Ice Age glacigenic faces of flank polishing (◓), which at the same time are typical triangular-shaped slopes (◓ left half above), are covered with ground moraine up to decametres in thickness (■). Their highest occurrence has been observed at nearly 3000 m (the three ■ on the right). Characteristic slides of ground moraine (↓ small), as they are wide-spread in the prehistorically glaciated Karakorum, have taken - and still take - place, where the ground moraines are thickest. The quite fresh break-out (↓ small) shows the characteristic structure of a downthrow. The ground moraine is the thickest on the confluence spur of the side- to the main valley, where furrows, and now also earth pyramids, are in the process of development (→ black). (▽) is a debris fan from dislocated ground moraine, on to which a rock fall with large, edged boulders has collapsed. (↓ large) indicates two ravine-like side valley talwegs, steeply eroded into the bedrock. One of them (↓ large on the left) is still currently active, draining the side valley (⛉). Probably it has syngenetically dissected the ground moraine pedestal at the exit of the side valley. The other one (↓ large on the right) is non-active. It has only been eroded as a subglacial meltwater rill and then fallen dry after deglaciation. (○) marks a gravel terrace and (□) are limnic sediments which are embedded into a debris fan, built-up of dislocated moraine material. Both, the gravel and the limnites, have been heaped-up as subrecent to recent fluvial, i.e. glaciofluvial sediments (outwash) in the Indus valley, which, during Holocene to historic times, was temporarily blocked by rock avalanches or debris flows. After each break-through of the Indus they have been re-dissected. The fluvial cutting has taken place as far as into the bedrock itself (▼). Photo M.Kuhle, 14.8.1997.

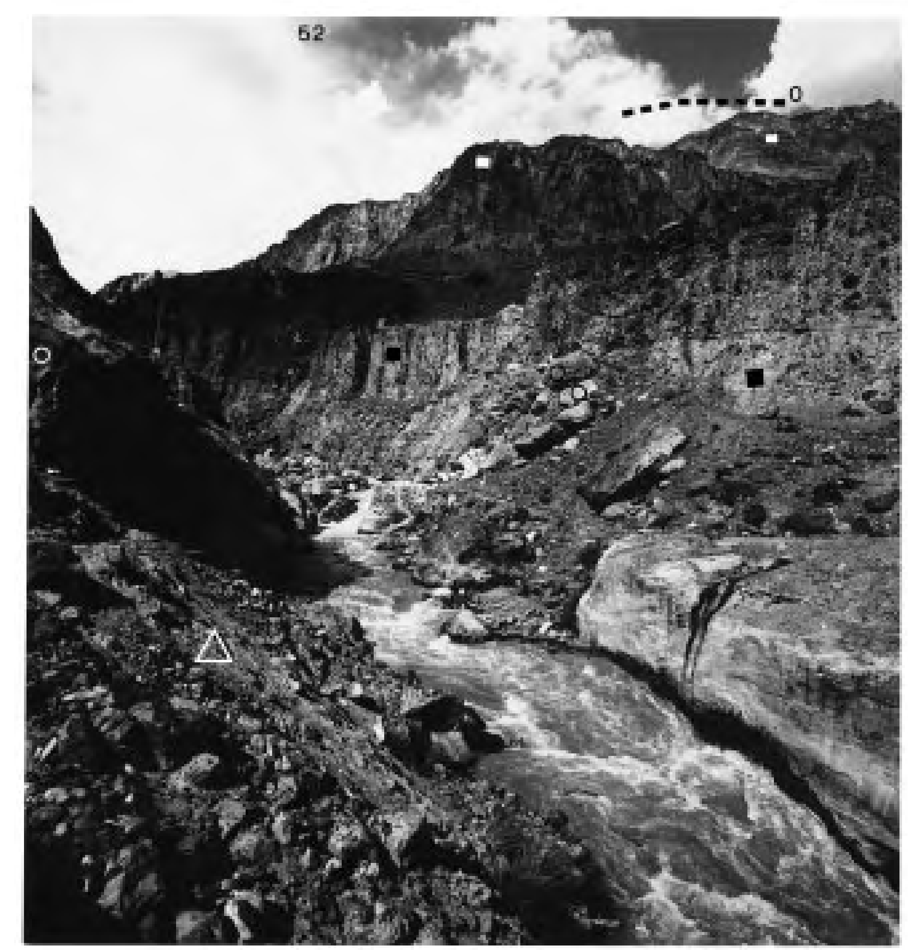




← *Photo 174.* Taken at 1680 m asl from the orographic right side of the Indus valley (35°42′ 32″ N/74°51′ 25″ E) opposite the junction of the Bulache Gah, 3 km down-valley of the Indus valley cross- profile Fig.54, facing SE into the left flank. (◓) is rock, rounded by abrasion at c. 2250 m, 600 m above the Indus (below ○ white); adjacent to it, these roundings have been destroyed by crumblings (⇩). (– –) marks the highest prehistoric glacier level of this Indus valley cross profile, verifiable by abrasion traces (◓); it might belong to the Late Glacial Stage I (Ghasa Stage, Tab 1). (■) are deposits of ground moraine in the flow shadow of the High Glacial (LGM) Bulache Gah glacier inflow into the Indus parent glacier. This orographic left side glacier flowed down from the 5569 (or 5559) m-high massif, which is currently still glaciated and forms the dividing crest to the SW-adjacent Astor valley (cf. Kuhle 1997:131/132 Fig.28 on the right of No.46). (▽) is a ground moraine wedge, which, after the abutment had melted, slipped down, and now - like the rest of the moraine surfaces - is becoming furrowed. The ground moraine is basally undercut by the Indus (■); (○ white) is a round-edged boulder, which, farther up-valley, has been rinsed by the torrential suspension water of the Indus and transported here. It lies only temporarily (up to the next prominent high water peak) on this very unstable talus slope (= debris slope with a maximum steepness). (□) shows the surface of a fluvial Indus terrace made up of sands, pebbles and metres-long rock fall- or moraine boulders, rinsed in situ or fluvially dislocated (○ black). Photo M.Kuhle, 14.8.1997.

→ *Photo 175.* At 1580 m asl from the orographic right flank near the Shengus Gali locality (35°42′ 51″ N/74°45′ 25″ E) seen facing E up the Indus gorge. (■ black, large) are accumulations of ground moraine up to decametres in thickness on the NNE slopes of the cross-profile Fig.55. Owing to its important thickness near the talweg of this gorge-stretch (■ black, large on the right) could be misinterpreted as debris of a rock avalanche. However, it is a remnant of a ground moraine pedestal in the glacier flow shadow behind the round-polished rock rib (◓ black). (⛉) marks the glacigenic trough profile, situated above the narrow gorge stretch (▼) near the talweg. (◓) are the glacigenic abrasion roundings reaching up to c. 3150 m and providing evidence of the Indus glacier level (LGM) (0 – –), so that a 1600 m-thick ice minus the height of the pedestal moraine is verifiable. (■ small) are the highest deposits of moraine. Here, too, a misinterpretation as rock avalanche debris can definitely be ruled out, because they are situated at a height of c. 800-1000 m above the Indus talweg and show a solid overlay of loose rocks on the 30 to 40°-steep slopes. (◁) is moraine material, dislocated by spring erosion, slope flushing and debris flow; (○) are polymict boulders metres in size, washed out of the moraine- and moraine-slope debris by the Indus. (⇩) is one of numerous rock crumblings as a function of the steepness of the walls. Photo M.Kuhle, 14.8.1997.

← *Photo 176.* 2 km down-valley of the cross-profile Fig.56 at 1540 m asl, from the right side of the Indus near the Burumdoir locality in the junction area of the Khalota Gah (35°46′ 05″ N/74°45′ 42″ E) facing SSW looking up the Indus valley. (■) mark the ground moraine cover of the eastern valley flank (Fig.56), which in part is many decametres-thick and reaches up to 2650 m. However, Hewitt (1998:4 Fig.1 No.96) has here recorded in his general map a “rock avalanche”. The steep moraine surfaces are furrowed by characteristic microfluvial-rills. (◓) are rounded, glacigenic abrasion forms, which in many places are still covered by ground moraine. (△ on the left above) is a debris cone adjusted to the ground moraine surface, and therefore recognizable as a post-High Glacial accumulation. (– –) indicates the LGM-glacier-level at somewhat above 3100 m. (⇩) marks rock crumblings; (△ on the right below) is ground moraine undercut by the Indus, which slides down as a talus slope. (The author agrees, if Hewitt considers this place as being the locality of his “rock avalanche”. In addition, the very thick ground moraine overlay (■ black) is in the process of a typically slow (see above) landslide since the deglaciation and the loss of an abutment connected to it). Round-edged to rounded polymict moraine boulders (○) the size of metres, washed-free or dislocated, lie on - or are embedded into - an alluvial floor of the Indus (□). Photo M.Kuhle, 14.8.1997.



↑ *Photo 178.* Panorama taken at 1440 m asl from the junction of the Phuparash Lungma and Phuparash river (foreground on the left) (Photo 177) looking from the orographic right side into the Indus main valley (35°51′ 10″ N/74°44′ 55″ E): from facing E up the Indus with the 5324 m-high Godoy-Gali-peak (or Godeli, No.90) on the W-crest of the Haramosh (7397 or 7409 m; Fig.2/1 No.53), via SW to the orographic left mountain spur (centre, to the right) and WSW down the Indus (U small) as far as W again into the right Indus valley flank (right margin). (■) are ground moraine covers, i.e. - remnants which can be evidenced on the slopes as well as on flat ledges and near the valley floor. In many places they overlie glacigenically polished rock bottoms (first and second ◓ from the left) and rounded remains of barrier mountains (“riegel”), shaped like roches moutonnées (second ◓ white from the left); but also glacigenic abrasion forms without a moraine overlay (the four ◓ from the right) have been observed. The Indus valley cross-profile (U small) as well as the concave polish form, still cloaked with ground moraine, situated between the roche moutonnée and the left Indus valley flank, show a typically glacigenic trough-form (U large). (▲) is moraine, the round-edged boulders of which have been compacted through their downslope displacement. Intercalated rock falls have also been met. (○ white) is a c. 14 m-high historic, fluvial terrace of the Indus. (△) marks sediment of moraine and then debris flow from the Phuparash Lungma, dislocated many times. It also contains polymict, edged and rounded boulders up to several metres in length, and will be taken in by the Indus with the next high-water. (– –) is the maximum prehistoric glacier level at somewhat over 3100 m, reconstructed with the help of remnants of ground moraine and abrasion roundings. (○ black) is a present-day W-exposed cirque glacier below the Godoy-Gali-peak (or Godeli No.90), which reaches down to c. 4650 m asl (orographic ELA = 4900 m; climatic ELA = 4800 m). Photo M.Kuhle, 14.8.1997.

← *Photo 177.* At 1440 m asl, N of the Sassi settlement, looking from the Indus valley (Photo 178) (35°51′ 10″ N/74°44′ 55″ E) into the orographic right tributary valley, up the Phuparash Lungma, taken towards the NNE (No.52). (■ black) is basal ground moraine material containing rounded, polymict boulders the size of metres. Two layers of ground moraine are concerned here: (■ black on the right) is that in the underlying bed, (■ black on the left) that in the hanging layer. Above them are further ground moraine layers (■ white) into which numerous rock falls might be incorporated, so that it is not always possible to distinguish between them and the moraine. Additionally, in many places the moraine material could have slid down or been tipped over since the deglaciation. (○ black) are two round-edged boulders of light granite (○ black, below) and dark phyllite (○ black, above) which originate from an upper moraine layer (■ white) and have been tipped over downslope. (○ white) marks a bank of sedimentary bedrock, showing remnants of a pothole wall, i.e. flush bowls of the Phuparash river. (△) is prehistoric moraine material, which has been undercut and thus slides downslope. (– – 0) indicates the highest verifiable, probably High Glacial (LGM = Stage 0) glacier surface at a good 3100 m asl at the up-valley mountain spur in the confluence area of the Phuparash Lungma and Indus valley (see Photo 178 left margin). The talweg of the side valley has been dissected so steeply that, despite a glacier filling which was about 1500 m thick, no trough-profile has been developed but rather a glacigenically V-shaped valley. No.52 indicates the position of the Malubiting (7453 m) at the valley head, the summit of which is not visible from here. Photo M.Kuhle, 14.8.1997.

↑ *Photo 179.* Panorama taken at 1420 m asl on the orographic right side, c. 50 m above the Indus river (35°49′ 50″ N/74°39′ 40″ E), 2 km NE of the Shuta locality : from facing E (left margin) up the Indus valley with the Godoy-Gali-peak (or Godeli No.90), via SSE (centre) into the orographic left valley flank as far as SW (right margin) down-valley. The view up-valley shows a trough-like valley cross-profile (▢), the concave form of which has been glacigenically widened (see also Fig.57), with decametres-thick mantlings of moraine (■ black) on to which rock avalanches (□) have come down since the deglaciation. Where the loose rock is placed in apposition to the glacigenically abraded rock (◓ on the left), fresh cone forms (▷ on the left) are situated. They consist of displaced ground moraine (■ white on the left, still in an original high position, i.e. in situ) transported down from the wall high above, but also of the debris of crumblings. Corresponding cone forms (△ middle of the panorama) of dislocated ground moraine (the three ■ on the right) are adjusted to a remnant of the Indus terrace (○). (■ white, large) shows dark ground moraine, which occurs adjacent to light ground moraine (first ■ black from the right) on the orographic left flank. It is more heavily dispersed into earth pyramids than the light one. The ground moraine (■) lies on abraded rock faces, which are in part also polished (◓ small). (◓ large, foreground) is perfectly preserved glacier scouring with a polish in fine-crystalline gneiss and fine-grained quartzite; a ferromanganese crust has developed on its surface. (— —) is the LGM-glacier-level at c. 3100 m asl, reconstructed according to ground moraines and flank abrasions. Photo M.Kuhle, 14.8.1997.

← *Photo 180.* Panorama at 1420 m asl, 2 km NE of the Shuta locality on the orographic right, 50 m above the Indus talweg (35°49′ 50″ N/74°39′ 40″ E), looking facing N up the valley slope. In the foreground below is the road, blasted into the rock slope of gneiss (the shady band below is the 1.5 m-high wall created by the blasting). (◓) is one of the numerous rounded knobs, which, under the high pressure of the ice burden and with a water film on the glacier ground, has been polished out by the Ice Age Indus glacier. Due to its banking, the rock face is horizontally grooved. Besides its rock-polish, shining in the sunlight, separate flush bowls (▽), too, point to the presence of hydrostatically confined water under the polishing glacier. (◓) indicates by its flat scour slope and steep lee slope an ice stream direction from the right to the left, following the Indus valley. These processes of detraction, dependent on regelation, could attack on the vertical release joints in the gneiss. Orientated to an only centimetres-thick ferromanganese crust, the rounded rock faces splinter-off concordantly (▼). This process has to be described as exfoliation. The glacier polish reaches 400-500 m-high up the valley flank. However, with increasing steepness, it has been more and more damaged by crumblings (⇩). (— — fine) is the highest prehistoric glacier surface about 3100 m asl, evidenced by abrasion roundings. (— — bold) runs at an altitude of c. 2000 m, above the culmination of the glacially streamlined hill (⇩ on the right) over which the ice must have flowed. This minimum height of the ice level is locally verifiable by the rounded mountain ridge. Photo M.Kuhle, 14.8.1997.

↑ *Photo 181.* At 1390 m, panorama taken c. 80 m above the Indus from the orographic right valley slope (35°47′ N/74°37′ 21″ E), 0.5 km E of the Jigi Gali locality: from facing NNW (left margin), via NE (centre) up the Indus valley, as far as SE (right margin) looking down-valley. (○) is the lowest, here c. 50 m-high, fluvial Indus terrace, which can be followed over a length of at least 17 km from the Sassi settlement as far as the inflow of the Gilgit river (cf. Photo 178 and 179). Up to the highest terrace level (□) at 1520 m asl, i.e. 210 m above the Indus river, two further fluvial terrace levels are interposed (between □ and ○). The highest terrace mantles glacigenic roche moutonnée forms (◓ on the left and right below □) in gneiss bedrock. (⊔) is the cross-profile polished to a trough in the lower section of the Indus gorge, 8 km above the inflow of the Gilgit river. (◓ white on the left) indicate abrasion forms on the outcropping edges of gneiss-strata crumbled away in many places (⇩); the edged crumbling debris (▼) develops coarse-blocky tali, covering basal ground moraine layers (■ black). Active cones of debris flow come out from larger rills (▷). However, ground moraine (■ white on the left) lies also as far as close to the glacier polish line (— — left half). (The three white ■ from the right) are ground moraine remnants in higher positions on the orographic left; they partly cover glacigenic abrasion faces of the bedrock (the three ◓ from the right) up to a thickness of decametres (e.g. ■ on the very right), the upper margins of which testify to the prehistoric ice level (— — white on the right). These ground moraines are currently dissected to rills by the down-flowing water (■ below — — white and black on the right). Photo M.Kuhle, 14.8.1997.

← *Photo 182.* Panorama at 1470 m altitude, c. 180 m above the Indus (□) from the confluence spur between the Indus- (from the left) and Gilgit river (from the right) (35°45′ 24″ N/74°37′ 42″ E), 3.5 km SSE of the Jigi Gali locality: from facing E (left margin) via S (⊔) down-valley up to SW (right margin) looking into the orographic right Gilgit valley flank. (○) are the four levels of river terraces known from Photo 178, 179 and 181 (○) up to c. 200 m (○ white) above the Indus (□). (▽) marks the c. 100 m-high, distally c. 6 km-wide debris flow fan situated near the Bundschi settlement, which has been discharged from the junction of the Bundschi (Bunji) Gah from the orographic left (E) valley side, from the 5559 m-summit (No.91 marks the position of the mountain which is not visible from here). It is largely made up from dislocated moraine material. A Late Glacial lateral moraine complex, i.e. a lateral kame, accumulated against the thawing Indus glacier, can be observed at the valley exit on the orographic left (■ I-II). 6 km behind the debris flow fan (▽) and the kame (■ I-II), also from the left (E), the Astor valley joins the Indus valley. The author's glacier reconstructions concerning this valley have already been discussed in detail (Kuhle 1988b:588; 1988c:11; 1989:271-273; 1991:299; 1993:108-110; 1996; 1997; 1998a:90-94; the 8126 m-high Nanga Parbat-massif rises behind it (on the left below No.92 in the clouds)). No.92 is the 1965 m-hill at the back of which the Saz Nala joins from the orographic right (from the W) (cf. Fig.58). Here, the Indus valley shows a trough-cross-profile (⊔; Fig.58) with abraded rock flanks (◓) and a large-scale ground moraine overlay (■). (0 — —) is the highest level of the ice stream network verifiable with the help of preserved glacier indicators like these. It runs about 3100 m and can be classified as belonging to the LGM. (▼) is a basal flank steepening developed by fluvial or subglacially fluvial undercutting. Photo M.Kuhle, 14.8.1997.

↑ *Photo 183.* Panorama from the orographic left flank of the Chitral valley, a good 4 km down-valley of Drosh, taken at c. 1350 m asl (35°32′ 30″ N/71°49′ E; Fig.2 on the left above No.97) from facing SSW down-valley towards Mirkhani (left margin) via WNW into the orographic right valley flank with the alluvial- and mudflow fan (△) of Utsiak (on the right of the middle) up to NNE up-valley as far as the confluence of Mastuj and Shishi near Drosh (right margin). (■) are ground- and lateral moraine bodies with a trough-shaped profile of the slope line, which during the melting-process of the Chitral valley glacier have first been covered kame-like by a concordant mantle of crumblings from the rock walls above, accumulated against the ice margin, and have later been dissected downward from the wall furrows (↓). (– –) is the LGM-glacier level documented by flank abrasions (◓). Photo M.Kuhle, 21.9.1995.

← *Photo 184.* Light erratic granite boulder (for scale: rucksack and a 143 cm-long stick) in ground moraine on dark sedimentary bedrock, on the culmination of the mountain ridge polished round by the glacier ice between Tirich (Mir)- (on the left) and Mastuj valley (right) NE above the Zani pass, facing NE (3850 m asl; 36°21′ N/72°12′ E). The granite boulder testifies to an ice transfluence of the Tirich Mir glacier. Photo M.Kuhle, 22.9.1995.

→ *Photo 185.* At 3985 m asl facing E (centre) across the saddle of the Rothang (Jot) pass (32°21′ 45″ N/77°14′ 50″ E, 3980 m) looking diagonally up the Lahaul valley. No.9 is the 5620 m-peak; (◓ black) is the orographic right flank polishing of the Lahaul valley, reaching up to 3400 m, to the polish line of the LGM (– –). (◓ white) shows a rock threshold rounded by the glacier abrasion of the Ice Age transfluence pass; (■) marks a hilly ground moraine. Photo M.Kuhle, 17.8.1993.

← *Photo 186.* At 1550 m asl looking up the Tori valley to the NE on to the 4971 m-peak (No.8). 1.5-3 m-long, round-edged erratic granite boulders (○) (32°12′40″ N/76°22′35″ E) form an orographic right lateral moraine (■) which sets in at 1660 m asl (■ on the right), c. 250 m above the talweg (▼). The bedrock in the underground consists of finely grained sedimentary rock (schist). (– –) is the surface level of the LGM-Tori glacier, which, accordingly, had still a thickness about 250 m here. It came to an end as a hammerhead-like piedmont glacier c. 2 km down-valley outside the valley. Photo M.Kuhle, 29.10.1996.

→ *Photo 190.* From a good 1500 m asl (28°20′ 64.4″ N/83°57′ 19.2″ E: GPS-measurement), 350 m above the talweg (↓), seen along the orographic right flank down the Seti Khola (valley) to the S. The erratic gneiss boulder (■) (a further large, i.e. 3 m-long boulder is situated up-slope) lies on round-polished bedrock schist (◓) in an unstable position. At the time when the Seti Khola glacier has filled the 2.5-3 km-wide valley (Stage 0, cf.Tab 1) at this thickness (350 m), it must have reached at least as far as the Yamdi Khola (⇩). Photo M.Kuhle, 24.3.1998.

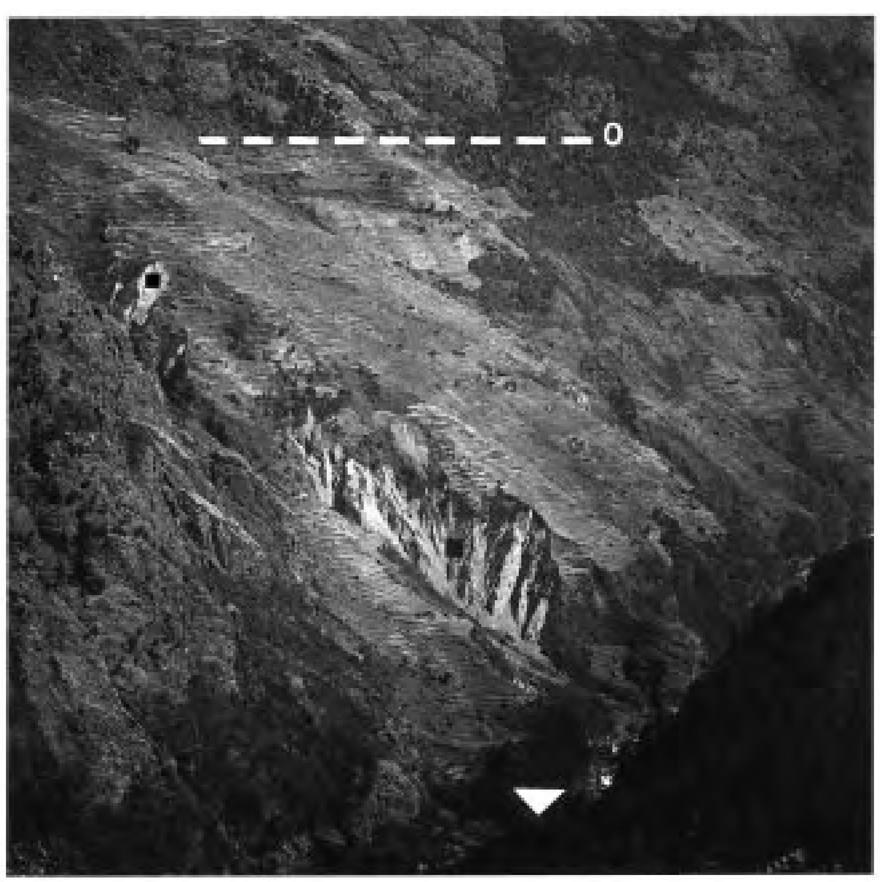
← *Photo 187.* Taken at the exit of the Triund valley from the orographic left side at 1390 m asl from the left lateral moraine root (■ white) (32°12′ 55″ N/76°21′ 10″ E) facing WNW and looking on to the opposite lateral moraine (■ black). Here, the moraine ledges (■) with their erratic augen-gneiss and granite boulders metres in size (○) up to a hut (↓) reach a height about 120 m above the talweg in the bottom of the tongue basin (□). (– –) is the surface height of the piedmont glacier tongue falling steeply away at the valley exit. Red Oligocene to Miocene sandstones outcrop in the underground. Photo M.Kuhle, 31.10.1996.

→ *Photo 191.* Edged and round-edged to facetted, but also rounded erratic granite and augen-gneiss boulders of up to 2.5 m in size from the Himalaya main-crest are situated on thinly-stratified sedimentary bedrock 60 m above the talweg on the right flank of the Madi Khola (the stick is 143 cm-long) (28°12′ 20″ N/ 84°05′ 20″ E) near the Chitepani settlement. Photo M.Kuhle, 31.1.1995.

← *Photo 188.* From Pakua (28°14′ N/83°43′ E) at c. 950 m, facing N (middle), looking at the lowest section of the trough-shaped glacier tongue basin (∪) in the lower Modi Khola between Gijan (on the right of ∪) and Dobila (left of ∪). (∪) is situated c. 1000 m up-valley of the LGM-glacier terminus (glacier mouth) of the Modi Khola glacier at c. 800 m asl. (– – 0) is the surface of its tongue, reconstructed according to the level of the kame terrace (■). Photo M.Kuhle, 16.10.1977

↓ *Photo 189.* Panorama across the Modi Khola from the orographic left flank S of Bhichuk (28°20′ 30″ N/83°48′ 20″ E, 1550 m asl) from facing SW down the trough valley (∪) with the lowest ice margin position at Dobila (↓), classified as belonging to the LGM (Stage 0), via WNW to the 3133 m-peak (No.10) up to N to the Annapurna South (No.8 = 7219 m) and to the Hiunchuli (No.9 = 6441 m), seen up-valley. (■) are ground moraine deposits; (△) shows the position of prehistoric, subglacial potholes; (– –) is the LGM glacier level. Photo M.Kuhle, 14.1.1995.

← *Photo 198.* Panorama at 1290 m asl from the orographic right flank of the Dadu valley (29°39′ 20″ N/102°11′ 10″ E) taken from 3 km upward of the junction of the Taitho: from facing NNE up the Dadu valley (◡), via E into the orographic left flank with a bulge-shaped ground moraine cover (third ■ from the left), via SE diagonally down-valley on to a Late Glacial (Stage I,II or III, cf. Tab 1) end moraine complex (■ white) of the Taitho side glacier, as far as SSE looking into a 40 m-high ground moraine exposure (■ on the very right) on the orographic right flank of the Dadu valley. (◓) is a glacier polishing which has been freshly preserved under this moraine cover. The ground moraine (■ on the very right) contains polymict, mainly granitic, edged, round-edged to facetted boulders 1 to 2.5 m in length (○), "swimming" in a clayey matrix. (□) is a fluvial terrace of Holocene to historic age. The ground moraine accumulations (■ black) and the trough form (◡) testify to a c. 300 m-thick prehistoric glacier-filling up to a height of the ice level about 1500 m (– –). It cannot be entirely ruled out that the over 100 m-thick, c. 400 m-high moraine remnant (■ white) concerns a lateral moraine remnant of the main glacier, which has survived in the flow shadow. However, the suggestion of a local front moraine of the Taitho-tributary glacier, which during the Late Glacial has advanced into the main valley, which was already free of ice, has to be preferred. Photo M.Kuhle, 17.6.2000.

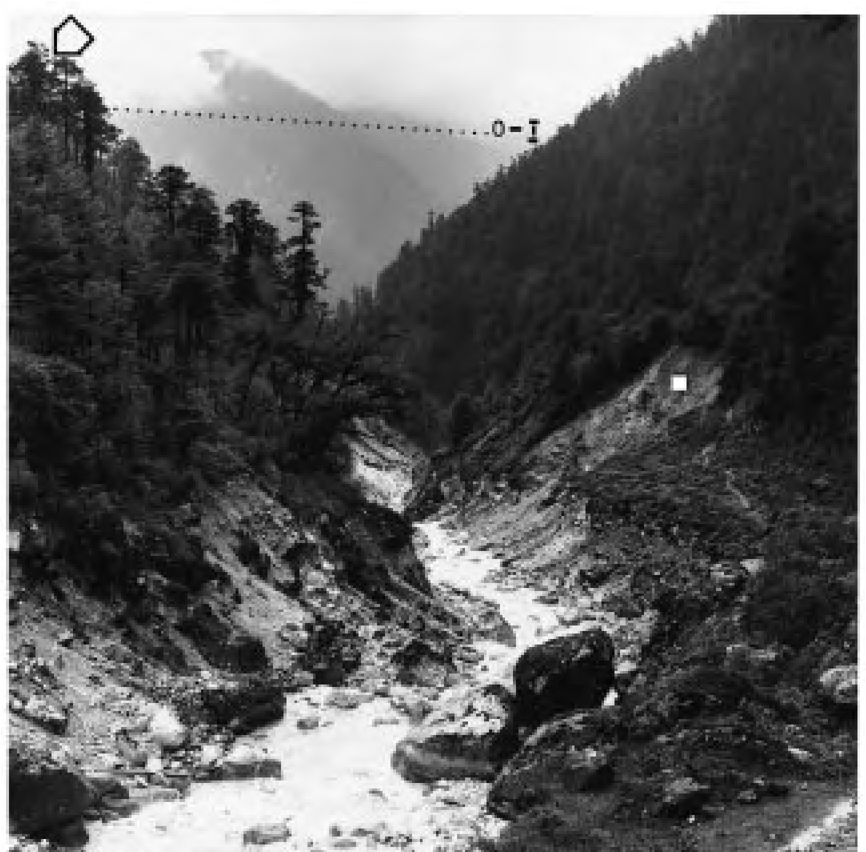


← *Photo 192.* On the orographic right, on the slope of the Bhote Kosi, the at least 40 m-thick ground moraine (■) reaches up to 300 altitudinal-metres above the Trisuli river (▼) as far as c. 1400 m asl (– –). Here (28°12′ N/85°14′ 50″ E), between the Haku (on the right up-valley) and Donga (on the left down-valley) settlements, it testifies to a still 300 m-thick valley glacier tongue (– – 0). Photo M.Kuhle, 10.3.1998.

→ *Photo 193.* Well-preserved glacigenic flank polishings (◓) in bedrock gneiss have survived c. 800 m above the valley bottom on the orographic left, in the valley cross-profile of the Jagat settlement in the Bhote- i.e. Tamba Kosi in the SSW-slope of the Rolwaling Himalaya on the Sunthali Danda massif (27°50′ N/86°18′ E) at 2000 m asl. Photo M.Kuhle, 11.4.1998.

← *Photo 194.* Taken at 1300 m from the orographic left flank of the Tamba Kosi below the Dolakha settlement, facing NE and looking up the Tamba Kosi and then the Khare Khola. No.1 is the Cho Oyu (8205 m), No.2 the Menlungtse (7181 m), both in the Himalaya main crest. (■) is a good 200 m-high kame (27°40′05″ N/86°07′ E), heaped up against the Ice Age Tamba Kosi glacier (0 – –) from the orographic right Dolti (also Doni) Khola (➞). Photo M.Kuhle, 12.4.1998.

➞ *Photo 195.* Taken from 2730 m asl from the orographic left flank 1 km S of the Surke settlement (27°39′ 40″ N/86°43′ E), looking up the Dudh Kosi (valley). The Dudh Kosi glacier, which, according to glaciogeomorphologic criteria, has been classified as belonging to the LGM, has polished out a trough valley (▢) the flanks of which indicate glacigenic abrasions (◓) as far as c. 3800 m, so that a minimum height of the prehistoric glacier surface can be reconstructed (– –). The glacier has flowed on a c. 150-200 m-thick - and in places even clearly thicker - ground moraine pedestal (■ white) over the rock bottom. In the meantime it has been dissected by the river (▼). In the pedestal of loose rock material, overthrust by the glacier, compressed glaciofluvial sediments are contained. Crumblings from the flanks, as e.g. rock falls, as well as debris fans and -cones (▽) have been deposited on its surface since the deglaciation. In the background the Late Glacial medial moraine inset (■ black) of Namche Bazar can be seen. Photo M.Kuhle 29.8.1982.



← *Photo 196.* Taken at 3200 m asl from the valley bottom of the middle Simbua Khola (27°32′ N/87°55′ 30″ E) filled with moraine, facing SW looking down-valley. (■) is a 55 m-high ground moraine exposure; opposite, on the orographic left side, the ground moraine pedestal (below ⇩) is over 200 m-high; 2.3 km down-valley at 3000 m asl, a subglacially developed ravine stretch continues. Rocks, rounded by the ground polishing, extend into it. (– – 0-I) is the LGM- to Late Glacial surface of the glacier level. (⇩) marks the position of the Ice Age Lamite Bhanjyang transfluence pass. Photo M.Kuhle, 5.5.1999.

↑ *Photo 197.* At 1580 m asl facing W, looking into the orographic right flank of the Dadu valley, made up of a mountain spur between two side valleys (30°03′ 10″ N/102°12′ E). This c. 350 m-high mountain spur has been completely overflowed and abraded by the ice (◓), so that it presents the classic form of a truncated spur. (– –) is the locally evidenced minimum surface height of the glacier. On the lower slope the spur is covered with over 10 m-thick moraine material (■ black). It contains metres-sized polymict, facetted boulders, among them granite boulders. (■ white) is a ground moraine- or kame complex at the side valley exit. Photo M.Kuhle, 9.6.2000.

In the Madi Khola (valley) the (probably LGM-) valley glacier, flowing down from the Annapurna IV, II and Lamjung Himal, has extended up to c. 630 m asl (28°12’20″ N/84°05’20″ E). This is proved by lateral moraines and erratic gneiss boulders on the orographic left (Photo 191) (Kuhle 1998a: 87).

7.4. The LGM-ice margin positions of the Langtang-, Himal SW- and Ganesh Himal SE-slope and in the S-slope of the Menlungtse-group, Rolwaling Himal (Fig. 1 No. 25)

On the orographic right flank of the Bhote Kosi as far down as its talweg (Trisuli river), decametres-thick ground moraines have been preserved (Photo 191). The lowest occurrences of ground moraine have been met at c. 900–1000 m asl near the Donga settlement. Up to here, i.e. up to the junction of the Mailung Khola (28°05′ N/85°13’20″ E), has reached the terminus of the valley glacier as a joint outlet glacier of the then connected Langtang- and Ganesh Himal ice stream network.

In the Tamba Kosi the LGM-glacier in the cross-profile at the Jagat settlement has amounted to a minimum thickness of 800 m (Photo 193) (cf. König 1999: 374). Here, at 900 m asl, a kame near the Malepu settlement (Photo 194) provides evidence of an ice thickness of still 200 m, so that the glacier tongue end might have been situated 4 km down-valley at 860 m asl, at the start of the valley narrow SW below the Marbu settlement (27°38′ N/86°06′ E).

7.5. Observations on the LGM-Dudh Kosi glacier terminus (Khumbu Himal) and the Ice Age Yalung- i.e. Simbua Khola glacier as an orographic left tributary stream of the Tamur parent glacier (Kangchendzönga) (Fig. 1 No. 4 and 26)

Heuberger (1986: 30 etc.) has described the lowest prehistoric ice margin of the Dudh Kosi glacier as being situated at 1580 m asl below the Khari-Khola inflow. The author wishes to correct his suggestion that the Dudh Kosi glacier has reached further down than up to 1800 m asl, namely up to the Deku Khola inflow (27°38′ N/86°42′ E) at 1560 m asl, during the LGM (Kuhle 1988b: 587). Due to an ice thickness about 1000-1200 m only 15 km up-valley, in the cross-profile at the Ghat settlement (Photo 195 ▬ ▬ on the right) – where the glacier surface had already lain at nearly the level of the snow-line – the author meanwhile assumes that the Dudh Kosi glacier tongue has come to an end c. 20 km further down-valley between 1100 and 900 m asl, in the confluence area with the Hingu Khola (27°29′ N/86°43′ E). Near the Jubing settlement, situated down-valley, the author has observed smooth denudation forms on the rock flanks, neither corresponding to linear erosion nor to crumblings, so that it is to be supposed that these are glacigenic abrasion forms. Unambiguous indicators, however, have not been found. Up-valley of this gorge-relief as far as the Surke settlement, these indicators, too, are largely lacking because of the extreme flushing-out and work of the torrent in the Holocene.

The author has reconstructed an Ice Age Kangchendzönga-S-slope glacier, the LGM-Tamur glacier, reaching up to the Thuma settlement at 890 m asl (Kuhle 1990b). In the lower 4 km of the Simbua Khola, Late Glacial lateral moraines of the Ghasa Stage I (cf.Tab. 1) have been found, extending at the Hellok settlement into the Tamur main valley (ibid.: 418–421). König (1999: 376, 381/82) has confirmed these results – among other findings – by an orographic right lateral moraine situated 600 m above the Simbua Khola valley bottom. During his field work in 1999, the author (Kuhle) has encountered a ground moraine pedestal in an increasing thickness in the upper to middle Simbua Khola (Photo 196 ■), which has been multifariously modified and fluvially dissected since the deglaciation. Down-valley this pedestal peters out into the level mapped as lateral moraines (Kuhle 1990b: Fig. 9, (I) half-right above Hellok). Accordingly, it is also a dissected ground moraine pedestal. In the orographic left flank of the Simbua Khola at 3400–3430 m asl, decametres-thick ground moraine deposits with rounded components and polymict boulders have been observed as far as the Lamite Bhanjyang (pass) (27°30’59″ N/87°53’45″ E; Photo 196 ⇩). All these findings prove 1. that the Simbua Khola glacier has reached the Tamur parent glacier and, until the Late Glacial, was one of its tributary streams; 2. that this valley glacier was at least 600 m-thick (▬ ▬) in its middle course and 3. has thus overflowed the Lamite Bhanjyang (pass), situated just 400 m above the valley bottom, down into the SE-adjacent Kabeli Khola at a thickness of at least 200 m. Owing to this transfluence the Simbua Khola glacier level (▬ ▬0–I) in its function as an overspill into a Himalaya fore-chain-valley without a self-glaciation worth mentioning, must have remained rather constant from the High- (LGM); Stage 0) as far as into the Late Glacial (Ghasa Stage I or even II).

7.6. The lowest LGM-ice margin position in the Dadu He valley (also Ta-tu-ho or Tung-ho) in E-Tibet (Fig. 1 No. 28)

According to field- and laboratory investigations carried out on the E-margin of Tibet, an Ice Age Dadu-He-parent-glacier has been reconstructed. Due to the fresh forms preserved and in consideration of the extremely destructive and reshaping forces of the monsoon-specific morphodynamics, it has be classified as belonging to the LGM. This main glacier has flowed down from E-Tibet and been fed by numerous side glaciers, i.e. outlet glaciers from the E-margin of the Tibetan inland ice (Kuhle 1982b, 1982c, 1987e, 1991a, 1997, 1998a), but it has also been supplied by the connection to the local ice stream network of the Minya Konka-massif. With the help of ground moraines and glacigenic lateral forms, as e.g. several hundred-metres-high kames, the LGM glacier infilling of the Che Chu (dshu), reaching the town of Kangting (also Tatsienlu, 2620 m asl) from the N, has been evidenced. Between Kangting and the inflow of the Tatsienlu-ho (valley) into the Dadu He valley at 1650 m asl, flank abrasions have widened the Tatsienlu gorge to a ‘gorge-shaped trough’. Up to 600 m above the river mouth, a 30–70 m-high moraine has been preserved at the Wassöko settlement, which can be approached as a lateral-, i.e. medial-moraine between the side- and parent glacier. But on the opposite side of the tributary valley ground moraine has also survived (30°05′ N/102°12′ E). In the course of the continuing 60 km down the Dadu valley (main valley), from Wassöko as far as the junction with the Taitho (valley), i.e. from 1620 m down to 1240 m asl, the author in many places has mapped further ground moraine covers and lateral forms in continuation of those moraines (Photo 197, 198). Additional clear evidences of the LGM-Dadu valley parent glacier occur e.g. on the orographic left side, immediately above the town of Luding (or Luting shao). Here, too, the thickness of the valley glacier might have amounted to 500–600 m. Above the inflow of the Taitho, through which the Ice Age Hailuogou- (Hailoko-) and Yan-tsöko glaciers have flowed down from the Minya Konka SE- and NE flank into the Dadu main glacier, the main glacier had still a thickness of c. 300 m (Photo 198). Accordingly, the lowest LGM-ice margin position of this eastern outlet glacier of the Tibetan inland ice must have been situated at c. 1150 m asl at 29°30′ N/102°11'30″ E. Here, below the Wantung settlement, a markedly winding, narrow gorge valley stretch starts, which was probably free of ice.

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References

Ampferer, O. (1928): Beiträge zur Glazialgeologie der westlichen Südtiroler Dolomiten.– Zeitschrift für Gletscherkunde, für Eiszeitforschung und Geschichte des Klimas, **16**: 242–260.

Bürgisser, H.M.; Gansser, A.; Pika, J. (1982): Late Glacial lake sediments of the Indus valley area, northwestern Himalaya.– Eclogae geologische Helvetica, **75** (1): 51–63.

Cronin, V.S. (1989): Structural setting of the Skardu intermontane basin, Karakoram Himalaya, Pakistan.– Geological Society of America Special Paper, **232** (Tectonics of the Western Himalayas, Eds: Manlinconico, L.L.; Lillie, R.J.): 213–216.

Dainelli, G. (1922): Studi sul Glaciale. Risultati Geologici e Geografici, Relazioni scientifiche della Spedizione Italiana De Fillipi nell' Himalaya, Caracorum e Turchestan Cinese (1913–1914). Vol. III, Ser. II.

Dreimanis, A. (1939): Eine neue Methode der quantitativen Geschiebeforschung.– Zeitschrift für Geschiebeforschung, **15**.

Dreimanis, A. (1979): Selection of genetically significant parameters for investigation of tills.– In: Schlüchter, C. (Ed): Moraines and Varves. p. 167–177; Rotterdam (Balkema).

Dreimanis, A. (1982): INQUA-Commission on Genesis and Lithology of Quaternary Deposits. Work Group (1) – Genetic classification of tills and criteria for their differentation.– In: Progress report on activities 1977–1982 and definitions of glacigenic terms. p. 12–31; Zürich (ETH Zürich).

Dreimanis, A.; Vagners, U.J. (1971): Bimodal distribution of rock and mineral fragments in basal tills.– In: Goldthwaite, R.P. (Ed): Till. p. 237–250.

Ehlers, J. (1994): Allgemeine und historische Quartärgeologie. Enke, Stuttgart. 358 p.

Engelhardt, W.v. (1973): Die Bildung von Sedimenten und Sedimentgesteinen. – Sediment-Petrologie: Engelhardt, W.v.; Füchtbauer, H.; Müller, G.; Teil III; Schweizerbart, Stuttgart. 378 p, 133 Abb., 55 Tab.

Finsterwalder, R. (1938): Die geodätischen, gletscherkundlichen und geographischen Ergebnisse der Deutschen Himalaya Expedition 1934 zum Nanga Parbat.– Deutsche Forschung, Neue Folge, mit der Karte der Nanga Parbat Gruppe 1 : 50000 und 1 : 100000, **2**.

Fort, M. (1986): Glacial extension and catastophic dynamics along the Annapurna front, Nepal Himalaya.– In: Kuhle, M. (Ed): Intern. Symp. über Tibet u. Hochasien (8.–11. Oktober 1985), Geogr. Inst. Univ. Göttingen, Göttinger Geogr. Abh. Vol. 81. S. 105–125; Göttingen.

Godwin-Austen, H.H. (1864): On the Glaciers of the Muztagh Range.– Proceedings of the Royal Geographical Society, **34**: 19–56.

Haldorsen, S. (1983): The characteristics and genesis of Norwegian tills.– In: Ehlers, J. (Ed): Glacial deposits in North-West Europe p. 11–17; Rotterdam.

Haserodt, K. (1989): Zur pleistozänen und postglazialen Vergletscherung zwischen Hindukusch, Karakorum und Westhimalaya.– Beiträge und Materialien zur Regionalen Geographie, **2**: 182–233.

Heuberger, H. (1986): Untersuchungen über die eiszeitliche Vergletscherung des Mt. Everest-Gebietes, Südseite, Nepal.– Göttinger Geographische Abhandlungen, **81** (Internationales Symposium über Tibet und Hochasien vom 8.-11.10.1985, Ed: Kuhle, M.): 29–30.

Hewitt, K. (1998): Himalayan Indus Streams in the Holocene: Glaciers-, and Landslide- 'Interupted' Fluvial Sytems.– In: Stellrecht, I. (Ed): Karakorum – Hindukush – Himalaya: Dynamics of Change. Culture Area Karakorum, Scientific Studies 1. p. 1–28; Köln (Rüdiger Köppe Verlag).

Hewitt, K. (1999): Quaternary Moraines vs Catastrophic Rock avalanches in the Karakoram Himalaya, Northern Pakistan.– Quaternary Research, **51**: 220–237.

Hewitt, K. (2001): Catastrophic Rockslides and the Geomorphology of the Hunza and Gilgit River Valleys, Karakoram Himalaya.– Erdkunde, **55**: 72–93.

Hövermann, J.; Kuhle, M. (1985): Typen von Vorlandvergletscherungen in Nordost-Tibet.– Regensburger Geographische Schriften, **19/20** (Ingo Schäfer Festschrift): 29–53.

Iturrizaga, L. (1997): Glacier outburst floods threatening the settlement Shimshal (North-West-Karakorum).– In: Mahanta, K.C. (Ed): People of the Himalayas. Journal of Human Ecology, Special Issue. Vol. 6. S. 69–76; Delhi, India (Kamla-Raj-Enterprises).

Iturrizaga, L. (1998): Die Schuttkörper in Hochasien. Eine geomorphologische Bestandsaufnahme und Typologie postglazialer Hochgebirgsschuttkörper im Hindukusch, Karakorum und Himalaya. Dissertation, Geographisches Institut der Universität Göttingen, 2 Bände (Text- und Phototeil), 320 p. & 164 p.

Iturrizaga, L. (1999): Typical debris accumulation forms and formations in High Asia.A glacial history-based concept of the origin of the Postglacial debris accumulation landscapes in subtropical high mountains with selected case examples from the Hindu Kush, the Karakoram and the Himalayas.– GeoJournal, **47** (1/2, Tibet and High Asia (V), Ed: Kuhle, M.): 277–339.

Iturrizaga, L. (2001): Lateroglacial valleys and landforms in the Karakoram Mountains (Pakistan).– GeoJournal (Tibet and High Asia VI, Glacio-geomorphology and prehistoric Glaciation in the Karakoram and Himalaya. Ed: Kuhle, M.): 291–322.

Kalvoda, J. (1992): Geomorphological Record of the Quaternary Orogeny in the Himalya and the Karakoram. Development in earth Surface Processes Elsevier, Amsterdam, Londo, New York, Tokyo. 315 p.

Kamp, U. (1999): Jungquartäre Geomorphologie und Vergletscherung im östlichen Hindukusch, Chitral, Nordpakistan.– Berliner Geographische Studien, **50** (Eds: Haserodt, K.; Weddeling, H.): 254.

Kick, W. (1956): Der Chogo-Lungma-Gletscher im Karakorum.– Zeitschrift für Gletscherkunde, **3**: 335–347.

Kick, W. (1964): Der Chogo-Lungma-Gletscher im Karakorum.– Zeitschrift für Gletscherkunde, **5**: 1–59.

Kick, W. (1991): Bericht 1989 über das Chogo-Lungma-Gletscherende.– Zeitschrift für Gletscherkunde, **25**: 139–145.

König, O. (1999): Preliminary results on the last high-glacial glaciation of the Rolwaling Himal and the Kangchenjunga Himal (Nepal, East-Himalaya).– GeoJournal, **47** (1/2, Tibet and High Asia (V), Ed: Kuhle, M.): 373–384.

Kuhle, M. (1974): Vorläufige Ausführungen morphologischer Feldarbeitsergebnisse aus den SE-Iranischen Hochgebirgen am Beispiel des Kuh-i-Jupar.– Zeitschrift für Geomorphologie, N.F. **18** (4): 472–483.

Kuhle, M. (1976): Beiträge zur Quartärgeomorphologie SE-Iranischer Hochgebirge. Die quartäre Vergletscherung des Kuh-i-Jupar.– Göttinger Geographische Abhandlungen, **67**: Bd. I: 1–209; Bd. II: 1–105.

Kuhle, M. (1980): Klimageomorphologische Untersuchungen in der Dhaulagiri und Annapurna-Gruppe (Zentraler Himalaya).– In: Tagungsbericht und wissenschaftliche Abhandlungen des 42. Deutschen Geographentag Göttingen. p. 244–247; Wiesbaden (Steiner).

Kuhle, M. (1982a): Der Dhaulagiri- und Annapurna-Himalaya. Ein Beitrag zur Geomorphologie extremer Hochgebirge.– Zeitschrift für Geomorphologie Supplement, **41** (Suppl. Bd.): Bd. I (Text): 1–229; Bd. II (Abb.): 1–183 und Geomorph. Karte 1 : 85000.

Kuhle, M. (1982b): Was spricht für eine pleistozäne Inlandvereisung Hochtibets?– Sitzungsberichte und Mitteilungen der Braunschweigischen Wissenschaftlichen Gesellschaft, **6** (Sonderband: Die Chinesisch/Deutsche Tibet-Expedition 1981, Braunschweig-Symposium vom 14.-16.04.1982): 68–77.

Kuhle, M. (1982c): Erste Chinesisch-Deutsche Gemeinschaftsexpedition nach NE-Tibet und in die Massive des Kuen-Lun-Gebirges 1981. Ein Expeditions- und vorläufiger Forschungsbericht.– In: Hagedorn, H.; Giessner, K. (Eds): Tagungsber. und wiss. Abhandlungen des 43. Deutschen Geographentages Mannheim 1981. p. 63–82; Wiesbaden (Steiner).

Kuhle, M. (1982d): An expediton to an unexplored region of Tibet. German and Chinese research in the mountains.– Reports of the DFG, German Research, **3**: 9–12.

Kuhle, M. (1982e): Periglazial- und Glazialformen und -prozesse in NE-Tibet.– Sitzungsberichte und Mitteilungen der Braunschweigischen Wissenschaftlichen Gesellschaft, Sonderheft, **6** (Die Chinesisch/Deutsche Tibet-Expedition 1981, Braunschweig-Symposium vom 14.-16.04.1982): 19–24.

Kuhle, M. (1982f): A Typology of Glaciers in relation to the vertical distance.– Journal of Glaciology and Cryopedology, **1982**: 1–26.

Kuhle, M. (1983a): Der Dhaulagiri- und Annapurna-Himalaya. Ein Beitrag zur Geomorphologie extremer Hochgebirge. Empirische Grundlage; Ergänzungsbd. III.– Zeitschrift für Geomorphologie, **41** (Suppl. Bd.): 1–383.

Kuhle, M. (1983b): A New Expedition in Tibet – a Contribution to Climatology and High Mountain Research.– Universitas, **5** (1): 59–63.

Kuhle, M. (1984a): Das Mt. Chomolungma-Massiv (Sagarmatha- oder Mt. Everest-Massiv (27°59′ N/86°56′ E) – Zur Morphologie des Himalaya zwischen tibetischem Hochland und S-lichen Vorketten.– Geographische Rundschau, **36**: 298 & 300.

Kuhle, M. (1984b): Auswertung von Spacelabaufnahmen aus Hochasien: Die Kuen-Lun-N-Abdachung zur Tsaidam-Depression (ca. 35°45′-37°40′ N/91°30'–92°52′ E) – Ausdeutung einer Satellitenphotographie über Feldarbeitsbefunde benachbarter Areale mit analoger geomorphologischer Sequenz.– Geographische Rundschau, **36**: 299 & 301.

Kuhle, M. (1984c): Zur Geomorphologie Tibets, Bortensander als Kennformen semiarider Vorlandvergletscherungen.– Berliner Geographische Abhandlungen, **36** (Ferd. v. Richthofen-Symposium 1983): 127–138.

Kuhle, M. (1984d): Former Glacier Stades in Mountain Area Surrounding Tibet.– In: 25. Congres International de Geographie Paris 1984 (27.-31.08.84), Abstracts. Vol. Tome II Thèmes 21 à 31 et 40. p. 51–52; Caen, France.

Kuhle, M. (1985a): Permafrost and Periglacial Indicators on the Tibetan Plateau from the Himalaya Mountains in the South to the Quilian Shan in the North (28–40° N).– Zeitschrift für Geomorphologie N.F., **29** (Bd. 2): 183–192.

Kuhle, M. (1985b): Ein subtropisches Inlandeis als Eiszeitauslöser. Südtibet- und Mt. Everest-Expedition 1984.– Georgia Augusta, Nachrichten aus der Universität Göttingen, **42**: 35–51.

Kuhle, M. (1985c): Glaciation Research in the Himalayas: A New Ice Age Theory.– Universitas, **27** (4): 281–294.

Kuhle, M. (1986a): Former glacial stades in the mountain areas surrounding Tibet – In the Himalayas (27–29° N: Dhaulagiri-, Annapurna-, Cho Qyu-, Gyachung Kang-areas) in the south and in the Kuen Lun and Quilian Shan (34–38° N: Animachin, Kakitu) in the north.– In: Joshi, S.C.; Haigh, M.J.; Pangtey, Y.P.S.; Joshi, D.R.; Dani, D.D. (Eds): Nepal-Himalaya – Geo-Ecological Perspektives. p. 437–473.

Kuhle, M. (1986b): New Research in High Asia, Tibet and the Himalayas (The International Symposium on Tibet and High Asia, October 8.-11. 1985 in Göttingen).– GeoJournal, **12** (3): 341–343.

Kuhle, M. (1986c): The South Tibet and Mt. Everest-Expedition 1984 – Geographical investigations in High Asia. Wissenschaftlicher Tonfilm, 45 min. Farbtonfilm Film D 1607, Produktion des Instituts für den wissenschaftlichen Film (IWF). Göttingen (German and English Version).

Kuhle, M. (1986d): Südtibet- und Mt. Everest-Expedition 1984- oder: Ein subtropisches Inlandeis als Eiszeitauslöser?– Universitas, **41** (1): 64–78.

Kuhle, M. (1986e): Die Vergletscherung Tibets und die Entstehung von Eiszeiten.– Spektrum der Wissenschaften; Scientific American, **9/86**: 42–54.

Kuhle, M. (1987a): Absolute Datierungen zur jüngeren Gletschergeschichte im Mt Everest-Gebiet und die mathematische Korrektur von Schneegrenz-berechnungen.– In: Hütteroth, W.-D. (Ed): Tagunsbericht und wissenschaftliche Abhandlungen des 45. Deutschen Geographentages Berlin 1985. p. 200–208; Stuttgart (Steiner).

Kuhle, M. (1987b): A numerical classification of glaciers by means of specific relief parameter.– Journal of Glaciology and Geocryology, **9** (3, Sept. 1987, Chinese Society of Glaciology and Cryopedology, Academia Sinica): 207–214.

Kuhle, M. (1987c): Glacial, Nival and Periglacial Environments in Northeastern Quinghai-Xizang-Plateau.– In: Hövermann, J.; Wenjing, W. (Eds): Reports on the Northeastern part of the Quinhai-Xizang (Tibet)-Plateau by the Sino-West-German Scientific Expedition 1981. p. 176–244; Beijing, China (Science Press).

Kuhle, M. (1987d): Die Rekonstruktion des kaltzeitlichen Tibet-Eises und Energiebilanzmessungen bis 6650m ü.M. als Basis einer reliefspezifischen Eiszeittheorie.– In: Becker, H. (Ed): Tagungsbericht und wissenschaftliche Abhandlungen des 46. Deutschen Geographentages München 1987. Vol. 46. Ak-Sitzung 'Neuere Forschungen in der Klimatologie'. p. 600–601; Stuttgart (Steiner).

Kuhle, M. (1987e): The Problem of a Pleistocene Inland Glaciation of the Northeastern Qinghai-Xizang-Plateau.– In: Hövermann, J.; Wenjing, W. (Eds): Reports on the Northeastern Part of Quinghai-Xizang (Tibet)-Plateau by the Sino-German Scientific Expedition 1981. p. 250–315; Beijing, China (Science Press).

Kuhle, M. (1987f): Subtropical Mountain- and Highland-Glaciation as Ice Age Triggers and the Waning of the Glacial Periods in the Pleistocene.– GeoJournal, **14** (4): 393–421.

Kuhle, M. (1987g): Die Wiege der Eiszeit.– Geo, **1987** (2): 80–94.

Kuhle, M. (1988a): Neueste physisch-geographische Forschungsergebnisse aus Hochtibet und angrenzenden Gebieten.– In: Becker, H. (Ed): Tagungsbericht und wissenschaftliche Abhandlungen des 46. Deutschen Geographentages München 1987. p. 605–607; Stuttgart (Steiner).

Kuhle, M. (1988b): The Pleistocene Glaciation of Tibet and the Onset of Ice Ages- An Autocycle Hypothesis.– GeoJournal, **17** (4, Tibet and High-Asia. Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 581–596.

Kuhle, M. (1988c): The Pleistocene Glaciation of Tibet and the Onset of Ice Ages – An Autocyclic Hypothesis.– In: International Congress 'The Neogene of Karakoram and Himalayas' March 21th – 23rd, 1988. p. 11; Leicester, UK; Abstract (Department of Geography, University of Leicester).

Kuhle, M. (1988d): Zur Geomorphologie der nivalen und subnivalen Höhenstufe in der Karakorum-N-Abdachung zwischen Shaksgam-Tal und K2 Nordsporn: Die quartäre Vergletscherung und ihre geoökologische Konsequenz.– In: Becker, H. (Ed): Tagungsbericht und wissenschaftliche Abhandlung des 46. Deutschen Geographentag 1987 München. p. 413–419; Stuttgart (Steiner).

Kuhle, M. (1988e): Die eiszeitliche Vergletscherung W-Tibets zwischen Karakorum und Tarim-Becken und ihr Einfluâ auf die globale Energiebilanz.– Geographische Zeitschrift, **76** (3): 135–148.

Kuhle, M. (1988f): Zur Auslöserrolle Tibets bei der Entstehung von Eiszeiten.– Spektrum der Wissenschaften; Scientific American, **1/88**: 16–20.

Kuhle, M. (1988g): Geomorphological Findings on the Build-up of Pleistocene Glaciation in Southern Tibet, and on the Problem of Inland Ice. Results of the Shisha Pangma and Mt. Everest Expedition 1984.– Geo-

Journal, 17 (4, Tibet and High-Asia, Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 457–513.
Kuhle, M. (1988h): Letzteiszeitliche Gletscherausdehnung vom NW-Karakorum bis zum Nanga Parbat (Hunza-Gilgit- und Indusgletschersystem).– In: Becker, H. (Ed): Tagungsbericht und wissenschaftliche Abhandlungen des 46. Deutschen Geographentages München 1987. AK- Sitzung 'Neueste physisch-geographische Forschungsergebnisse aus Hochtibet und angrenzenden Gebieten'. p. 606–607; Stuttgart (Steiner).
Kuhle, M. (1988i): Die Depression der Schneegrenzen – Neuere Erkenntnisse zur Eiszeit.– Forschung – Mitteilungen der DFG, **1/88**: 19–22.
Kuhle, M. (1988j): Eine reliefspezifische Eiszeittheorie. Nachweis einer tibetischen Inlandvereisung und ihrer energetischen Konsequenzen.– Die Geowissenschaften, **6** (5): 142–150.
Kuhle, M. (1988k): Snow-Line Plunge changed the Face of the Old World.– Reports of the DFG, German Research, **3**: 15–18.
Kuhle, M. (1988l): Topography as a Fundamental Element of Glacial Systems. A New Approach to ELA-Calculation and Typological Classification of Paleo- and Recent Glaciation.– GeoJournal, **17** (4, Tibet and High-Asia, Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 545–568.
Kuhle, M. (1988m): Subtropical Mountain- and Highland-Glaciation as Ice Age Triggers and the Waning of the Glacial Periods in the Pleistocene.– Chinese Translation Bulletin of Glaciology and Geocryology, **5** (4): 1–17.
Kuhle, M. (1988n): Heutige und eiszeitliche Vergletscherung Hochtibets. Ergebnisse der Südtibet- und Mt. Everest Expedition 1984.– Publikationen zu wissenschaftlichen Filmen des Institutes für den Wissenschaftlichen Film (IWF), Sektion Naturwissenschaften, Serie 10, D 1649: 1–36.
Kuhle, M. (1988o): Heutige und eiszeitliche Vergletscherung Hochtibets. Ergebnisse der Südtibet- und Mt.-Everest-Expedition 1984. Wissenschaftlicher Tonfilm, 43,5 min. Farbtonfilm Film D 1649, Produktion des Instituts für den wissenschaftlichen Film (IWF). Göttingen (German and English version).
Kuhle, M. (1989): Die Inlandvereisung Tibets als Basis einer in der Globalstrahlungsgeometrie fussenden, reliefspezifischen Eiszeittheorie.– Petermanns Geographische Mitteilungen, **133** (4): 265–285.
Kuhle, M. (1989a): The cyclus of the ice-age – an Ice-Age-Theory on the reconstruction of a Tibetan Ice Sheet.– Studia Geomorphologica carpathobalcanica, **13**: 163–186.
Kuhle, M. (1989b): Ice-Marginal Ramps: An Indicator of Semiarid Piedmont Glaciations.– GeoJournal, **18**: 223–238.
Kuhle, M. (1989c): Die terrestrisch induzierte Eiszeitära des Quartärs und der extraterrestrisch ausgelöste Interglazialzyklus.– In: Jahrbuch der Marburger Geographischen Gesellschaft und des Fachbereichs Geographie der Phillipps-Universität (MGG). p. 178–180; Marburg/Lahn.
Kuhle, M. (1990a): The Cold Deserts of High Asia (Tibet and Contiguous Mountains).– GeoJournal, **20** (3): 319–323.
Kuhle, M. (1990b): New Data on the Pleistocene Glacial Cover of the Southern Border of Tibet: The Glaciation of the Kangchendzönga Massif (8585m, E-Himalaya).– GeoJournal, **20**: 415–421.
Kuhle, M. (1990c): The Probability of Proof in Geomorphology – an Example of the Application of Information Theory to a New Kind of Glacigenic Morphological Type, the Ice-marginal Ramp (Bortensander).– GeoJournal, **21** (3): 195–222.
Kuhle, M. (1990d): Geographische Forschungen in Hochasien. Neue Daten zur Rekonstruktion des pleistozänen Tibetischen Inlandeises – Befunde der Expedition 1989.– In: Jahrbuch der Marburger Geographischen Gesellschaft und des Fachbereiches Geographie der Phillipps-Universität. Vol. 1990. p. 19–22; Marburg/Lahn ().
Kuhle, M. (1990e): Bericht über Beiträge der Arbeitskreissitzung: Neue Forschungen in Hochasien (Arbeitskreis Hochasien) auf dem Deutschen Geographentag in Saarbrücken 1989.– Geographische Rundschau, **42** (6): 356–357.
Kuhle, M. (1990f): The Glaciation of Tibet and its Global Climatic Effects.– Universitas, **32** (3): 229–240.
Kuhle, M. (1990g): Ice Marginal Ramps and Alluvial Fans in Semi-Arid Mountains: Convergence and Difference.– In: Rachocki, A.H.; Church, M. (Eds): Alluvial fans – A field approach. Vol. 3. p. 55–68;Chester-New York-Brisbane-Toronto-Singapore (John Wiley & Sons Ltd).
Kuhle, M. (1991): Die Vergletscherung Tibets und ihre Bedeutung für die Geschichte des nordhemisphärischen Inlandeises.– Sitzungsberichte der Akademie der Wissenschaften und der Literatur Mainz, Paläoklimaforschung, **1** (Klimageschichtliche Probleme der letzten 130 000 Jahre, Ed: Frenzel, B.): 293–306.
Kuhle, M. (1991a): Observations Supporting the Pleistocene Inland Glaciation of High Asia.– GeoJournal, **25** (2/3, Tibet and High Asia, Results of the Sino-German Joint Expeditons (II), Eds: Kuhle, M.; Xu Daoming): 133–233.
Kuhle, M. (1991b): Glazialgeomorphologie. Wissenschaftliche Buchgesellschaft, Darmstadt. 213 p.
Kuhle, M. (1991c): New Results on the Pleistocene Glaciation of Tibet and its impact in Glacioisostatic Movement of the Plateau.– Bulletin of the INQUA-Neotectonics-Commission, **14**: 87.
Kuhle, M. (1991d): The Pleistocene Glaciation of Tibet and the Onset of Ice-Ages – An Autocycle Hypothesis. International Union for Quarternary Research, Special Proceedings, Review Reports; INQUA 1991, Symposia 4: Quaternary Paleo-Ice-Cap and Inland-Ice of the Tibetan plateau; XIII International Congress, August 2–9, 1991, Beijing, China: 72.
Kuhle, M. (1992): New Findings on the Ice-cover in between Issyk-Kul and K2 (Tian Shan, Karakorum) during the Last Glaciation.– In: (): Abstracts. International Symposium on the Karakorum an Kunlun Mountains June 5–9, 1992 Kashi China. p. 76;Kashi, China (Chinese Academy of Sciences (CAS), National Natural Science Foundation of China (NSFC), Centre National de la Recherche Scientifique (CNRS)).
Kuhle, M. (1993): The Pleistocene Glaciation of the Himalaya and Tibet and its Impact on the Global Climate: A Relief-specific Ice Age Theory.– Journal of the Nepal Research Center (JNRC), **9**: 101–140.
Kuhle, M. (1993a): Eine Autozyklentheorie zur Entstehung und Abfolge der quartären Kalt- und Warmzeiten auf der Grundlage epirogener und glazialisostatischer Bewegungsinterferenzen im Bereich des tibetischen Hochlandes.– Petermanns Geographische Mitteilungen, **137** (3): 133–152.
Kuhle, M. (1993b): A Short Report of the Tibet Excursion 14–A, Part of the XIII INQUA Congress 1991 Beijing.– GeoJournal, **29** (4): 426–427.
Kuhle, M. (1994a): Tibet and High-Asia. Results of the Sino-German and Russian-German Joint Expeditions (III).– GeoJournal, **33** (2/3, Tibet and High Asia, Ed: Kuhle, M.): 131–328.
Kuhle, M. (1994b): Present and Pleistocene Glaciation on the North-Western Margin of Tibet between the Karakorum Main Ridge and the Tarim Basin Supporting the Evidence of a Pleistocene Inland Glaciation in Tibet.– GeoJournal, **33** (2/3, Tibet and High Asia, Results of the Sino-German and Russian-German Joint Expeditions (III), Ed: Kuhle, M.): 133–272.
Kuhle, M. (1994c): New Findings on the Glaciation in High Asia: Results of the Expeditions 1989, 1992, 1993 to Central Tibet and the Western Karakorum and Himalaya Mountains. International Symposium and Field Workshop on Glacial Deposits in Monsoon Asia, 27.07.1997, Lanzhou, China; Abstract: 13.
Kuhle, M. (1994d): New Findings on the Ice-cover between Issyk-Kul and K2 (Tian Shan, Karakorum) during the Last Glaciation.– In: Zheng Du; Zhang Qingsong; Pan Yusheng (Eds): Proceedings of the International Symposium on the Karakorum and Kunlun Mountains (ISKKM), Kashi, China, June 1992. p. 185–194; Beijing (China Meteorological Press).
Kuhle, M. (1995a): Glacial Isostatic Uplift of Tibet as a Consequence of a Former Ice Sheet.– GeoJournal, **37** (4): 431–449.
Kuhle, M. (1995b): New Results Concerning the Age Glaciation of Pamir, Karakorum and Himalaya: Findings of the Expeditions 1992–1994/95. Abstracts of the International Symposium on Karakorum-Hindukush-Himalaya: Dynamics of Change, Sept. 29th- Oct. 2nd, 1995, Islamabad, Pakistan.
Kuhle, M. (1995c): New Results concerning the Ice Age Glaciation in High Asia, in particular the Ice Sheet Glaciation of Tibet – Findings of the Expeditions 1991–1995.– Terra Nostra, Schriften der Alfred-Wegener-Stiftung, **2** (International Union for Quaternary Research XIV, International Congress, Berlin): 149.
Kuhle, M. (1995d): New Findings on the Former Glaciation of Russian Tian Shan (Kirgizia) and Eastern Sajan Mountains in South Sibiria and its Climatic Implication. Global Changes and Geography, The IGU Conference Moscow, Russia, August 14.–18., 1995, Moscow; Abstract: 193.
Kuhle, M. (1996): Rekonstruktion der maximalen eiszeitlichen Gletscherbedeckung im Nanga Parbat Massiv (35°05′–40° N/74°20′–75° E).– Beiträge und Materialien zur Regionalen Geographie, **8**

(Forschung am Nanga Parbat. Geschichte und Ergebnisse, Ed: Kick, W.) Inst. f. Geographie, Technische Universität Berlin: 135–156.
Kuhle, M. (1996a): Die Entstehung von Eiszeiten als Folge der Hebung eines subtropischen Hochlandes über die Schneegrenze – dargestellt am Beispiel Tibets.– Der Aufschluss, **47** (4): 145–164.
Kuhle, M. (1996b): Glazial-geomorphologische Expedition in die Karakorum-Nordseite 1986.– Publikationen zu wissenschaftlichen Filmen des Institutes für den Wissenschaftlichen Film (IWF), Technische Wissenschaft/Naturwissenschaft, **12** (Film C 1856): 185–256.
Kuhle, M. (1997): New Findings concerning the Ice Age (Last Glacial Maximum) Glacier Cover of the East-Pamir, of the Nanga Parbat up to the Central Himalaya and of Tibet, as well as the Age of the Tibetan Inland Ice.– GeoJournal, **42** (2–3, Tibet and High Asia. Results of Investigations into High Mountain Geomorphology, Paleo- Glaciology and Climatology of the Pleistocene (Ice Age Research) IV, Ed: Kuhle, M.): 87–257.
Kuhle, M. (1997a): Tibet and High-Asia IV, Results of Investigations into High Mountain Geomorphology, Paleo-Glaciology and Climatology of the Pleistocene (Ice Age Research). Geojournal **42** (2/3); Ed. Kuhle, M. Kluwer, London/ Dordrecht/ Boston. 85–336 p.
Kuhle, M. (1997b): The Ice-Age Glaciation of West-Tibet between Karakorum and Tarim Basin (W-Tibet) and its Impact on the Global Energy Budget.– In: Shams, F.A.; Nawaz, M. (Eds): Volume of Abstracts. Colloquium on Geology and the Human Life Lahore: 4.-6.01.1997. p. 53–54;Lahore (Pakistan Academy of Geological Science).
Kuhle, M. (1997c): Periglacial Keyforms and Indicators of Permafrost and their Relationships with Ice Age Glacier Surfaces in Asia.– Frozen Ground, International Permafrost Association, **21**: 11.
Kuhle, M. (1998a): Reconstruction of the 2.4 Million qkm Late Pleistocene Ice Sheet on the Tibetan Plateau and its Impact on the Global Climate.– Quaternary International, **45/46**: 71–108 (Erratum: Vol. 47/48:173–182 (1998) included).
Kuhle, M. (1998b): Neue Befunde zur hochglazialen (riâ- bis würmzeitlichen) Inlandvereisung Tibets aus Süd- bis Zentralwest-Tibet mit weiteren Hinweisen auf ihre global-klimatische Bedeutung als Eiszeitauslöser.– Berliner Geographische Abhandlungen, **63** (Forschungsergebnisse zur Klimageschichte und Reliefentwicklung Nordafrikas und Asiens. Dieter Jäkel-Festschrift, Eds: Böse, M.; Hofmann, J.): 121–151.
Kuhle, M. (1998c): New Findings on the Inland Glaciation of Tibet from South and Central West Tibet with Evidences for its Importance as an Ice Age Trigger.– Himalayan Geology, **19** (2, The role of the Tibetan Plateau in forcing global climatic changes, Ed: Tandon, O.P.): 3–22.
Kuhle, M. (1998d): Weitere Befunde zur hoch- (pre-LGM und LGM) und spätglazialen Gletscherbedeckung in Süd-, Zentral- und Westtibet.– In: Hubberten (Ed): Band für Alfred Wegener Institut, Potsdam, 8. u. 9.5.1998.
Kuhle, M. (1998e): New Findings Supporting the Pleistocene Ice Sheet on the Tibetan Plateau: Results of the researches 1992–1997.– In: Fukusawa, H. (Ed): Palaeohydrology with an emphasis on humid, temperate and tectonically active Zones. Kumagaya and the Japan Alps 4-11.09.1998. Abstracts.;Kumagaya/Japan; Abstract ().
Kuhle, M. (1998f): Late Pleistocene Megaflood Deposits as a product of numerous outbreaks of Late Glacial ice dammed lakes in Tibet and its bordering mountains.– A new concept for High Asia deduced from a very extended glaciation.– In: (): Symposium on flood and Megaflood Deposits: Recent and ancient examples. 15th International Sedimentological Congress IAS, Alicante, Spain, 13–17th, April 1998. p. 2; Alicante.
Kuhle, M. (1998g): Landschaftsentwicklung extremen Hochgebirges. Karakorum und Kuenlun. Begleittext zum Film C 2017 'Karakorum'.– Publikationen zu wissenschaftlichen Filmen des Institutes für den Wissenschaftlichen Film (IWF), Technische Wissenschaft/Naturwissenschaft, **13**: 97–147.
Kuhle, M. (1998h): Neue Ergebnisse zur Eiszeitforschung Hochasiens in Zusammenschau mit den Untersuchungen der letzten 20 Jahre.– Petermanns Geographische Mitteilungen, 142, **3/4** (Eds: Pachur, H.-J.; Wünnemann, B.): 219–226.
Kuhle, M. (1998i): The Mechanism of the Genesis of Ice Ages induced by the Uplift of the Tibetan Plateau.– In: Owen, L. (Ed): 1998 Annual Meeting of IGCP 415 Grand & Meetings of Working Groups 2 & 7, Manali and the Lahul Himalaya, Abstracts. p. 4; Riverside (University of California).
Kuhle, M. (1998j): New Findings Supporting the Pleistocene Ice Sheet on the Tibetean Plateau: Results of the researches 1992–1997.– In: Owen, L. (Ed): 1998 Annual Meeting of IGCP 415 Grand & Meetings of Working Groups 2 & 7, Manali and the Lahul Himalaya, Abstracts. p. 3; Riverside (University of California).
Kuhle, M. (1998k): The Ice Age Glaciation of East-Pamir (36°40′–39°10′ N/74°40′—76°10′ E).– In: Stellrecht, I. (Ed): Karakorum – Hindukush – Himalaya: Dynamics of Change. Culture Area Karakorum, Scientific Studies 4/1. p. 29–47; Köln (Rüdiger Köppe Verlag).
Kuhle, M. (1999): Reconstruction of an approximately complete Quaternary Tibetan Inland Glaciation between the Mt. Everest- and Cho Oyu Massifs and the Aksai Chin. – A new glaciogeomorphological southeast-northwest diagonal profile through Tibet and its consequences for the glacial isostasy and Ice Age cycle.– GeoJournal, **47** (1–2, (Results of Investigations into High Mountain Geomorphology, Paleo-Glaciology and Climatology of the Pleistocene), Tibet and High Asia (V), Ed: Kuhle, M.): 3–276.
Kuhle, M. (1999a): Tibet and High Asia (V) (Results of Investigations into High Mountain Geomorphology, Paleo-Glaciology and Climatology of the Pleistocene) GeoJournal **47** (1/2); Ed. Kuhle, M. Kluwer Academic Press, London/ Dordrecht/ Boston. 394 p.
Kuhle, M. (1999b): Maximum ice cover in High Asia during the Ice Age – its extent, age and paleoclimatic impact.– Terra Nostra, Schriften der Alfred-Wegener-Stiftung, **99** (2, 14th Himalaya-Karakorum-Tibet Workshop, Kloster Ettal 24.–26. March 1999, Eds: Sobel, E.; Appel, E.; Strecker, M.; Ratschbacher, L.; Blisniuk, P.): 90–91.
Kuhle, M. (1999c): The Uplift of Tibet above the Snowline and its Complete Glaciation as Trigger of the Quaternary Ice Ages – A Hypothesis for the Ice Age Development. Abstract.– Geological Society of America (GSA) Publications, **31**: 141.
Kuhle, M. (2000a): The Uplift of Tibet above the Snowline and its Complete Glaciation as Trigger of the Quaternary Ice Ages. – A Hypothesis for Ice Age Development.– International Project on Paleolimnology and Late Cenozoic Climate IPPCCE, **13** (Ed: Shoji Horie): 36–59.
Kuhle, M. (2000b): Pleistocene Glaciations in the Himalayas and Tibet: New Findings from the Himalaya North Slopes to Central and Western Tibet.– Marburger Geographische Schriften, **135** (Environmental Changes in High Asia. Proceedings of an International Symposium 29th of May to 1st of June 1997 under the auspices of the UNESCO, Eds: Miehe, G.; Zhang Yili): 1–14.
Kuhle, M. (2000c): New Findings Supporting the Pleistocene Ice Sheet on the Tibetan Plateau as a Trigger of the Quaternary Ice Ages – A Hypothesis for Ice Age Development.– In: Zheng Du; Zhu Liping (Eds): Formation and Evolution, Enviromental Changes and Sustainable Development on the Tibetan Plateau – Proccedings of International Symposium on the Qinghai-Tibetan Plateau (Xining 1998). p. 96–115; Xining, China (Academy Press).
Kuhle, M. (2002): A relief-specific model of the ice age on the basis of uplift-controlled glacier areas in Tibet and the corresponding albedo increase as well as their positiv climatological feedback by means of the global radiation geometry.– Climate Research, **20**: 1–7.
Kuhle, M.; Grosswald, M.G.; Dyurgerov, M.B. (1997): Quaternary Glaciation in North-Western High-Asia.– Data of Glaciological Studies, **81** (Proceedings of the International Symposium 'Seasonal and Longterm Fluctuations of Nival and Glacial Processes in Mountains', Tashkent Symposium 12-19.09.1993): 70–79.
Kuhle, M.; Herterich, K.; Calov, R. (1989): On the Ice Age Glaciation of the Tibetan Highlands and its Transformation into a 3-D Model.– GeoJournal, **19** (2): 201–206.
Kuhle, M.; Jacobsen, J.P. (1988): On the Geoecology of Southern Tibet – Measurements of Climate Parameters including Surface- and Soil-Temperatures in Debris, Rock, Snow, Firn and Ice during the South Tibet- and Mt. Everest Expedition in 1984.– GeoJournal, **17** (4, Tibet and High-Asia, Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 597–615.
Kuhle, M.; Kleindienst-Andreé, D. (1994): Glazial-geomorphologische Expedition in die Karakorum-Nordseite 1986. Filmton-Farbfilm 16mm, Dauer 88min, produziert im Institut für den wissenschaftlichen Film (IWF); Film: V 2520–C 1856, Göttingen (German and English Version).
Kuhle, M.; Kleindienst-Andreé, D. (1998): Landschaftsentwicklung extremen Hochgebirges. Karakorum und Kuenlun. Lichtton-Farbfilm C 2017 'Karakorum',Institut für den Wissenschaftlichen Film (IWF), 50 Min; Göttingen (German and English version).

Kuhle, M.; Kuhle, S. (1997): Der quartäre Klimawandel – System oder geschichtliches Ereignis? Überlegungen zur geographischen Methode am Beispiel von Eiszeittheorien.– Erdkunde, **51**: 114–130.

Kuhle, M.; Meiners, S.; Iturrizaga, L. (1998): Glacier-Induced Hazards as a Consequence of Glacigenic Mountain Landscapes, in Particular Glacier- and Moraine-Dammed Laks Outbursts and Holocene Debris Production.– In: Kalvoda, J.; Rosenfeld, C.L. (Eds): Geomorphological Hazards in High Mountain Areas. (GeoJournal Library.), p. 63–96; Netherlands (Kluver Academic Publishers).

Kuhle, M.; Wenjing, W. (1988): The Sino-German Joint Expedition to Southern Tibet, Sisha Pangma and the Northern Flank of Chomolungma (Mt. Everest) 1984.– GeoJournal, **17** (4, Tibet and High-Asia, Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 447–455.

Kuhle, M.; Daoming, X. (1991): Results of the Sino-German Joint Expeditions (II).– GeoJournal, **25** (2/3, Tibet and High Asia, Eds: Kuhle, M.; Xu Daoming): 131–303.

Kuhle, M.; Xu Daoming (1999): Quaternary glaciation in the Qinghai-Xizang (Tibetan) Plateau.– In: Zheng Benxing; Shen Yongping (Eds): Problems on Quaternary Glaciation Research in the Qinghai-Tibetan Plateau. Contributions Collections of Research on Quaternary Glaciation and Environments in the Qinghai-Tibetan Plateau. Vol. 3. p. 480–484; Lanzhou, China (Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences).

Lydekker, R. (1881): Geology of part of Dardistan, Baltistan and Neighbouring Districts.– Rec. GsuI., **14**.

Lydekker, R. (1883): The Geology of Kashmir and Chamba Territories.– Mem. Gsul., **22**.

Maull, O. (1958): Handbuch der Geomorphologie. 2nd ed. Verlag Franz Deuticke, Wien. 642 p.

Meiners, S. (1996): Zur Rezenten, Historischen und Postglazialen Vergletscherung an ausgewählten Beispielen des Tien Shan und des Nord-West-Karakorum.– GeoAktuell, **2**: 1–200.

Meiners, S. (1997): Historical to Postglacial glaciation and their differentiation from the Late Glacial period on examples of the Tian Shan and the N.W. Karakorum.– GeoJournal, **42** (2–3, Tibet and High Asia, Results of Investigations into High Mountain Geomorphology, Paleo-Glaciology and Climatology of the Pleistocene (Ice Age Research IV), Ed: Kuhle, M.): 259–302.

Meiners, S. (1998): Beobachtungen zur jüngeren Vergletscherungsgeschichte im Nordwestkarakorum und zentralen Tienschan.– Petermanns Geographische Mitteilungen, **142** (3/4): 227–232.

Meiners, S. (2001): The post to late glacial valley reconstruction on the Haramosh north side (Mani, Baska, Phuparash valleys).– GeoJournal, (Tibet and High Asia VI, Glacio-geomorphology and prehistoric Glaciation in the Karakoram and Himalaya): Ed.: Kuhle, M.): 323–344.

Nielsen, P.E. (1983): Lithology and genesis of Danish tills.– In: Ehlers, J. (Ed): Glacial deposits in North-West Europe. p. 193–196; Rotterdam.

Norin, E. (1925): Preliminary notes on the late Quaternary glaciation of the Northwest Himalaya.– Geografiske Annaler, **7**.

Oestreich, K. (1906): Die Täler des nordwestlichen Himalaya.– Petermanns Geographische Mitteilungen, Ergänzungsband, **155**: 1–106.

Owen, L. (1988a): Terraces, Uplift and Climate, the Karakoram Mountains, Northern Pakistan. Unpublished Ph.D. thesis, Department of Geography, university of Leicester, UK (unpublished).

Owen, L. (1988b): Wet-sediment deformtion of Quaternary and recent sediments in the Skardu Basin, Karakoram mountains, Pakistan.– In: Grott, D.G. (Ed): Glaciotectonics. Forms and Processes; Rotterdam (Balkema).

Schneider, H.J. (1956): Geologische und erdmagnetische Arbeiten im NW-Karakorum.– Erdkunde, **10**: 1–93.

Schneider, H.J. (1957): Tektonik und Magmatismus im NW-Karakorum.– Geologische Rundschau, **46**: 426–476.

Schreiner, A. (1992): Einführung in die Quartärgeologie. 257 p.

Searle, M.P. (1991): Geology and Tectonics of the Karakoram Mountains. John Wiley & Sons, New York, London. 358 S.

Shroder, J.F. (1989): Geolosphic development of the W-Himalayas.

Shroder, J.F., Jr.; Owen, L.; Derbyshire, E. (1993): Quaternary glaciation of the Karakoram and Nanga Parbat Himalaya.– In: Shroder, J.F., Jr. (Ed): Himalaya to the sea: Geology, Geomorphology and the Quaternary. p. 132–158; New York (Routledge).

Troll, C. (1938a): Der Nanga Parbat als geographische Erscheinung. Ein Bildbericht.– Zeitschrift für Erdkunde, **6** (1/7): .

Troll, C. (1938b): Der Nanga Parbat als Ziel deutscher Forschung.– Zeitschrift der Gesellschaft für Erdkunde Berlin, **73**: 1–26.

Tucker, M. (1996): Methoden der Sedimentologie. 366 p.

Visser, P.C. (1935): Gletscherbeobachtungen im Karakorum.– Zeitschrift für Gletscherkunde, **22**: 20–45.

Visser, P.C. (1938): Glaziologie. Wissenschaftliche Ergebnisse der niederländischen Expedition in den Karakorum und die angrenzenden Gebiete in den Jahren 1922, 1925 und 1929/30 und 1935. Hersg. DH. C. Visser u. Jenny Visso-Hooft; Bd. II; E.J. Brill, Leiden: 1–216.

Wissmann, H.v. (1959): Die heutige Vergletscherung und Schneegrenze in Hochasien mit Hinweis auf die Vergletscherung der letzten Eiszeit.– Akademie der Wissenschaften und der Literatur Mainz, Mathetematisch-naturwissenschaftliche Klasse, **14**: 1103–1407.

Zanettin, B. (1964): Geology and Petrology of Haramosh Mango Gusor Area.– In: Italian Expeditions to the Karakoram (K2) and Hindu Kush. Vol. III Geology-Petrology; Leiden (Brill).

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Lateroglacial valleys and landforms in the Karakoram Mountains (Pakistan)

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Abstract

Lateroglacial landforms play a major role in the geomorphological landscape assemblage of the Karakoram Mountains. Nevertheless, in the past they have received only little attention in the glacial-geomorphological literature. In this article, the lateroglacial landscape will be presented as a geomorphological landscape unit. The Karakoram glaciers with lengths of up to 60 km are accompanied by lateroglacial sediment complexes over tens of kilometers. Besides their large horizontal distribution, they are spread over a considerable vertical range and occur between 2500 m–5000 m.

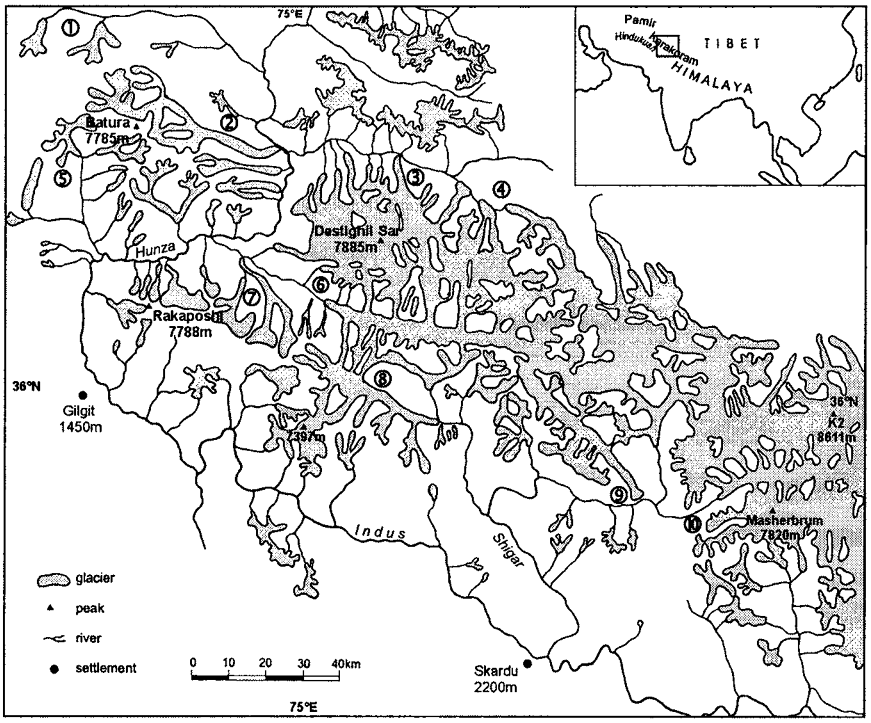
The traditional view is that primary processes of rock disintegration such as ice avalanches and freeze-thaw processes as well as glaciofluvial sediments are the main debris suppliers for the formation of lateroglacial sediment complexes. However, the investigation of the lateroglacial sediment landscape of the Karakoram glaciers showed, that firstly the secondary debris supply in form of reworking of older glacigenic deposits (Late glacial slope moraines) represents a major debris source. Secondly, the lateroglacial sediments are composed to a major part of debris supplies from the tributary valleys. In this regard, the sediment input by mudflow events accords a prominent role. Therefore a considerable proportion of the lateroglacial sediments is of non-glacial origin. This fact has to be taken into consideration regarding glacier reconstruction in recent unglaciated mountain valleys. Further on, resedimented mudflow deposits could be identified as important parent material for recent lateral moraine formation. The distribution of lateroglacial valleys ('lateral moraine valleys') was traditionally closely linked to differences in insolation, which are in the subtropical latitude very high ('ablation valleys'). Therefore the S-faced valley flank was seen as the favourable location for lateroglacial valleys. However, field observations on more than 20 glaciers in the Karakoram Mountains proved that lateroglacial valleys occur in all exposures, and can be even absent in S-exposure. Topographical factors seem to be more important than insolation differences for the distribution pattern. Only the distribution of 'true ablation valleys' can be regarded as a result of insolation differences. In fact, they can act as initial form for the formation of lateral moraine valleys.

Introduction: The problem of terminology

The Karakoram glaciers (Fig. 1) are accompanied along their lateral margins by remarkable expansive sediment complexes over distances of several tens of kilometers. Up to now the genesis and composition of this lateroglacial sediment assemblage is little studied. Therefore a consistent terminology for this geomorphological unit is still missing. The first researchers who made observations along the lateroglacial sediment landscape of the Karakoram glaciers were Workman (1905) and Oestreich (1906, 1911/12). Oestreich named the lateroglacial depressions along the Chogolungma glacier 'Randtälchen' (*small marginal valleys*). Later on Visser (1928, 1938) recognized that these geomorphological features seem to be characteristical key forms of subtropical high mountain areas. He introduced for this – in his opinion - climatic-controlled phenomenons the term 'Ablationsschlucht' resp. 'Ablationstal' (*ablation valley*). Nowadays the 'ablation valley' has become the most common expression in the glacial geomorphology for those landforms. But nevertheless, this genetic term caused much confusion among geomorphologists (Hewitt 1989), because not every ice-marginal depression is a result of ablation processes. v. Klebelsberg (1938) favoured the more neutral term 'Ufertäler', which was subsequently also adopted by Kick (1956) and Haserodt (1989). In this article these marginal sediment complexes are termed as 'lateroglacial' or 'lateroglacial' valleys.[1]

In the last decades of research, lateroglacial valleys were noted in the Karakoram, especially in the works of Haserodt (1989), Hewitt (1989, 1993), Owen & Derbyshire (1989), Kuhle (1991), Kamp (1999) and Iturrizaga (1999a, 1999b, 2000). They are also known from other mountain areas such as from the Himalayas (Strachey 1847, Odell 1925, Schwarzgruber 1939), from the Alps (Flaig 1938) and from the Andes (Jordan 1991). Jorstad (1957) provides a de-

[1] In the English nomenclature the term "*lateroglacial*" is already applied to the debris accumulations which are induced by glacigenic processes (Church & Ryder 1972), whereas in the German terminology "*lateroglazial*" is used for the space and sediments which stretches along the lateral margins of the glacier (v. Klebelsberg 1950, Eggers 1961). In the latter sense, the term "*lateroglacial*" is applied in this article.



① Yishkuk glacier

② Batura, Pasu, Ghulkin, Ghulmit glaciers

③ Lupghar, Momhil, Malangutti glaciers

④ Yukshin Gardan, Yazghil, Khurdopin, Virjerab glaciers

⑤ Kukuar, Hassanabad glaciers

⑥ Hispar glacier

⑦ Bualtar, Hopar glaciers

⑧ Chogolungma glacier

⑨ Biafo glacier, Deste glacier

⑩ Baltoro glacier

Figure 1. The research areas in the Karakoram Mountains.

tailed summary of the early research work about ablation and lateroglacial valleys in general.

Main characteristics of lateroglacial valleys

Almost every Karakoram glacier is accompanied by lateroglacial valleys in some parts. They are mostly non-continuous forms. Where mountain spurs stand out against the main valley or in glaciated confluence areas, the lateroglacial valleys are interrupted (Photos 3, 11). Therefore they are not really true valleys because they do not have a consistent gradient. Some of the longest continuous lateroglacial valleys with length of up to 20 km are developed along the Batura and Barpu glaciers (Photos 1, 11, 12). They can reach a width of up to several hundred meters (Photo 2). The glaciers themselves are up to 2–3 km broad. In most cases the marginal valleys are separated from the glacier by the lateral moraine (‘*lateral moraine valleys*’) (Fig. 4). The moraine wall prevents the direct debris transfer from the glacier to the lateroglacial valleys. Therefore the debris development in those lateroglacial valleys is well protected against glacial activities by the moraine ridge. The maximum height of the inner slope of the lateral moraine can amount up to 200 m (Photo 23); the height of the outer slope mostly not exceeds 50–70 m, except along dam glaciers. In most cases the latter is only 5–30 m high (Photo 4). This conspicuous moraine, which is characteristic for the majority of the Karakoram glaciers, was termed ‘Grosse Lateralmoräne’ (*Great Lateral Moraine*) by Kick (1956) (Photos 4, 7 & 8). As it is shown below, this landform does not represent a single moraine wall and least of all the sedimentary legacy of one glacier advance. Often the seemingly uniform moraine walls consist of several closely nested moraine ridges, which are in turn composed of several superimposed individual moraine layers (Photos 9, 10).

Lateroglacial valleys represent a special geomorphological unit. The main characteristic of the lateroglacial sediment regime is the damming effect of the lateral moraine or the glacier itself. The lateroglacial sediments differ from the normal cone-shaped deposits of unglaciated valleys in that they are usually not undercut by the receiving stream and also do not have a central incision canyon. Therefore the mudflow cones and alluvial cones normally show a uniform surface and are not composed of several levels (Photos 2 & 3). Only when the glacier shrinks and the ice abutment is absent for a long time, the cones are gradually dissected.

Very common in the lateroglacial valleys are temporary lakes, which are mostly dammed by mudflows and avalanche deposits (especially along Chogolungma, Hispar, Batura, Momhil glaciers) or build up in confluence areas (Photos 6, 22).

Altitudinal distribution of lateroglacial valleys and landforms in the Karakoram

Fig. 2 gives a rough overview of the altitudinal distribution of selected types of debris accumulations in the Karakoram. The '*glacial transitional debris accumulations*' or '*transglacial sediments*' (slope moraines and morainic alluvial and mudflow cones) show the most wide spread distribution and occur mainly between 1500 m and 4000 m. This category comprises the transformation and reshaping of glacial deposits by post-sedimentary processes after deglaciation. Lateroglacial sediments also provide a considerable part of the debris accumulations in the Karakoram. The glacier tongues in this subtropical mountain range extend to remarkable low altitudes. Thus the distribution of lateroglacial sediments covers an altitudinal range of 2500 m ranging from approximately 2500 m to 5000 m. The maximum upper limit is theoretically given by the height of the snow line. Due to the fact that a major part of the glaciers are avalanche-fed glaciers (Turkestan and Muztagh type), the snow line runs at approx. 4900 m–5200 m in the steep valley flanks. Therefore the distribution of lateroglacial valleys starts usually 1000 m–1500 m lower than the snowline, where the valley bottom begins and debris deposition becomes possible (Photos 11 & 15). Relict lateroglacial valleys occur up to 1000m above the present lateroglacial valleys at a height between 3700 m and 4100 m (Photos 36 & 37). In some cases they can easily mistaken for 'little surge valleys' (cf. Heim 1932, Hewitt 1999). The latter are the product of catastrophic landslides.

The size of the lateroglacial valleys is not proportional to the size of the glaciers. Very large glaciers (e.g. Baltoro glacier, Photo 25) can be almost depleted of marginal sediments, whereas small glaciers (e.g. Ghulkin glacier, Photo 35) are accompanied by broad lateroglacial valleys. That can be explained by the fact, that most of the Baltoro glacier surface runs comparatively high (above 4000 m) and the steep granitic valley flanks impede the deposition and preservation of morainic material.

In general, the conditions for debris deposition in the Karakoram are very favourable, because longitudinal valleys, which provide enough space and flat areas, largely divide the mountain range. Nevertheless, the Karakoram glaciers are embedded in a deeply dissected mountain relief. Primary processes of rock disintegration such as ice avalanches and freeze-thaw processes provide huge amounts of debris. Slope moraines from the Late Glacial glaciation supply another major source of debris. They are reworked by several glacier advances and retreats. Among the avalanche-fed glacier types a positive factor for debris deposition is the abrupt break in slope gradient. It changes very sudden from over 40° in the feeding area to less than 5° in the ablation area (e.g. Khunyang Chhish, Barpu, Ghulkin, Hassanabad, Pumari Chhish glaciers, Photo 15). Moreover, the Karakoram glaciers possess a remarkable huge ablation area. Whereas in the Alps the ratio between accumulation and ablation areas is 2 : 1 or 3 : 1, the situation can be even inverse in the Karakoram. The Batura and Momhil glaciers show a ratio of 1 : 2, the Khurdopin glacier of 1 : 3 and the Virjerab glacier of 1 : 4 (Visser 1938). Therefore very favourable conditions for debris deposition are present along these glaciers.

Types of lateroglacial depressions

A very heterogeneous assemblage of lateroglacial depressions and corresponding sediments is developed along the Karakoram glaciers, even on glaciers, which seem to be comparable when considering their supply areas and their topographic constellation. Fig. 3 shows some selected forms of lateroglacial depressions. The morphological transition from the valley flank to the glacier emerges in different variations. The formation of an ablation valley (Fig. 3, A & B, cf. Photo 21) is a direct consequence of insolation and reflection effects in the dry and thin high mountain air. Due to the strong heating of the rock and the ensuing transfer of sensible and latent heat, the glacier ice is melting back at its margins (Visser 1938). The extent varies from some meters to decameters. This is a wide spread landscape feature in this subtropical latitude with high insolation rates. The ablation valley cannot be considered as a form of general ice shrinkage. It also occurs on advancing glaciers. The ablation valley can exist between the valley flank and the glacier (Fig. 3A), but it also emerges between the lateral moraine and the glacier (Fig. 3B).

In contrast to the ablation valley, the lateral moraine valley (Fig. 3E, Photos 1, 3, 4, 7) is separated by the lateral moraine from the glacier (Fig. 4). It is the most widespread lateroglacial sedimentation form along the Karakoram glaciers. The lateral moraine valleys can be divided into two types: 1. The V-shaped lateral moraine valley, in which the lateral moraine is directly connected with the adjacent valley flank or talus cones (e.g. along Yazghil, Ghulkin, Ghulmit and Pumari Chhish glaciers, Photo 8). 2. The V-shaped lateral moraine valley with a true valley bottom floor, where fluvial and lacustrine sediments are deposited (e.g. along Khurdopin, Malungutti, Chogolungma glaciers, Photo 2). Very well developed V-shaped lateral moraine valleys can be found along the dam and pedestal

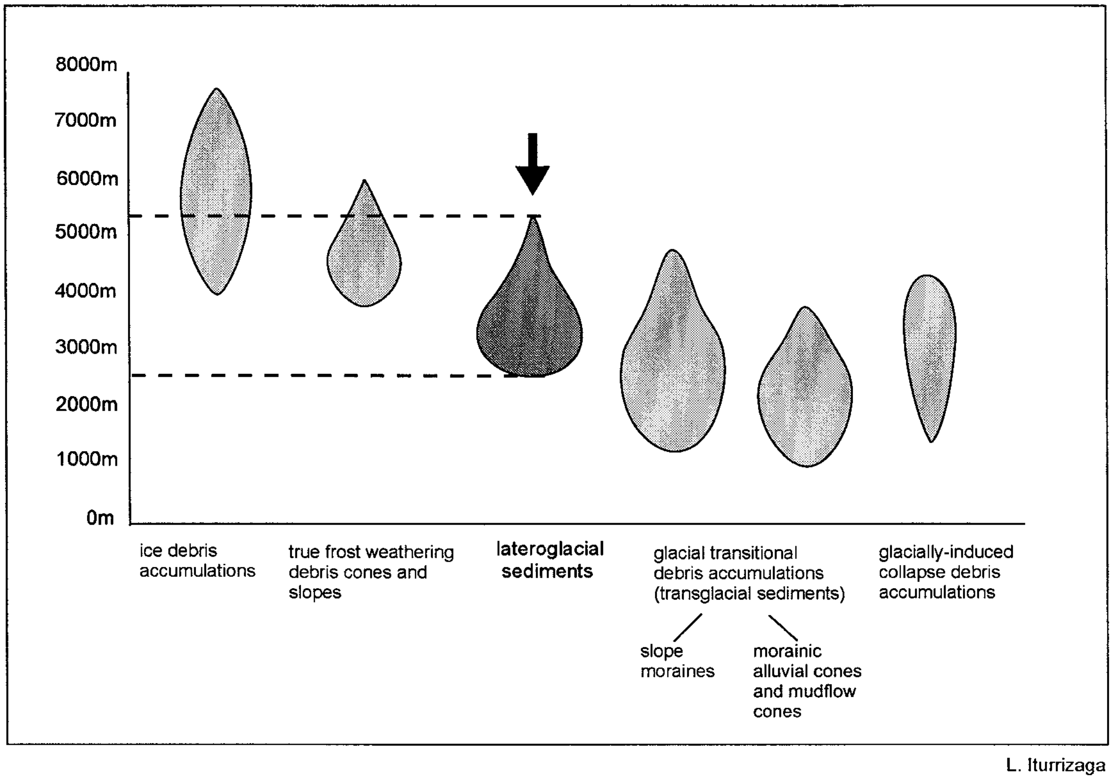


Figure 2. Distribution of main types of debris accumulations in the Karakoram (approximate altitude belts).

glaciers.[2] Their depth reach up to 100 m. They represent not fluvial erosion forms, but accumulation forms which are due to the moraine deposition against the adjacent valley flank. In general, fluvial incision and corresponding terracing in the lateroglacial valleys is very rare. Between Guchisim (3650 m) and Fatmahil (3300 m) at the Batura glacier, the fluvial drainage is so high, that linear erosion takes place and even the lateral moraine is dissected by the lateroglacial streams (Photo 24). But in many lateral moraine valleys a lateroglacial drainage pattern is even absent.

In some parts, the lateroglacial sediments are deposited in form of a lateral moraine terrace (Fig. 3F). The moraine ridge might have been eroded by glacial undercutting or it is also possible that ridge formation never took place at all. If the debris supply comes from the glacier (supraglacial meltwater discharge), a lateroglacial bank sandur is present (kame terrace) (Fig. 3D). They are relatively rare along the Karakoram glaciers. A further type represents is the supraglacial lateral depression (Fig. 3C, Photo 17). The term refers to the space between a supraglacial lateral moraine ridge on the glacier and the valley flank or the adjacent lateral moraine.

The term 'kame terrace', which was introduced by Jamieson (1874), is most common as description of lateroglacial sediment complexes in glacial geomorphology (Flint 1971). However, the kame terrace describes a geomorphological form after deglaciation and not in recent glaciated mountain areas. Further on, the kame terraces supposed to be building up by glaciofluvial sediments. Therefore it is not appropriate for most of the sediment complexes along the Karakoram glaciers, which represent highly polygenetic forms.

The genesis and distribution of lateroglacial valleys: Insolation differences, topographical conditions and debris supply areas

Visser (1928, 1938) suggested that the genesis and therefore the distribution of lateral moraine valleys[3] are dependent on exposition. According to Visser, the development of these lateroglacial depressions is supposed to be better at the S-faced valley sides along the W-E flowing glaciers flowing W-E than along the N-faced valley sides. In the case of N-S running glaciers, lateroglacial valleys should be present at both sides, but be smaller in size. First observations onof about 20 selected glaciers[4] in the Karakoram evidenced that lateral moraine valleys occur principally on both sides along the glaciers in all expositions (Photos 1, 3, 4 & 9). In fact, the S-sides show sometimes better developed lateroglacial valley. This is not due to insolation effects, but because of higher frequency of ice-avalanches at the N-faced

[2]cf. Heim (1933): He recognized the 'Dammgletscher' (dam glacier) as specific type in the glacial geomorphological landscape assemblage (in the research area of the Minya Gongkar-Massif in East-Tibet). Its genesis is discussed in Kuhle (1991).

[3]Visser (1938) considered the lateral moraine valleys as ablation valleys (s. Photo 1).

[4]Research work was carried out at the following Karakoram glaciers: Aldar Kush, Baltoro, Batura, Barpu, Bualtar, Biafo, Chogolungma, Ghulkin, Gulmit, Hassanabad, Hispar (Kunyang Chhish, Pumari Chhish, Yutmaru), Kukuar, Khurdopin, Lupghar, Malangutti, Momhil, Pasu, Shujerab, Skoro, Virjerab, Yazghil and Yishkuk.

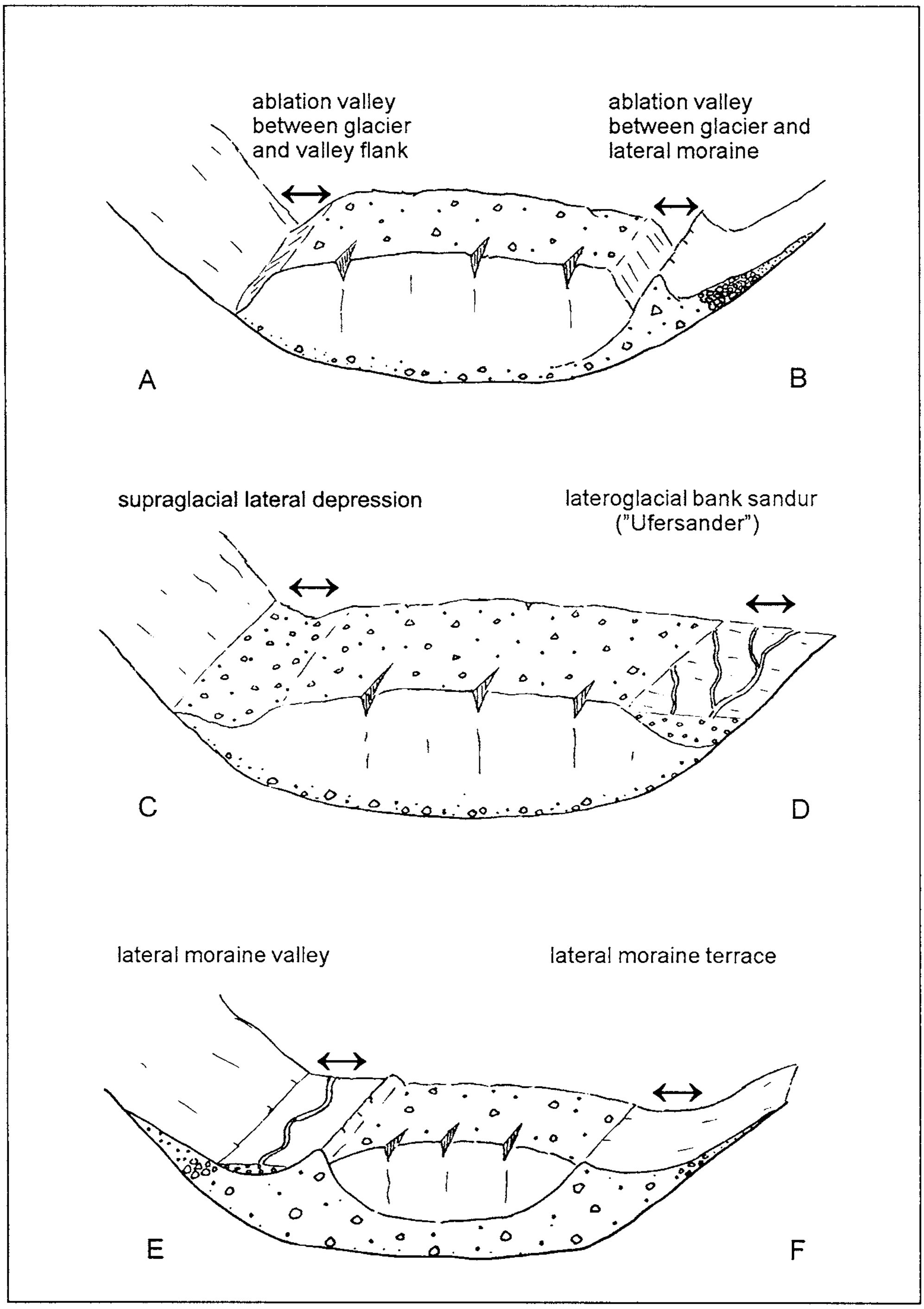


Figure 3. Types of lateroglacial depressions.

valley flanks. In some cases the distribution can be even inverse. Along the Ghulkin glacier, the lateroglacial valley occurs in S-exposition, whereas the neighbouring Ghulmit glacier is accompanied by a lateroglacial valley at its N-facing side. Both glaciers flow in W-E direction. The same situation is the case along the neighbouring Barpu and Bualtar glaciers (Photos 4, 11). On glaciers running N-S (e.g. Aldar Kush, Yishkuk and Khurdopin glaciers), asymmetric distribution of lateral moraine valleys was noticed, but there is no preference of W- or E-exposure.

The occurrence of lateroglacial valleys is rather linked to topographical factors – and indirectly to exposure-exposition – than to differences in insolation values on the opposite valley flank sides (Photos 5, 6, 24). In principe, the N-facing lateroglacial valleys already peter out at lower altitudes. N-exposition is more favourable for the development of glaciers, even more so in combination with high catchment areas. Therefore expansive glaciations or in particular high-active ice-avalanche cones impede the formation of lateroglacial valleys. Along the Hispar glacier the lat-

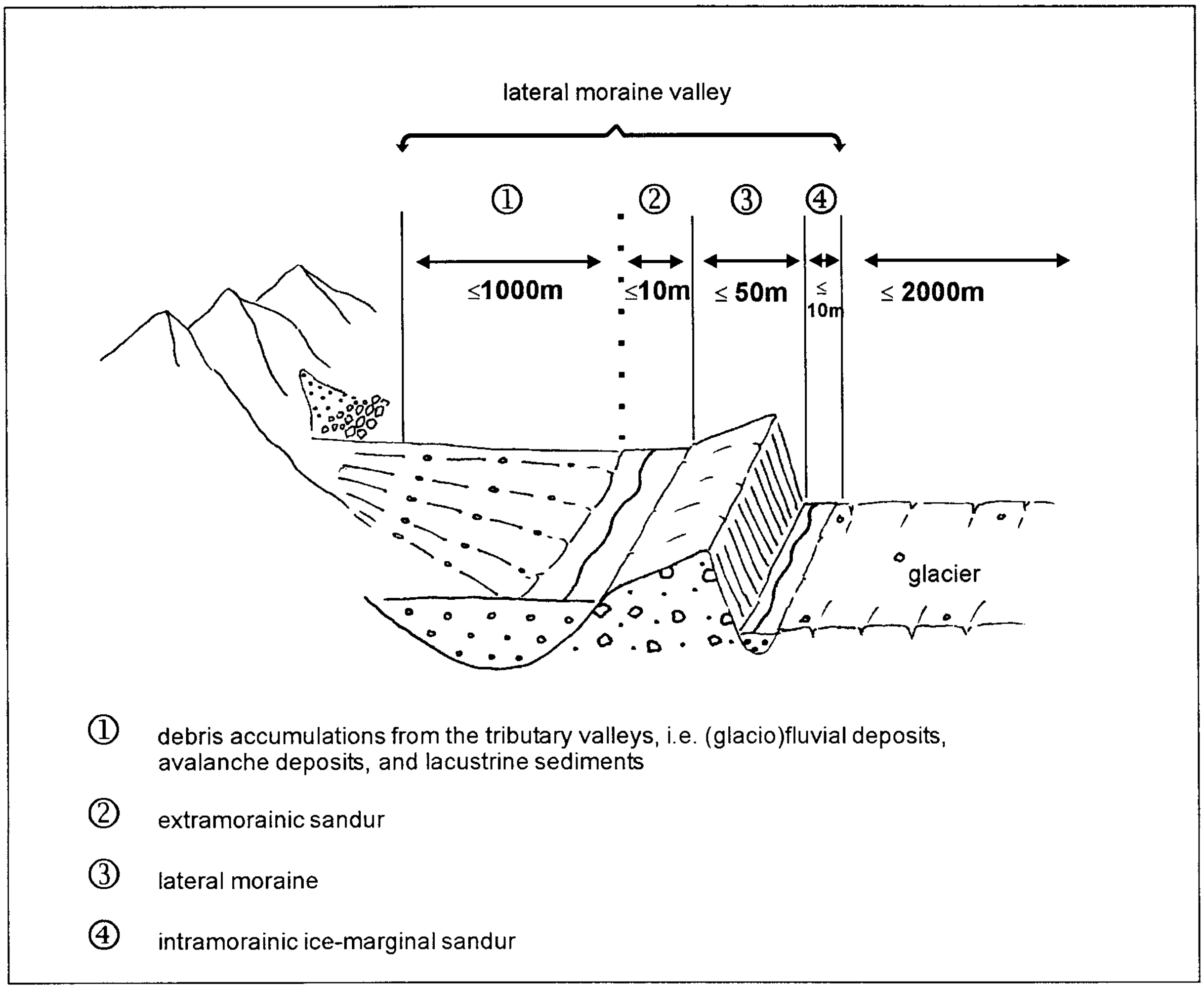


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Figure 4. The geomorphological units of the lateral moraine valley.

eroglacial valley in N-exposure already ends in 3800 m, whereas in S-exposure the marginal valley reaches up to almost 4400 m (Photo 5). Visser's observations on exposure might be very true for pure ablation valleys, because their genesis is directly dependent on insolation effects. But most of the lateroglacial valleys are separated by the lateral moraine ridge from the glacier and do not represent the type of ablation valleys. The initial form of the lateroglacial valley can be an ablation valley, but it cannot be seen as an obligatory precondition.

Two genetic approaches are mentioned in the literature to explain the development of the lateral moraine valleys. Workman (1905) believed that the lateroglacial sediments ('*maidans*') are relicts of interglacial terraces (Fig. 6)[5]. According to that view the lateral moraines must be subsequently deposited on the glaciofluvial terraces. Visser (1928, 1938) suggested that the origin of the lateral moraine valleys goes back to insolation effects (Fig. 6). The glacier ice melts back more intense at its margins due to the reflection of heat by the valley flanks. Later on these 'ablation valleys' are filled up with debris, which derives from the glacier margins. This genetical approach was very soon questioned (v. Klebelsberg 1938, Kick 1956, Wiche 1960, Hewitt 1993), but no alternative explanation was offered. Nevertheless, the term 'ablation valley' remained the most common geomorphological expression for this lateroglacial depression. Kuhle (1991) describes the combined complex of lateral moraine and kame terrace as '*Uferbildung*' and established with this approach a more comprehensive view of the lateroglacial sediment landscape.

Field observation revealed that many glaciers show a close interfingering of Late Glacial slope moraines and younger lateroglacial landforms (Photos 33, 34 & 35)[6]. The lateroglacial valleys are actually composed to a considerable part of resedimented moraine material (Fig. 7). During the gradually down-melting of the glacier surface moraine remnants remain along the lateroglacial margins, partly as

[5]The genesis of lateroglacial sediments (interglacial terraces versus kame terraces) was especially discussed by Bobek (1935) and v. Klebelsberg (1950) for localities in the Austrian Alps (Inn Valley). Bobek (1935) introduced the idea of '*Eisrandterrassen*' (ice-marginal terraces).

[6]See for research studies on prehistoric extent of glaciation in the Karakoram Mountains, among others, Oestreich (1906), Dainelli (1922), Derbyshire et al. 1984, Kuhle (1988, 1994, 1998, 2001) and for studies on the postglacial glacier extent Kick 1989, Haserodt 1989, Kalvoda 1992, Meiners 1997.

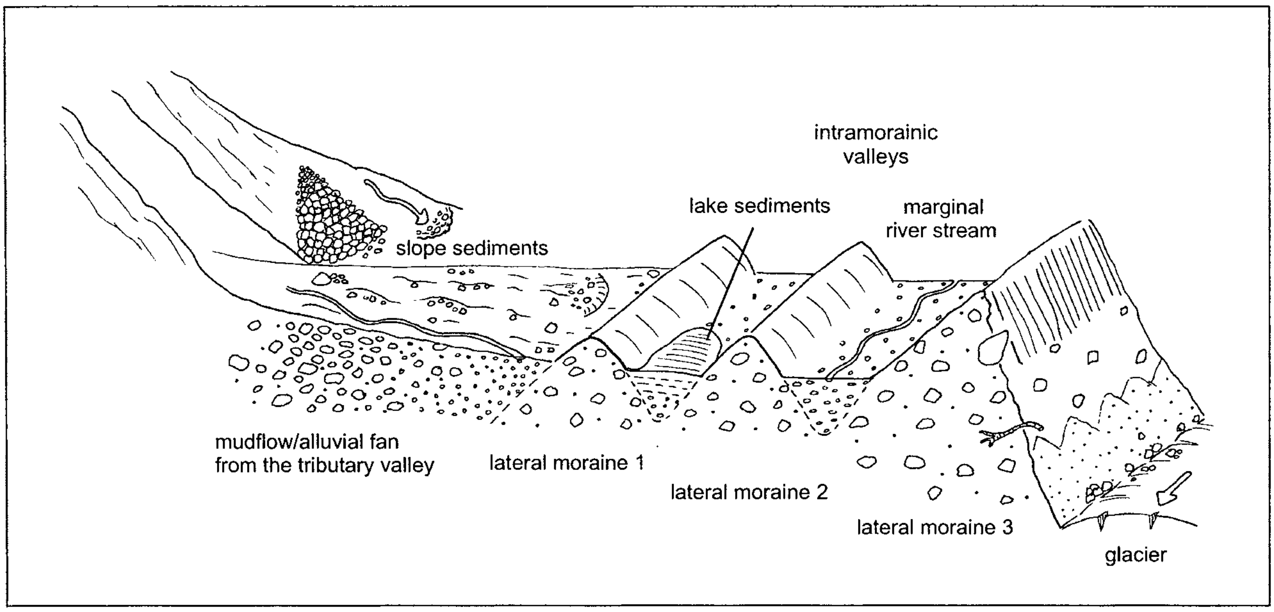


Figure 5. Schematical cross section through a multilateral moraine complex (morainic accretion).

terraces, partly as amorphous deposits. The glacier does not fill up the whole width of the valley. In this connection, the lateroglacial valleys can be interpretated as lateroglacial recessional moraines, which were over and over resedimented and compacted by the glacier during the deglaciation process. In the recent lateroglacial environments, strongly degenerated slope moraines are preserved up to a height of 4000 m (cf. Photo 32). It has also to be considered that the extent of glaciation in the Karakoram has been once smaller than today. In this time, the lateroglacial sediment complexes and lateroglacial valleys were much wider. In the course of glacial readvances the lateroglacial hummocky moraines were picked up by the glacier ice and piled up along the glacier margins.

The debris source areas of the lateroglacial valleys

Up to now the origin of lateroglacial sediments was mainly attributed to glaciofluvial processes in form of the concept of 'kame terraces' resp. '*Ufersander*'. But apart from the Late Glacial moraine material, the main debris supply for the lateroglacial sediment complexes derives from the tributary valleys and not from the glacier. The sediment cones - alluvial fans, mudflow and avalanche cones - drain into the ice-marginal depressions (Photos 2, 3 & 24). They leave behind considerable debris accumulations (Photo 33), because debris transfer is rather low in the lateroglacial valleys.

In principle, two different kind of lateroglacial accumulations can be distinguished in reference to their debris supply areas (Fig. 8): longitudinal and transverse debris accumulations. The first type is deposited parallel to the glacier flow (A). It occurs especially along glaciers, which have no lateral moraine. These glaciofluvial deposits appear after the deglaciation as kame terraces. These purely glaciofluvial sediments are very rare in the lateroglacial environment. The second type are the transverse debris accumulations (B1), which are sedimented by the rivers of the tributary valleys into the glaciated main valley. These kame cones are the main contributor of sediment load for the lateral moraine valleys. The distal base of the debris accumulations is formed by ground moraine material. Another type of transverse debris accumulation is the product of resedimentation processes of the lateral moraine by supraglacial meltwater release and moraine accumulations by overlapping ice tongues (B2).

The lateral moraine: mudflows as supply area for the formation of lateral moraines

Different types of lateral moraines border the Karakoram glaciers[7]. A single representative moraine type – as Winkler (1996) has demonstrated it for alpine and Norwegian glaciers – is not present in the Karakoram. Due to the great length of the glaciers, the variety of glacier types and the wide altitudinal distribution, a lot of different lateral moraine types are present in the lateroglacial environment (i.e. sander moraines, boulder moraines, layered moraines, hummocky moraines etc.).

In most cases, the lateral moraine itself presents a highly polygenetic landform. The lateral moraine is mainly formed by dumping processes of supraglacial debris from the recent glacier margins, by englacial debris transfer or by pushing and redistribution processes of (pre-glacial) debris accumulations. The large size of the lateral moraine is a result of repeated glacier advances. The old 'moraine core' is again and again superimposed by new supraglacial debris.

[7]It is necessary to make a distinction between the 'supraglacial lateral moraine' ('*Seitenmoräne*') and the 'abandoned supraglacial moraine' ('*Ufermoräne*') which is deposited besides the glacier. The later can also still contain an ice-core.

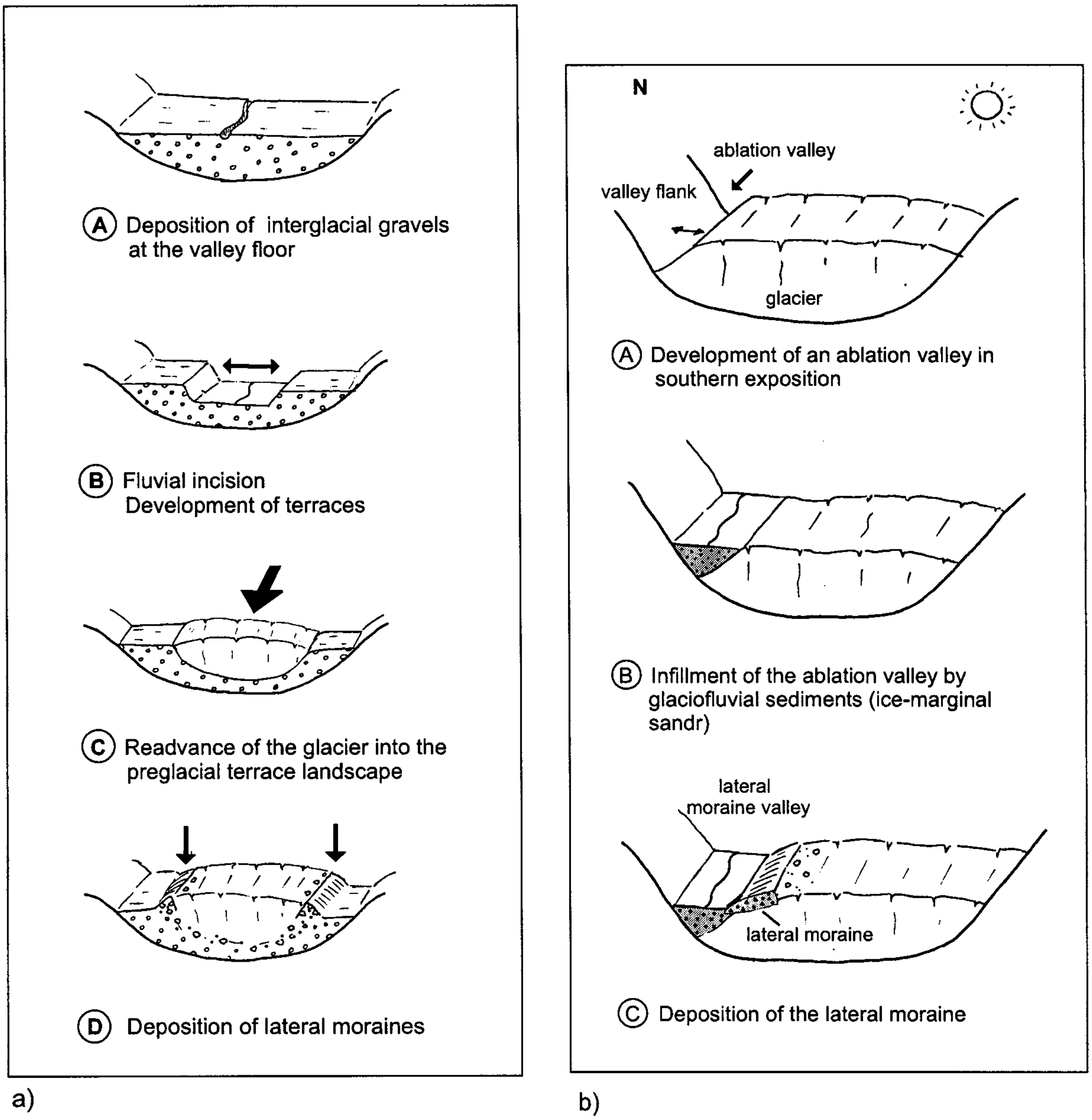


Figure 6. Genesis of lateral moraine valleys according to a) Workman (1905) (interglacial terraces) and to b) Visser (1928, 1938) ('ablation valleys').

A synchronization of the 'Great Lateral Moraine' with the '1850'-moraines from the Alps is very tempting (Mayewski & Jeschke 1979), but this might be a too simplified parallelization (Kick 1989). However, a large number of the high lateral moraines are even today superimposed by new supraglacial debris (i.e. Pumari Chhish glacier, Iturrizaga, in press) and the '1850-advance' was certainly not the last event which reached the lateral moraine crests. ^{14}C-dating of fossil tree trunks in the top section of a lateral moraine of the Momhil glacier, 10 km valley inwards, indicates an age of 1495 +/- 45 ^{14}C-years (Photo 27). Nevertheless, the moraine crest can also be reached by younger glacier advances, which in turn successively uncover more and more material of the older part of the moraine. Fossil wood in the lateral moraine in the lower section of the Lupghar glacier is dated even at its base at 800 $+/-45$ ^{14}C years.

In general, lateral moraine superposition and accretion are closely interlocked, which has to be considered in regard of the age determination. At the glacier tongue areas, which terminate at confluence positions and where the valleys become wider, moraine accretion represent a common phenomenon. The accretion walls can amount up to over a dozen generations, such as along the Malungutti glacier (Photo 39). The individual ridges, which in turn are composed of superimposed moraine layers, can be separated by true intermorainic small valleys in which lacustrine sediments are embedded (Fig. 5).

The internal fabric of the lateral moraines ranges from component- to matrix-supported textures. In principal, at higher altitudes dominate the boulder moraines, whereas in the lower glacier sections strongly matrix-supported moraines are dominant. However, the short avalanche glaciers, such as the Ghulkin, Ghulmit or Pumari Chhish

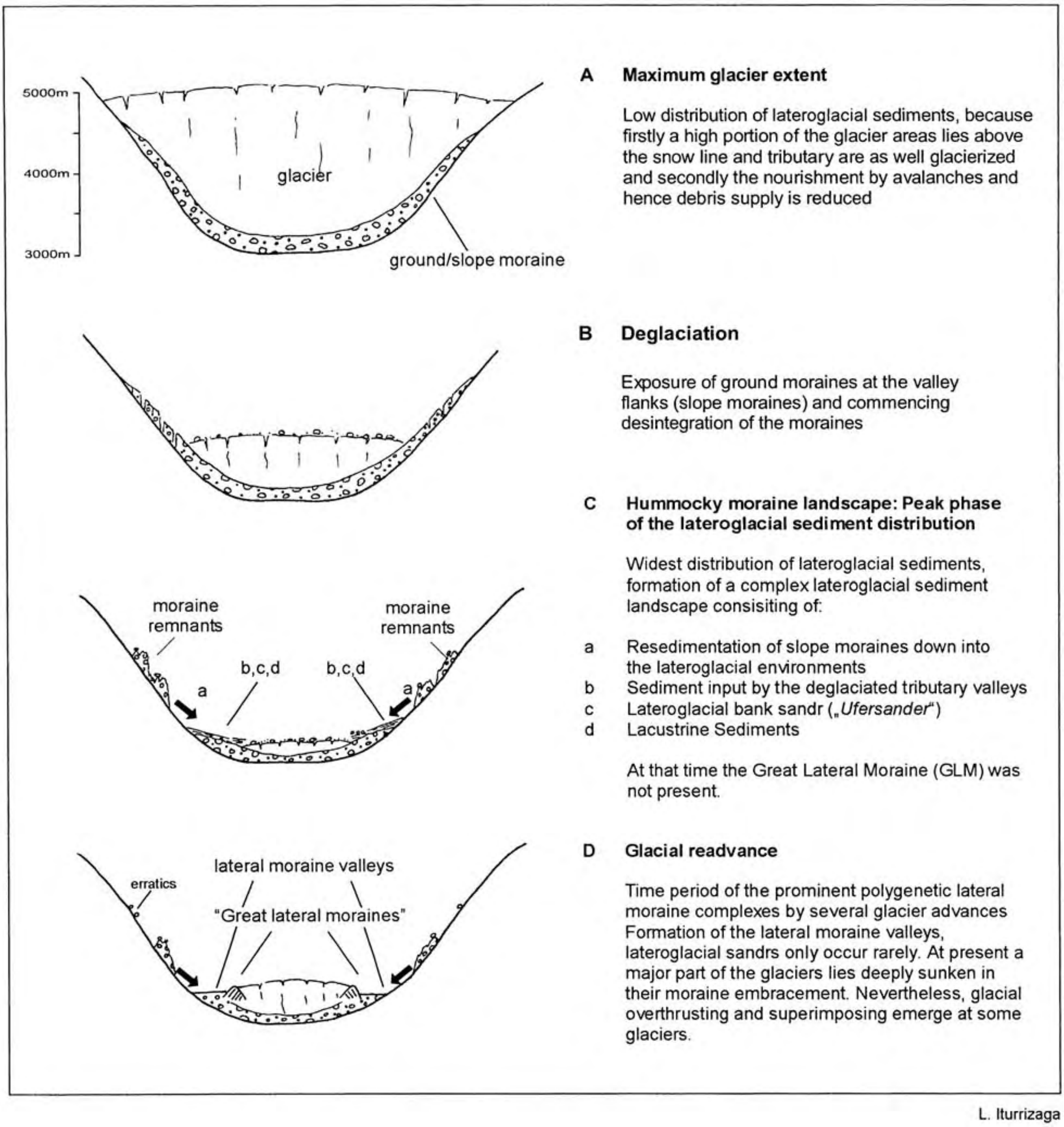
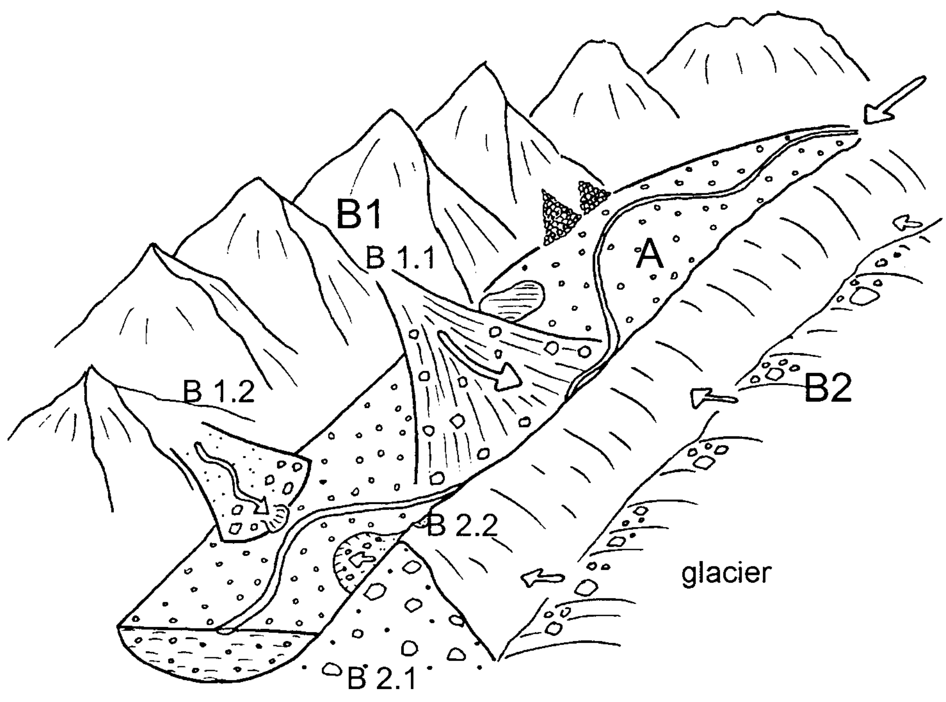


Figure 7. Genesis of the lateral moraine valleys deduced from the glacial history.

glacier show also in their lower parts extremely coarse-grained lateral moraines with individual boulders of house-size. The layered structure is typical for many gabled-shaped lateral dump moraines (cf. Humlum 1978, Photo 13), whereby meltwater is involved in the lamination process. This process must be to distinguished from dry dumping, which produces rather fall-sorted ice-contact screes. In some cases, the question arises whether the layered lateral moraines are not actually dislocated glaciofluvial ice-marginal sediments, which were originally deposited horizontally. Hummocky lateral moraines mostly occur along wider valley sections, such as in the lower part of the Hispar glacier (Photo 9).

In the present literature rock fall is considered as a major contributor for the lateral moraine genesis (Small 1983: 250). The debris material of the lateral moraine is broken up by frost weathering processes from the valley flank and then falls onto the glacier surface. The rock fall debris is transported glacier downwards and subsequently lateral moraines are building up by supraglacial dumping processes. Apart from these processes mudflow events could be identified as important source area for the recent formation of lateral moraines along the Karakoram glaciers (Photos 18, 19 &



A **Lateroglacial longitudinal sediments:** The direction of sedimentation is parallel to the glacier flow. The source area for these sediments is the glacier resp. supraglacial meltwalter (kame terrace).

B **Lateroglacial transverse sediments:** The direction of sedimentation is perpendicular to the glacier flow. The debris is supplied by the tributary valleys.

B1 **Transverse sediments deposited from the valley flank side**

B 1.1 **Kame cone:** Debris accumulations (e.g. mudflow cone, podest moraine) of the tributary valley are deposited against the lateral moraine ("Stauschuttkörper").

B 1.2 **Slope deposits:** Smaller debris accumulations (e.g. slope mudflow cones, talus cones) expand freely on the floor of the lateral moraine valley. They often consist of resedimented slope moraines.

B 2 **Transverse debris accumulations deposited from the glacier side**

B 2.1 **Lateral moraine:** Push, dumping and melting processes built up the lateral moraine.

B 2.2 **Morainic debris flows:** Supraglacial meltwater release can result in small debris flows. The sediment of the lateral moraine is displaced into mudflow lobes.

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Figure 8. Source areas of debris supply in lateroglacial (lateroglacial) valleys.

20). High-energy mudflows run through the lateral moraine valley and terminate on the glacier surface (Photo 23). The parent material of these mudflows often consists of Late Glacial slope moraines. In most cases the mudflows are triggered by sudden high meltwater-discharges from glaciers or permanent snow patches during high-pressure weather conditions. On the one hand the mudflows destroy the recent lateroglacial valleys, but on the other hand they provide the source material for the subsequent formation of lateral moraines.

The present state of the lateroglacial valleys

The majority of the glaciers are framed by high rising lateral moraine complexes, which are nowadays transformed by post-sedimentary processes. In general, the lateroglacial valleys are at present destroyed by different processes. They

↑ *Photo 1*. The 58km long, W-E flowing Batura glacier is bordered by extensive Lateroglacial valleys. They show a width of up to several hundred metres. These broad lateroglacial sedimentation belts are typical for the Karakoram glaciers. They reach their largest extent where tributary sediments fans enter the main valley (*transverse debris accumulations/kame cones*). Therefore a major part of these sediment forms are to a considerable part non-glacial. Despite the large main valley glaciation an almost independent development of debris accumulation takes place along the glacier margins. Their development is not dependent on insolation effects. They occur in S- and N-exposure. But ablation valleys provide the initial depression for debris deposition. Birch trees have especially colonized the gravel floor, whereas juniperus can be found at the distal lateral moraine slopes. View from the left Batura glacier side at 3300 m looking W to Fatmahil; Batura Ice Fall. Photo: L. Iturrizaga 29.09.2000.

↓ *Photo 2*. The alluvial fan (▲) drains as transversal sediment cone into the Lateroglacial valley of the Batura glacier shown in photo 1. After deglaciation it will remain as kame cone. At the right margin the fluvial deposits (△) of the Lateroglacial valley are just visible. The type of lateral moraine varies between a hummocky moraine (■) and a seemingly more single-ridged moraine (□). Photo: L. Iturrizaga 05.10.2000.

← *Photo 3*. Along the 50km long W-E flowing Chogolungma glacier Lateroglacial valleys occur on both valley flanks and accompany the glacier up to 3800m on N-facing slopes and up to about 4200m on S-facing slopes. The lateral moraine is strongly overworked by supra-glacial meltwater release and by ice-overlappings (↘) onto the valley floor of the Lateroglacial valley near Arencho. The outer slopes of the lateral moraines show an angle of slope between 25-30°, whereas the inner slopes are inclined at 40° and more. View from 3800m valley downwards looking SE. Photo: L. Iturrizaga 19.07.2000.

↓ *Photo 4*. View from Shishkin (2850m) to the upper catchment area of the Bualtar glacier (resp. Hopar glacier) with Diran (7266m) in the background. The Bualtar glacier shows also an asymmetric distribution of Lateroglacial valleys: only at the NW-faced side of the Bualtar glacier a broad lateral moraine valley is present, whereas at the opposite side is only bordered by moraine ledges. The lateral moraine valley lies up to 150m above the present glacier surface. Photo: L. Iturrizaga 05.08.2000.

↑ *Photo 5*. View onto the orographic right lateral moraine valley in Bitanmal (3775m), Hispar glacier, in S-exposure. Several nested lateral moraine walls (☐) were incised by the tributary mudflow cone (▲). Only the outermost lateral moraine is still intact. In this case the drainage to the Hispar glacier takes place a little bit further down-valley. A further lateral moraine level lies directly on the valley flank (not visible in the picture). The lateroglacial valleys in N-exposure are already heavily snow-covered. High lateral moraines fringe the glacier (↓). Photo: L. Iturrizaga 07.06.1999.

← *Photo 6*. Along the Hispar glacier the lateral moraine valleys already terminate at 3900m in N-exposure due to high frequent ice-avalanches, whereas in S-exposure they accompany the glacier up to an elevation of 4300m. In the foreground, a glacigenic mudflow cone (kame cone) (▲) is deposited against the lateral moraine complex. Tributary stream breaks through the lateral moraine (↓). The lateral moraine complex is composed of several winded walls, in which are embedded house-sized boulders. Note tents as scale (▲). The slopes are covered by ground moraine (■). View from 4200m, above Skambarish, towards SE to the Balchhish Range. Photo: L. Iturrizaga 14.06.1999.

↑ *Photo 7*. View from 3680m towards SW to the Yuskhin Gardan glacier. In the foreground the left lateral moraine is visible, which was overridden by the glacier 20 years ago (↘). The large and bright granite boulders as well as the small moraine ridges on the old moraine (↙) are geomorphological witnesses of the event. Valley downwards the lateral moraine valley is completely undercut by the glacier advance. At the opposite valley flank side the Lateroglacial sediments in NW-exposure are destroyed and are covered by talus cones (*moraine-cored talus cones*). The glacier is framed by the Kanjut Sar (7760m) to the left and the Yukshin Gardan Sar (7641m) to the right. Photo: L. Iturrizaga 07.07.2001.

↓ *Photo 8*. A typical V-shaped Lateroglacial valley occurs along the Pumari Chhish glacier at an altitude between 3900m and 4200m. The talus cones are directly connected with the lateral moraine. A Lateroglacial stream does not occur. Photo: L. Iturrizaga 09.06.1999.

↑ *Photo 9*. The debris-covered Hispar glacier shows considerable vertical amounts of recession. Its surface is dotted with supraglacial lakes. High rising lateral moraine complexes, which are strongly gullied, are present along both glacier sides. Note also the high-rising lateral moraines of the subordinated Lower Skambarish glacier (●). In the foreground nested moraine ridges (↘) with a high portion of big boulders border the Lateroglacial valley. Grouped earth pyramids with heights of several metres (←) witness the prehistorical glaciation, which also provided the debris material for the formation of the Lateroglacial sediment complexes. View from 4200m (Skambarish) towards the glacier tongue. Photo: L. Iturrizaga 14.06.1999.

↑ *Photo 11*. View towards SE from 4500m to the upper catchment area of the Barpu glacier with Spantik (S, 7027m) and Malubiting (M, 7453m). Lateroglacial sediment complexes are present in W- and E-exposure. Especially along the orographic right-hand side mudflow cones drain into the lateroglacial margins, but also to a considerable extent directly into the glacier. At many locations the Lateroglacial streams break through the lateral moraine (←). The height of the distal lateral moraine slopes varies between some metres and 30m. At the outer slopes of the glacier the Lateroglacial valley can be interrupted (↙). In Girgindil (3750m) the multiphased kame cone (↓) shown in Photo 38 is visible. A large-scale collapse landslide is exposed at the left valley side (↘). Photo: L. Iturrizaga 17.08.2000.

← *Photo 10*. The view looking SW along the Hispar glacier shows that in its lower part (3500m-3300m) the lateral moraine valley changes to a broad hummocky moraine landscape. Former multi-complex lateral moraines are transformed into a hilly assemblage of sediments (■). The youngest ridge-shaped lateral moraine is only preserved in the upper part of the glacier. The Lateroglacial sediments occupy almost one third of the area of the valley cross-section. In this case the Lateroglacial depression act as real drainage area and is taken up by a rather big stream creating a valley-like topography. The valley flanks are up to several hundred metres above the valley floor covered with ground moraine. The village Hispar located at a kame cone is visible in the background (↓) Photo: L. Iturrizaga 01.06.1999.

↑ *Photo 12*. View from 4500m towards the glacier tongue of the Barpu glacier (2800m). In the background the Bualtar glacier is visible. The lateral moraine appears as uniform asymmetric wall. However, not only moraine superposition is the dominant process regarding the formation of the lateral moraine, also moraine accretion is very common. Very narrow, multi-ridged moraine walls crown the moraine top. The distal moraine slopes are often fall-sorted due to supraglacial (dry) dumping processes. They show an angle of slope of 20-30°, whereas the angles of the proximal slopes reach up to 70°. Photo: L. Iturrizaga 17.08.2000.

↓ *Photo 13*. Typical lateral sander moraine at the right-hand side of the Barpu glacier at 3200m. The layered moraine displays an obvious clast orientation from the glacier (on the right-hand side) towards the Lateroglacial valley. The moraine is only little matrix-supported, the proportion of gravel and sand is high. The diameter of clasts reaches up to several metres. Photo: L. Iturrizaga 05.08.2000.

← *Photo 14*. View from the top of the lateral moraine of the 70m high and up to 70° inclined proximal moraine cliff wall of the Momhil glacier. About 3,20m below the top fossil tree trunks, embedded into a dark weathered soil horizon, look out of the moraine (↑). The wood was ^{14}C-dated at 1495 +/- 45 ^{14}C-years. This date provides a minimum age of the moraine and a maximum age of the subsequent glacier advance. The "wood layer" is overlain by lacustrine sediments (○). The moraine is strongly dissected by crevasses and susceptible to collapse processes. Note man at the outcrop as scale (↙). Photo: L. Iturrizaga 29.07.2001.

Thanks are due to Mr Shambi Khan, Mr Ali Shah and Mr Farhad Karim for the sample taking.

↓ *Photo 15*. The Pumari Chhish glacier is a classical avalanche-fed glacier. The steep valley flanks rise over 3000m above the glacier surface. The snowline runs in about 5300m within the wall. The highest peak in the catchment area is the Kunyang Chhish (7852m). Due to the topographical conditions the Lateroglacial valleys begins only at about 4500m. Photo: L. Iturrizaga 09.06.1999.

↑ *Photo 16*. View from the Shambi Khan Camp (4070m) valley upwards. The Lateroglacial valley is abandoned and the lateral moraine gradually peters out. Now the debris accumulations show the typical dual structure of a moraine base (■) and talus cones (▲) on top of it. In a while they will be transformed into moraine-cored sediments. Photo: L. Iturrizaga 14.07.2001.

↓ *Photo 17*. View from close to Gore II (4375m) onto the Biange glacier. Lateroglacial sediments occur only very rarely in this altitude range. However, pedestal moraines (■) are quite widespread in the upper catchment area of the Baltoro glacier. A supraglacial depression (↘) accompanies the glacier at the orographic left-hand side. The Muztagh Tower (7273m) is the highest peak of this tributary glacier. Photo: L. Iturrizaga 02.07.1997.

↑ *Photo 18*. View towards S from 4000m at the mudflow lobe near Sekrwar (3850m) at the Khurdopin glacier. In the year 2000 the right lateral moraine valley of the Khurdopin glacier was completely destroyed by a glacial-induced mudflow event out of the W-facing Sekrwar valley. The multiphased mudflow (■) stretches over almost 1km on the white Khurdopin glacier margin. Since then small mudflows appear every once a while. The mudflow detritus provides the parent material for the recent formation of lateral moraines. Photo: L. Iturrizaga 12.07.2001.

↓ *Photo 19*. View towards N from 3950m onto the mudflow cone at Sekrwar, which devastated the lateral moraine complex (↘). Fresh mudflow lobes (→), only some hours old, extent over the cone surface. A new lateral dump moraine (●) is deposited in the foreground. The mudflow dammed the englacial water transfer and ephemeral lakes are impounded at the glacier margin. The highest lake level (↓) is visible about 10m above the recent lake level at the inner moraine slope. Photo: L. Iturrizaga 14.07.2001.

↑ *Photo 20*. Supraglacial lateral moraines in the transition to lateral dump moraines. The surface moraine consists of mudflow deposits of Sekrwar. This mudflow deposits in turn are composed of moraine material. Therefore the lateral moraine is formed by debris, which is already strongly overworked (rounded components). Photo L. Iturrizaga 11.07.2001.

← *Photo 21*. Ablation valleys are not easily to distinguish from phenomenons of ice retreat. The lateroglacial environment of the Kuk-I-Jerav glacier at 3550m is displayed at the photograph. True ablation valleys are mostly found in higher altitudes (> 4000m). Photo: L. Iturrizaga 11.10.2000.

↑ *Photo 22*. At the left-hand Chogolungma glacier side large avalanche cones (▲) block the Lateroglacial valley and even break through the lateral moraine. Lake sediments are deposited valley downwards (■) and valley upwards (■). The moraine breakthrough (↘) towards the glacier could be caused by a small lake outburst. The next avalanches will terminate directly on the glacier surface. Photo: L. Iturrizaga 21.07.2000.

← *Photo 23*. Up to 200m high inner slopes of the lateral moraines (●) are exposed along the Kukuar glacier (■). Due to the missing ice abutment the Lateroglacial valleys are nowadays destroyed by fluvial processes of the tributary valleys. The adjacent valley flanks rise up to 5800m and are the source area for high-energy mud flow processes. They run through the lateral moraine valley and end on the glacier surface (▲). Photo: L. Iturrizaga 26.08.2000.

↑ *Photo 24*. Lateroglacial valley at Guchisim (3650m) along the Batura glacier in SW-exposure. In NE-exposure the Lateroglacial sediment complexes are already finished along the main glacier. Only the tributary glaciers are framed by lateral moraines (↙). In the foreground the Lateroglacial river breaks through the multi-phased dump moraine and drains englacially (↓). Photo: L. Iturrizaga 04.10.2000

↓ *Photo 25*. In contrast to the Batura glacier the Baltoro glacier flowing E-W (59km) presents a surprisingly „clean" lateroglacial sedimentation environment. Unlike the other giant glacier streams of the Karakoram Mountains the extensive Lateroglacial valleys - and especially the "Great Lateral Moraine" - are missing along this glacier. Only at some locations - such as between Liligo and Robutze in the lower part of the Baltoro glacier – lateroglacial bank sandurs are present. Small talus cones are deposited directly on the glacier surface. The Broad Peak (8047m) is visible in the background, one of the four peaks over 8000 m in the upper catchment area of the Baltoro glacier. View from the left-hand side of the Baltoro glacier from 3850m looking E/NE. Photo: L. Iturrizaga 22.08.1997.

↑ *Photo 26*. The Virjerab glacier, over 40km in length, lies - like the Momhil glacier – down-wasted in its Lateroglacial sediment embracing. It resembles a dying glacier. Visser (1928) made the same observations 80 years ago. Lateral moraine valleys are almost absent. The prominent form of deposition is a more or less shallow morainic ledge. At many locations talus cones are superimposing the morainic base. View from 3900m towards SE. Photo: L. Iturrizaga 16.07.2001.

↓ *Photo 27*. View from 3650m towards S onto the upper catchment area of the Momhil glacier, 31km in length. The retreating glacier is completely debris-covered, even though six peaks over 7000m are gathered in the upper catchment area. The steep-sided and narrow valley topography offers unfavourable conditions for debris deposition. Only a shallow fringe of Lateroglacial sediments borders the glacier at its E-faced side. The lateral moraines are deposited in ledge-shape. The linear moraine walls are almost absent in the Momhil valley. The top of Dut Sar (6858m), on the right-hand side, is covered in clouds. Photo: L. Iturrizaga 27.07.2001.

↑ *Photo 28*. View from 3600m looking N along the upper part of the Kukuar glacier. The huge lateral moraine terraces are absent where the debris production from the valleys flanks is negligible. Only the corner locations in the confluence areas (▲) represent prominent places for debris deposition. In the background Seiri Porkush (6771m) and Kampir Dior (7168m) are visible. Photo: L. Iturrizaga 23.08.2000.

↓ *Photo 29*. En-bloc collapse (◆) in the lateral moraine at the right-hand side of the Momhil glacier. This slide was caused by drainage channels, which flow off subterraneously inside the talus cone and emerge at the inner slope of the lateral moraine. The cliff walls up to 70m high are patterned with undulated recession lines (↘). Despite their steepness the gully erosion is only very superficial at the moraine walls. Photo: L. Iturrizaga 27.07.2001.

↑ *Photo 30*. The Khurdopin glacier undercuts the lateral moraine valley at 3600m. The white glacier surface is also covered by mudflow deposits and reworked material of the lateral moraine. Whereas in the upper valley section the glacier surface lies several decametres below the lateral moraine crest, the glacier almost overtops the lateral moraine in the lower valley section (3500m). Photo: L. Iturrizaga 14.07.2001.

↓ *Photo 31*. The Yazghil glacier demolishes its former lateral moraine along its west-faced side at 3650m. In the background the glacier overtops the lateral moraine. New supraglacial debris is superimposed onto the old moraine (↓). Fall-sorted ice-contact screes fringe the high-rising moraine. The ice body recedes abruptly in the contact zone with the debris. The lateral outbreak of the glacier could be observed already in 1992. This locality is often filled up by lateroglacial ephemeral lakes. Photo: L. Iturrizaga 18.07.2001.

↑ *Photo 32*. Erratic granite boulder in 4250m at the orographic right-hand side of the Khurdopin glacier. It is placed 500m above the present valley bottom near Shiririn (cf. KUHLE 1998 for the Shimshal glaciation). The slope moraine deposits are largely removed at this locality, whereas a little bit more valley down- and upwards thick morainic accumulations prove the prehistorical glacier infillment. View towards the Khurdopin glacier tongue. Photo: L. Iturrizaga 10.07.2001.

↓ *Photo 33*. View from 3550m towards the confluence of Virjerab and Khurdopin glaciers. In the foreground the lateral moraine valley of the Khurdopin glacier is shown. At the right hand-side Late Glacial moraine deposits (■) cover the valley flank and are connected with the lateral moraine complexes (▲). A kame cone (●) is preserved in the confluence area and indicates a former glacier level. From time to time, the lateral moraine valley is flooded by the ice-dammed Virjerab lake. Note the lake levels in the morainic talus cones (↙). L. Iturrizaga 14.07.2001

↑ *Photo 34*. The cross-section of a Lateroglacial valley displays the close interfingering of lateral moraine (▲) and older slope moraines (■) along the common glacier tongue of the Khurdopin and Yukshin Gardan glacier at 3300m. To the left lies the glacier end (not visible). The coarse-grained, laminated lenses of fluvial origin are clearly recognizable at the outcrop profile, which mainly shows a bad sorting. The texture of the polygenetic composed sediment complex is mainly matrix-supported. In the outcrop are sporadically interspersed big boulders. The lateral moraine is perforated with the outlet channels of incorporated dead ice (↙). The lateral moraine as well as the slope moraines are reworked into morainic screes (△). Photo: L. Iturrizaga 07.07.2001.

↓ *Photo 35*. View from 3400m onto the glacier tongue of the Ghulkin glacier (2395m). The valley flanks are coated with Late Glacial moraine deposits (■). Around the glacier tongue the typical dilatation and accretion of lateral moraines occurs due to the more favourable relief conditions in the confluence area. Between a supposedly Neoglacial lateral moraine remnant (△) and the present lateral moraine is incised a intermorainic valley (↓). Photo: L. Iturrizaga 15.10.2000.

↑ *Photo 36*. At 3900m a relict Lateroglacial valley thrones 800m above the recent Barpu glacier surface. In this case the Lateroglacial valley is structurally bound. The apparent lateral moraine is actually rock-cored. The elevation of the Lateroglacial valley indicates the minimum height of the glacier surface during the Ice Age. Photo: L. Iturrizaga 16.08.2000.

↓ *Photo 37*. The Yazghil glacier is bordered by a relict lateral moraine valley (●) at 3750m. It runs about 350m above the present glacier surface. It is situated near to the confluence area with the Shimshal valley. The opposite valley flank is covered with huge Late Glacial residual morainic ramparts (△), which are nowadays disintegrated into morainic cones. Photo: L. Iturrizaga 17.07.2001.

↑ *Photo 38*. Two-phased kame cone at the right Barpu glacier side in Girgindil (3775m). The higher cone level (■) corresponds to the former height of the glacier surface. The younger cone (□) is at present subject to incision and drains directly to the Barpu glacier (↓). Photo: L. Iturrizaga 06.08.2000.

↓ *Photo 39*. View from 3100m onto the white Malungutti glacier in the confluence area with the Shimshal valley. Dynamic ice retreat is indicated by at least 10 closely nested moraine ridges. Moraine accretion is a very common feature in confluence areas, where the valley floors become wider. Intermorainic lakes (●) can be present in between the main moraine ridges. On the opposite side of the glacier, the older moraine level, up to over 100m in height, is visible (■). Photo: L. Iturrizaga 22.07.2001

are reworked by mudflows from the tributary valleys or the high lateral moraine slopes collapse due the absence of the former glacier abutment or by glacial undercutting. In higher altitudes they are gradually overcovered by talus cones and talus slopes (Photo 16). Moraine-cored talus cones are left behind. In the lower altitudes, lateroglacial meltwater streams break through the lateral moraine and drain directly to the glacier (Photos 11, 24). The lateral moraine valleys will be then degraded by headward erosion.

But in some cases, the glaciers override or break through the lateral moraine. New ice-contact deposits are piled up by supraglacial dumping processes (i.e. Yazghil glacier, Photo 31, Lupghar glacier, Khurdopin glacier, Photo 27, Barpu glacier). These are relatively rare and locally limited phenomenons which are bound to punctual uprising of the glacier surface. Those break-throughs mostly occur at higher altitudes around 3800 m–4000 m.

The vertical changes of the Karakoram glacier surfaces are considerable. During a time period of only some years the glacier height can experience shifts of up to several decameters (e.g. Yukshin Gardan, Khurdopin, Pumari Chhish glaciers). The glacier movement often takes place in form of kinematic waves. The glacier surface is not lifted up equally over the entire length and therefore lateral moraine formation occurs in a kind of patchwork-pattern.

Conclusion

In high mountain areas, the principal glacial sedimentation areas are situated at the lateroglacial margins of the glaciers. The proglacial landforms play a subordinated role among ice-marginal sediments, even though they received the most attention in the glacial-geomorphological literature. Due to the high meltwater release of the Karakoram glaciers, end moraines and related forms are rapidly destroyed. The Karakoram glaciers, decakilometers in length, rather block numerous unglaciated or only partly glaciated tributary valleys, which in turn drain into the lateroglacial environments and provide expansive amounts of non-glacial sediments. The latter sediments are closely amalgamated with the lateral moraine complexes. Especially after deglaciation, when the ice-abutment slowly disappears and collapse processes along the distal sediment cliffs take place, non-glacial and glacial sediments are highly mixed with each other. In particular kame cones and moraine-cored debris sediment cones witness the former glacier extent. On the other hand, in many cases only the lateral moraine is eroded and the non-glacial part of the kame formation is preserved. This rudiment is then difficult to distinguish from a ‘pure’ mudflow cone.

In general, the Karakoram glaciers represent with their huge lateral moraines and lateroglacial sediment complexes a landscape of glacier retreat. Therefore at many locations the lateroglacial valleys are slowly destroyed by fluvial processes of the side valleys. The lowering of the glacier surface produces up to 200 m high proximal slopes of the lateral moraines and consequently the support of the glacier is then missing. At the same time, the lateroglacial valleys are destroyed by extreme uprising of the glacier surface in an altitude at 3700 m–3800 m along the middle sections of some glaciers (Khurdopin, Yazghil, Lupghar glaciers). New lateroglacial valleys are partly built up.

In most cases, the development and distribution of lateroglacial valleys is dependent on topographical factors and not on exposure and reflexion effects. Those are often only the voids between glacier and adjacent valley flank, which are filled up by glacial and non-glacial sediments. A very active debris morphodynamic took place and still goes on in the direct vicinity of the glacier. A considerable portion of debris supply comes from the tributary valleys. Therefore the sediment structure is mainly non-glacigenic. In regard to the maximum glaciation it cannot be assumed that a larger lateroglacial debris environment was developed. In contrast, the more the relief is filled up with ice, the smaller become the debris supply areas.

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References

Bobek, H. 1935: Die jüngere Geschichte der Inntalterrasse und der Rückzug der letzten Vergletscherung im Inntal. *Jahrbuch der Geologischen Bundesanstalt*, Band **85**, 135–189. Wien.

Church, M. & J.M. Ryder 1972: Lateroglacial sedimentation, a consideration of fluvial processes conditioned by glaciation. *Geological Society of America Bulletin* **83**, 3059–3072.

Dainelli, G. 1922: Relazione Scientifiche della Spedizone italiana de Filippi, nell'Himalaia, Caracorum e turchestan Cinese (1913–14) serei II. Resultati geologici e geografici, vol. **3**, Bologna.

Derbyshire, E., Li Jijun, Perrot, F.A., Xu Shuying & R.S. Waters 1984: Quaternary glacial history of the Hunza valley Karakoram Mountains, Pakistan. Miller, K.J. (ed.), The International Karakoram Project., vol. **2** Cambridge: Cambridge University Press, 456–495.

Eggers, H. 1961: Moränenterrassen im Wallis: Morphologische Untersuchungen zu spätglazialen Formen und Vorgängen in den Schweizer Alpen. *Freiburger Geographische Arbeiten*, Heft **1**, 127 pp.

Flaig, W. 1938: Das Gletscherbuch. Rätsel und Romantik, Gestalt und Gesetz der Alpengletscher. Leipzig, 196 pp.

Flint, R.F. 1971: Glacial and Quaternary geology. New York, John Wiley and Sons, Inc.

Haserodt, K. 1989: Zur pleistozänen und postglazialen Vergletscherung zwischen Hindukusch, Karakorum und West-Himalaya. Haserodt, K. (ed.), Hochgebirgsräume Nordpakistans im Hindukusch, Karakorum und West-Himalaya: Beiträge zur Natur- und Kulturgeographie. Beiträge und Materialien zur Regionalen Geographie, **2**, 181–233, Berlin.

Heim, A. 1932: Bergsturz und Menschenleben. Fretz und Wasmuth Verlag A.G., Zürich, 218 pp.

Heim, A. 1933: Minya Gongkar. Forschungsreise ins Hochgebirge von Chinesisch-Tibet. Bern, Berlin 1933.

Hewitt, K. 1989: The altitudinal organisation of Karakoram geomorphic processes and depositional environments. *Zeitschrift für Geomorphologie*, Supplementband **76**, 9–32.

Hewitt, K. 1993: Altitudinal organization of Karakoram geomorphic processes and depositional environments. J.F. Shroder, jr. (ed.), Himalaya to the Sea. Geology, geomorphology and the Quaternary. Routledge Press, London, 159–183.

Hewitt, K. 1999: Quaternary Moraines vs Catastrophic Rock Avalanches in the Karakoram Himalaya, Northern Pakistan. *Quaternary Research* vol. **51**, Number 3, 220–237. Academic Press.

Humlum, O. 1978: Genesis of layered lateral moraines: implications for paleoclimatology and lichenometry. *Geografisk Tidsskrift* **77**, 65–72, Kopenhagen.

Iturrizaga, L. 1999a: Die Schuttkörper in Hochasien – Eine geomorphologische Bestandsaufnahme und Typologie postglazialer Hochgebirgsschuttkörper im Hindukusch, Karakorum und Himalaya. *Göttinger Geographische Abhandlungen*, Band **106**, 326 pp.

Iturrizaga, L. 1999b: Typical debris accumulation forms and formations in High Asia. A glacial-history-based concept of the origin of Postglacial debris accumulation landscapes in subtropical high mountains with selected examples from the Hindu Kush, the Karakoram and the Himalayas. M. Kuhle (ed.), *GeoJournal*, Tibet and High Asia V, vol. **47**, nos 1–2, 277–339.

Iturrizaga, L. 2000: The distribution of debris accumulations in the Rakhiot Valley, Nanga Parbat-N-Side (Pakistan). Miehe, G. & Zhang Yili (eds.), Environmental Changes in High Asia. Proceedings of an International Symposium at the University of Marburg. Marburger Geographische Schriften, Heft **135**, 28–39.

Iturrizaga, L., in press: Transglacial sediments in the Karakoram Mountains. A case study from the Shimshal Valley. In: Kreutzmann, H. (Ed.). Karakoram in Transition.

Iturrizaga, L. in press: Der Pumari Chhish-Gletscherausbruch (Karakorum / Pakistan): Geomorphologische Überprägungen des lateroglazialen Sedimentationsumfeld durch kurzzeitige Gletscherveränderungen. *Terra Nostra*, (DEUQUA 2002 in Berlin, 'Mensch-Klima-Landschaft').

Jamieson, T.F. 1874: On the last stage of the Glacial Period in North Britain. *Geol. Soc. London Quart. Jour.*, vol. **30**, 317–338.

Jordan, E. 1991: Die Gletscher der bolivianischen Anden. Erdwissenschaftliche Forschung. Franz Steiner Verlag Stuttgart, 365 pp.

Jorstad, F.A. 1957: Ablationstäler und Ufertäler. *Petermanns Geographische Mitteilungen* **101**, 98–100.

Kalvoda, J. 1992: Geomorphology record of the Quaternary orogeny in the Himalaya and the Karakoram. Developments in Earth Surface Processes **3**, 315 pp.

Kamp, U. 1999: Jungquartäre Geomorphologie und Vergletscherung im östlichen Hindukusch, Chitral, Nordpakistan. Inst. für Geographie der Techn. Univ. Berlin, 254 pp.

Kick, W. 1956: Der Chogo-Lungma-Gletscher im Karakorum. Zeitschrift für Gletscherkunde und Glazialgeologie, Band **3**, 335–347.

Kick, W. 1989: The decline of the last Little Ice Age in High Asia compared with that in the Alps. Oerlemans, J. (ed.), Glacier Fluctuations and Climatic Change, 129–142.

Klebelsberg, R.v. 1938: Visser's Karakorum-Glaziologie. In: Zeitschrift für Gletscherkunde, Band **26**, Heft 3/4, 307–320.

Klebelsberg, R.v. 1950: Das Silltal bei Matrei. Aus seiner jüngsten geologischen Vergangenheit. *Beiträge zur Heimatkunde von Matrei am Brenner. Schlern-Schriften84*, Universitätsverlag Wagner, 76–86, Innsbruck 1950.

Kuhle, M. 1988: The Pleistocene Glaciation of Tibet and the Onset of the Ice Ages – An Autocycle Hypothesis. In: *GeoJournal* 17, 581–595.

Kuhle, M. 1991: Glazialgeomorphologie. Wissenschaftliche Buchgesellschaft Darmstadt. 213 pp.

Kuhle, M. 1994: Present and Pleistocene Glaciation on the North-Western margin of Tibet between the Karakorum Main ridge and the Tarim Basin Supporting the Evidence of a Pleistocene Inland Glaciation in Tibet. M. Kuhle (ed.), GeoJournal, vol. 33, Tibet and High Asia III, no. 2/3, 133–272.

Kuhle, M. 1998: Reconstruction of the 2.4 Million km^2 Late Pleistocene Ice Sheet on the Tibetan Plateau and its Impact on the Global Climate. *Quaternary International*, vol. **45/46**, 71–108.

Kuhle, M. 2001: Glaciogeomorphological reconstruction of the maximum Ice Age (LGM) glaciation of the Central- and South Karakorum, the heights of its glacier levels and ice thicknesses as well as several lowest prehistoric ice margin positions in the Hindukush, Himalaya and in East-Tibet near the Minya Konka-massif. *GeoJournal* (ed. by M. Kuhle), Tibet and High Asia (VI). Glacio-geomorphology and prehistoric Glaciation in the Karakorum and Himalaya.

Mayewski, P.A. & P.A. Jeschke 1979: Himalayan and Trans-Himalayan glacier fluctuations since AD 1812. *Arctic and Alpine Research* **11**, 267–287.

Meiners, S. 1997: Historical to Postglacial glaciation and their differentiation from the Late Glacial period on examples of the Tian Shan and the N.W. Karakorum. M. Kuhle (ed.), *GeoJournal* 42, vol. **2–3**, Tibet and High Asia IV, 259–302.

Odell, N.E. 1925: Observations on the Rocks and Glaciers of Mount Everest. *The Geographical Journal*, vol. **66**, 289–335.

Oestreich, K. 1906: Die Täler des nordwestlichen Himalaya. *Ergänzungsheft Nr. 155 zu Petermanns Geographische Mitteilungen*, 106 pp. Gotha, Justus Perthes.

Oestreich, K. 1911/12: Der Tschochogletscher in Baltistan. *Zeitschrift für Gletscherkunde* **6**, 1–30.

Owen, L.A. & E. Derbyshire 1989: The Karakoram glacial depositional system. Derbyshire, E. & L.A. Owen (eds.), *Zeitschrift für Geomorphologie*, Supplementband 76, 33–74.

Schwarzgruber, R. 1939: Die Gangotrigruppe (westlicher Garhwal-Himalaja). *Zeitschrift des Deutschen Alpenvereins* **70**, 21–31.

Visser, P.C. 1928: Von den Gletschern am Obersten Indus. Zeitschrift für Gletscherkunde, vol. **16**, 169–229.

Visser, P.C. 1938: Glaziologie. Visser, Ph.C. & J. Visser Hooft (eds.): Wissenschaftliche Ergebnisse der Niederländischen Expeditionen in den Karakorum und die angrenzenden Gebiete in den Jahren 1922, 1925 und 1929/30. Band II, 215 pp.

Wiche, K. 1960: Klimamorphologische Untersuchungen im westlichen Karakorum. *Verhandlungen des Deutschen Geographentages*, Band **32**, 190–203. Franz Steiner Verlag

Winkler, S. 1996: Frührezente und rezente Gletscherschwankungen in Ostalpen und West-/Zentralnorwegen. Ein regionaler Vergleich von Chronologie, Ursachen und glazialmorphologischen Auswirkungen. *Trierer Geographische Studien*, Heft 15, 580 pp.

Workman, F.B. 1905: From Srinagar to the sources of the Chogo Lungma Glaciers. *Geographical Journal* **25**, 245–268.

GeoJournal **54:** 429–450, 2001.

The post to late glacial valley reconstruction on the Haramosh north side (Mani, Baska and Phuparash valleys)

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Abstract

The post to late glacial valley reconstruction is focused on the Mani- Baska and Phuparash valleys on the Rakaposhi-Haramosh Muztagh in the south Karakoram. The recently glaciated valleys join the Indus valley near Sassi at 1500 m. The knowledge of the tributary valley reconstruction can be seen in the context of the scientific discussion about the extent of glaciation along the main Indus valley. Today, the recent avalanche fed glaciers come down from high lying catchment areas with an average altitude of 6700–6800 m and terminate at 2700 m. Snow line runs at 4700–4800 m in the steep flanks which is common in the Karakoram Mountains. The postglacial extent is marked by the great lateral moraine (GLM) and reached down not more than 2.5–5 km away from the recent glaciers with a calculated snow line depression of 300 m in maximum. It can be shown that the valleys were already glaciated during the lastest Late Glacial down to the valley outlet at 1500 m. The snow line was depressed 600–700 m during that period. A high glacial ice filling of the Haramosh valley and glacial erosion of the flat top of the Darchan ridge as an intermediate valley head is strongly probable.

1. Introduction

The history of the landscape of the Haramosh valley is linked with the former glaciation history of the Indus Valley. The extent of the former glaciers Mani, Baska and Phuparash according to their glacio-geomorphic position, their snow line depression and relative age classification, using the method of Kuhle (1988b and 1994, p. 260) is reported in this article. Similar field work and research was done by the author in the N.W. Karakoram (Meiners, 1996; 1997; 1998a, 1998b). Investigations on the post to late glacial valley reconstruction were conducted on the south side of the Rakaposhi-Haramosh Muztagh by Wiche (1960) in the course of the Austrian Karakorum expedition and later in part by Haserodt (1989). The extent of the glaciers that determined the valley contours during the last glacial maximum ranged from just 5 km down-valley of the recent end up to the Haramosh valley outlet at Sassi. The research results of Kuhle (1988a, 1991b, 1998), which demonstrate an ice-age Hunza-Gilgit-Indus ice-stream net, are supplemented by his work (2001), previously by other authors held to be ice-free from the Astor valley up to the Skardu basin. The glaciation history of the Skardu basin as an area of glacial sediment deposits and the more East section of the Indus is described in detail at first by Dainelli (1922, cf. Loewe, 1924). The connection of the Haramosh valley described here in precisely this section of the Indus valley is to be considered from this point of view. The Mani, Baska und Phuparash valleys, only minimally glaciated today, were investigated in August/ September 2001 during a 5-week field trip.

2. Area under investigation

The catchment areas of the Haramosh valley (35°40′-36°07′ N/ 74°45′–75° E) that make up the south side of the Rakaposhi-Haramosh Muztagh are the subject of the present investigations on late to post-glacial valley reconstruction up to the present day. Two tributary valleys flow into the Haramosh valley (Figure 1) at 1700: the Phuparash valley, running in a north-south direction, and the Kutwal valley, running in an east-west direction. The latter divides into the two branches of the Mani and Baska glacier valleys, which lead into the Kutwal valley section at around 2200 m, about 300 m below the village of Iskere. The highest valley catchment areas include the peaks of the Haramosh 7409 m, Malubiting 7453 m, and the Phuparash peaks at 6785 m. The average catchment area altitudes are thus around 6800 m. The maximum relief energy is 5979 m. For further information see Table 1.

3. Mani glacier

The 11 km long Mani glacier (Figure 1) is completely covered by debris below 3250 m. The ice is covered by scattered boulders up to the valley head. The glacier undercuts the orographic left valley flank, while on the right side of the valley a broad lateral moraine valley has developed with a south exposure. The glacier is fed exclusively by avalanche or ice-balcony subsidence from the north-exposed Haramosh steep flank, which leads to the development of regenerated glaciers with ice debris cones at the foot of the flank. A

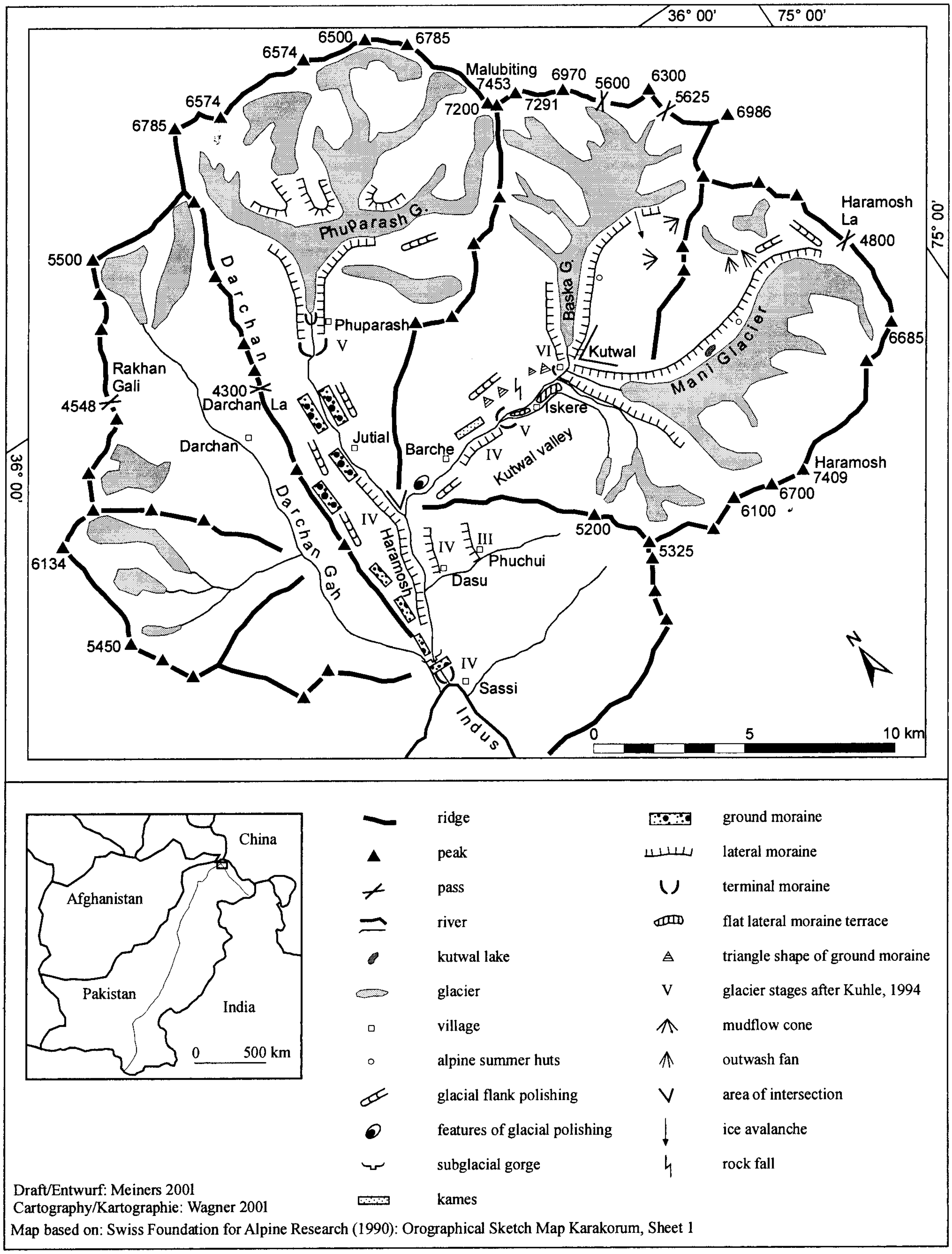


Figure 1. Glaciogeomorphological indicators of the Post and Late Glacial valley reconstruction of the Haramosh valley.

Table 1. Glaciogeomorphogical data of the area under investigation.

	Sassi/Haramosh	Phuparash	Kutwal	Mani	Baska
Coordinates	35°51′–55′ N 74°44′–46′ E	35°55′–36°04′ N 74°46′ E	35°55′ N 74°46′–51′ E	35°54′–55′ N 74°51′–58′ E	35°55–59′ N 74°51′–55′ E
Direction of valley course	N/S	N/S	E/W	E/NW	NE/SW
Exposure of glacier feeding areas	–	S and W	–	N	S
Catchment area	Malubiting/ Haramosh/ Phuparash	Phuparash/ Malubiting W	Haramosh Mutzagh	Haramosh Haramosh	Malubiting W Malubiting W
Valley length/km	5.0	17.0	7.5	14.2	10.0
Glacier length/km	–	9.0	–	11.0	8.8
Glacier end/m	–	2650	–	2700	2700
Glacier area/km^2		6.0		4.0	3.0
Maximum altitude of catchment area/m	7453	7453	7409	7409	7453
Average altitude of catchment area/m	6764	6839	6726	6724	6728
Snow line/m, Calc.	–	4745	–	4712	4714
Altitude of valley outlet/m	1474 (at Sassi)	1700 (Jutial)	1700 (Jutial)	2200 (Iskere)	2200 (Iskere)
Glacier type	–	avalanche fed type, without firn hollow	–	avalanche fed type, without firn hollow	avalanche fed type, without firn hollow
Total valley length/ km	34				

Meiners, 2001

total of 5 erosion channels are glaciated accordingly. Only the glacier immediately flowing down from the NW-flank of the main peak is continuous. The glacier thus belongs to the avalanche-fed type of glacier, without firn hollows. The recent orographic snow line is calculated to run at 4712 m, which places it at around half the vertical distance from the origin of a historical lateral moraine of a flank glacier up to the average catchment area altitude. The residual glacier body from the valley head to the end is thus an allogenous form around 1200 m below its snow line. The nourishment type results in heavy erosion and consequently a high debris potential, which is reflected as a surface moraine on the glacier.

The valley head forms a low chain through which the Haramosh La (pass) (Photo 3) leads over northwards into the Chogo Lungma glacier at 4800 m. In the valley basin on the south-exposed side, there are very small hanging flank glaciers (Photo 3). At 2700 m, the only flatly arched Mani glacier tongue is deeply sunk in its Great Lateral Moraines (GLM) (Photo 1, 9), which are so typical of the N.W. Karakorum (GLM according to Kick,1985). The GLM starting at the valley head already achieves an outer slope height of 8–10 m at the high-pasture settlement at 3400 m. The glacier surface level is sunk around 200 m into the moraine enclosure. Particularly at the intersection, the Great Lateral Moraine shows a division into two main levels (Photo 1). Apart from these, 2 to 3 subrecent moraine edges close to the glacier surface indicate very recent fluctuations in glacier level.

The very broad lateral moraine valley up to the head of the valley at 3500 m is disfigured below the high-pasture settlement by transversely running moraine walls (Photo 2). This is a former glacier outlet into the lateral moraine valley in a phase of the glacial maxima at the time of the Great Lateral Moraine (GLM). Five moraine walls can be differentiated from each other. Later glacial maxima of Postglacial blocked the former outlet by moraine accumulation.

In the midst of this accumulation, the Kutwal Lake formed at 3200 m. The lake is fed by rain water, but also by spring water from the moraine body. A few metres down the lateral moraine valley, a further small outlet can be made out. This situation is a mirror image of the historical and postglacial glacier fluctuations leaving the GLM, which otherwise tend to be monotone in a strongly undercut form and can no longer show any nuances in its current stage due to erosion. Wiche (1960, p. 194) concludes that the moraine outburst was due to the Mani glacier giving way to the pressure of two hanging glaciers of the Haramosh flank flowing in from orographic left, with a lower snow-line situation. Wiche (ibid.) classified these moraines in connection with the Great Lateral Moraine (GLM) to the High Glacial, which ended below Iskere at 2100 m in the shape of an undifferentiated terminal moraine, in which two ice ages are probably to be found.

A massive medial moraine intersection between the Mani and the Baska valley outlet marks the valley confluence area (Figure 1, Photo 7). Here, the orographic right GLM of the Mani transects left lateral moraine of the Baska glacier. On the intersection, several stages of the Mani lateral moraine fan out arch-wise, while the Baska lateral moraine is only single. The base of the intersection at approx. 2200 m is subject to regressive erosion through the undercutting of the melt water of the two glaciers. The ice margin is completed by the orographic left Mani lateral moraine and the orographic right Baska lateral formation, the surfaces of which both have a clear down-valley gradient, which is the true criterion that identifies them as a terminal moraine (Photo 7).

The snow-line depression for the ice margin at 2200 m below the beginning of the settlement terrace (Photo 7), at an average summit elevation of 6725 m + recent glacier end 2200 m : 2 = 4463 m, amounts to 250 m and is thus to be attributed to the most recent neoglacial stage (VI or VII Dhaulagiri after Kuhle, 1994).

4. Baska glacier

The roughly 9 km long Baska glacier (Figure 1), an avalanche fed glacier like the Mani glacier, is mainly fed from the steep flank of Malubiting 7453 m. In contrast to the Mani glacier, the valley flank is exposed to the south. Here, too, the recent snow line is located at 4714 m, so that it runs at a little lower than half the vertical distance from the origin of the GLM (3470 m) up to the average catchment area altitude. The glacier body, running in a SSW direction is completely covered by debris and also ends at 2700 m (Photo 7). Although there are many consistencies, in contrast, the glacier surface is by no means deeply sunk into its large lateral moraine. Indeed, at some points it even rises above the moraine. Such positions are then potential weak points in the glacier margin, which may enable the glacier ice to break through. Taking into account the danger of a possible break-through, the high-pasture settlement of Baska at 3165 m was established in a safe place further down-valley on the already wooded outer slope of the lateral moraine. Haserodt (1989, p. 213) explains the small height difference between the glacier surface and the lateral moraine with the presence of an enormous amount of debris being carried under the glacier, and ascribes it to the banked glacier ('Dammgletscher') type. Referring to Kuhle (1991a, p. 85) it has to be pointed out, that this 'Dammgletscher' does not end in a pedestal. Comparable banked glaciers in the Karakoram are the Siachen glacier on Nanga Parbat (Kuhle, 1991a, p. 84), the Juno and Hinarchi glaciers in the Bagrot valley (Haserodt ibid.), the Kunti glacier on Rakaposhi (Meiners, 1996, p. 115), or the Shispar (ibid., p. 103) and the Toltar on the south side of Batura (Meiners, in preparation).

The outer slope of the GLM achieves an impressive height of 120 m at the intersection with the Mani glacier, while the glacier surface is just a few metres below the crest. At two points at 3240 m and at the lower end at 3000 m, the glacier ice pushes over the moraine. The root of the GLM moraine lies at 3500 m (Photo 4). The glacier runs closely to the orographic right, south-exposed valley flank, so that the west-exposed end of the valley and the lateral moraine valley spacious. Massive mudflow cones, created from moraine debris mixed with the glacier melt water from smaller hanging glaciers are piled up on the valley floor (Photo 4).

From the main peak of Malubiting, a steep valley flank glacier with a large coverage of avalanche ice passes without breaking off, i.e. continuously, into the deep-lying glacier body. This may explain why a snow and ice avalanche recently occurred (July 2001), which crashed down at high speed parallel to the fall-line and surged over the lateral moraine (Photo 4). This event – which is quite rare according to the local population – cost two human lives and most of the sheep and goat herds that were grazing there. The surroundings of the break-through point were free of vegetation and covered by fresh debris, so it can be assumed that this is a more frequent event. However, the run and the vastness of the ice masses must have been far greater in this event than anything that had been seen before.

The glacier end forms a steep front in bare ice (Photo 7). The orographic left Baska lateral moraine transects with the orographic right moraine of the Mani glacier to form an intersection. A small lateral moraine remnant on the orographic right side (Photo 9, 7) and a lateral moraine crest markedly decreasing in height of the orographic left Mani lateral moraine suggest a common glacier end at 2200 m, for which a snow-line depression of 250 m can be calculated (see chapter 3).

5. Glacial features in the Kutwal valley up to its entry into the Haramosh valley and the confluence with the Phuparash valley

In the Kutwal valley, downstream of the glacier extension up to 2200 m described under chapter 3 a highest and oldest level of the Great Lateral Moraine terrace continues especially on the orographic left side. As the element with the largest area in this valley setting – apart from the Kutwal river terrace with a low step height – this is the main settlement level (Photo 7, 8).

On the opposite side of the valley, the dimensions of this area decrease quickly down-valley and the moraine surface is either covered by debris accumulations or eroded by undercutting. The height of the terrace increases down-valley and has a maximum of around 400 m in the area of the settlement Iskere at 2500 m (Photo 9). Below that place, the moraine terrace is strikingly undercut, both by the Kutwal river and, on the outer slope of the moraine, by the discharge of the smaller left Godeli glacier (Figure 1). A narrow ridge remains on which the cultivated fields are subject to constant erosion (Photo 8). The narrowing of this moraine ridge and the confluence of the two drainage channels coincides with a step in the longitudinal valley gradient, with a base level of 2100 m. Wiche (1960, p. 194) termed this locality an 'unclassified terminal moraine' and, together with the GLM moraines, assumed a Last Glacial Maximum. He also considers an overlapping of the last ice age (Würm age) and the one before (Riß age) at this point to be probable (ibid., p. 195). Judging by its shape, it is a strongly undercut lateral moraine terrace, which discontinues at the step at 2100 m base level. It lies 5 km downstream of the recent glacier end and around 3.8 km downstream of the ice margin at 2200 m, but only 100 m below the latter, so that a snow-level depression must only have amounted to 300 m here. The moraine accumulation can not precisely be identified as an ice margin, but marks a reaching down at least to 2100 m. Therefore it can be classified to the Postglacial in the narrower sense, to the neoglacial period (V, Nauri stage). Haserodt (1989, p. 212) classifies the GLM moraine and the Kutwal lake pointing to datings by Röthlisberger (1986, p. 86) of a comparable lateral moraine in the Bagrot valley to the Postglacial, but without taking into account the identified ice margins. Starting from this locality, the remains of a lateral moraine terrace are displaced to a narrow moraine border on the left valley flank (Photo 10), which continues with interruptions into the Haramosh valley and there represents the settlement terrace of Dasu at 1900 m (Photo 13).

A strikingly humped morainic remnant with a surface height of around 2050 m is located close to the Kutwal valley outlet, just before the confluence of the Phuparash valley (Figure 1, Photo 7, 11). This shape stands out from the valley flank, but is not mentioned by Wiche (1960). Haserodt (1989, p. 194) attributes this moraine ridge to a Late Glacial stage. It is difficult to place this morainic remnant in a chronological context through further glaciomorphological findings. It is older than Neoglacial, and yet is not connected with the orographic left lateral moraine leading into the Haramosh valley.

As can be seen in Photo 9 the Kutwal valley shows a glacigenic trough valley cross-profile. The steep valley flanks at the left side are covered with ground moraine while the right side is characterized by flank polishings (Photo 11, 9) which prove a prehistoric ice filling up to a height of more than 1000 metres above Barche (Photo 7). In the lower parts of the flank ground moraine was formed to residual cone-shaped debris accumulations, which was classified as a type by Iturrizaga (1999, p. 282).

6. Phuparash glacier

In addition to the Kutwal valley, the Phuparash valley belongs to the catchment area of the Haramosh valley (Figure 1). With a valley length of 17 km, the valley flows into the Haramosh valley at 1700 m. The average catchment area altitude of 6839 m is formed by the Malubiting (7453 m, 7200 m) and the Phuparash peaks (6500–6800 m). The Phuparash glacier is larger in area than the Mani and Baska glaciers. Here, too, the glacier end is south exposed at 2650 m (Photo 5). The glacier is again of the avalanche-fed type, so that a surface moraine completely covers the glacier tongue. The calculated snow line is comparable at around 4700 m.

A south exposed partial glacier has already lost contact with the main glacier. On the lowest section of the tongue of the Malubiting glacier coming from orographic left, Abies have become established on the surface moraine, which marks where the glacier has slowed down (Photo 5). The recent glacier outlet has formed precisely on this component.

The tongue end at 2650 m lies deeply sunk into the Great Lateral Moraine (Photo 6), which can be traced for around 2 km further down-valley up to the terminal moraine at 2500 m. An only minimal snow-line depression of 75 m contrasts with a depression of 250 m in the neighbouring Kutwal valley. However, the morphology of the moraines is clearly comparable, which means that they are concurrent accumulations. Also König (2001) points out the incongruity from snowline depression to position of the ice margin depending on relief. In contrast to the Mani and Baska glacier end, the end of the Phuparash glacier lies on a largely flat valley floor.

After this very flat valley course, there is a gradient link of 200 m in the longitudinal profile, accompanied by a narrowing of the cross-sectional profile of the valley. The river cuts into a massive ground moraine in the area of narrowing (Photo 12). Ground moraine covers both valley flanks up to the valley outlet and beyond. It is noticeable that the orographic right Phuparash valley flank (Darchan ridge) initially forms another ridge up to this narrowing, but then develops into a broad ridge on both sides of the valley divide (Photo 12, 9).

The altitude of the Darchan ridge is 4300 m in the region of the pass (Figure 1) and is thus around 1700 m above the recent end of the glacier tongue. Up to the valley outlet, the ridge drops to around 2700 m and thus achieves a level of around 1000 m above the valley bottom in the Haramosh valley.

7. Haramosh valley

The confluence of the Kutwal and the Phuparash valleys with the Haramosh valley is at 1700 m (Figure 1). From here, the roughly 5 km long Haramosh valley runs southwards and flows into the Indus river at Sassi at 1500 m. The valley section from Dasu up to the start of the Kutwal valley is characterised by a deep incision with a narrow V-shaped valley profile, the sides of which are covered with 200-300 m high ground moraine terraces and up to the Darchan ridge with ground moraine (Photo 12).

The settlement Dasu at 1900 m is located on such a ground moraine terrace which continues from the level described at the Kutwal valley. Down-valley of Dasu, both a higher moraine weal located 300 m above the Dasu level, marked by the settlement Phuchui, and the Dasu level itself comes to an end (Photo 13). However, this finds its counterpart on the opposite side of the valley in the spacious settlement terrace of Khaltaro E.

At the valley outlet at Sassi, the Haramosh river has cut a gorge deep into the solid rock. Sandy loose material, in which large blocks are embedded, forms the primary substance at 1500 m. Precisely this material is also found a little further up-valley of the confluence of the Haramosh and the Darchan valleys along the orographic right Indus valley, where massive ground moraine lies on ledges. Haserodt (1989, p. 196) describes these moraine findings at Sassi m as subsidiary valley outlet moraines in a largely ice-free Indus valley and attributes them to a Last Glacial Maximum (Würm) stage. This would mean that the Haramosh component must have spread out into the Indus valley like a hammer head. Photo 14 shows ground moraine terraces indus-upvalley of the Haramosh outlet. However, since moraines are also to be found further down-valley orographic right in the Indus valley up to the confluence of the Gilgit river (Kuhle, 2001, Fig. 52–57), this cannot be assumed. Erosion by a thick Indus glacier is also evident on the orographic left Haramosh subsidiary valley outlet. A solid rock with vertical layers is exposed by glaciofluvial undercutting, while the flattened surface has been glacially polished (Photo 14).

Referring to Kuhle (ibid., 1998, p. 90) a continuous Indus glacier joined with the Gilgit and the Hunza glacier component (Kuhle, 1989, p. 271–273; 1991b, p. 299; 1993, p. 108–110) and ended at 980 m or probably below 870 m more than 15 km downwards Sazin (Kuhle, 1988a, p. 588; 1997, p. 123). In the section of the Haramosh valley outlet he calculates an ice filling (LGM) up to 3100 m altitude (Kuhle, 2001, Fig. 57). Described valley outlet moraine indicates a snow line depression of 600–700 m and is thus to be attributed to the latest stage of Last Glacial (Sirkung stage IV).

Already in 1988a, Kuhle (p. 588) proved that all the tributary glaciers from the Karakoram S slope and the Nanga Parbat group were united in the Indus ice-stream network during the last ice age. He (p. 589) provisionally reconstructed late glacial advances for the Bagrot and Batkor valleys (Ghasa Stage I), which reached the Gilgit valley outside the basin at an altitude of 1300–1380 m. These valleys of the Karakoram S slope are immediate western neighbours of the Haramosh valley. In connection with the considerations regarding a high to late glacial glaciation, the valley head of the Mani glacier is of interest. Enclosed by peaks ranging up to a maximum of 6400 m with the smallest of hanging glaciers, an isolated ridge rises from 3500 m to 4200 m up to the steep valley flank (Photo 3). This crest is completely covered by morainic material and displays deformations and striations that demonstrate ice coverage. The related glacier filling requires a snow line of 3500 m, which places it 1200 m below that of today. This value is within the range of last glacial maximum snow-line depressions. According to Wiche (1960, p. 195), moraine terraces outside of the GLM moraine represent accumulations from the ice age before last. This opinion can be regarded as representative of the state of research in the mid-1950s.

8. Conclusion

The post to late glacial reconstruction of the Haramosh valley with its tributary valleys Phuparash, Mani und Baska is closely liked with the overal glaciation history of the Indus valley, into which the Haramosh (also called Phuparash) flows. All glacier valleys have a high Great Lateral Moraine in common, which rises to a height of 200–300 m at the glacier end. A more recent, historical level stands out markedly from the GLM of the Mani and Baska glacier. It was lying at 2200 m in a short distance to the recent end of the glaciers at 2700 m. The previous ice margins, classified to the latest neoglacial (Nauri stage) with a snow-line depression of 75–300 m m, lie in a distance of around 5 km apart. In the Kutwal valley, a clear identification as an ice margin at 2100 m is not possible. In the Kutwal valley, a lateral moraine terrace particularly well preserved on the left valley flank marks an ice filling which could be attributed to a latest Late Glacial stage. It too finds its counterpart in the lower Phuparash valley and in addition in the Haramosh valley. This level is probably continued in the Haramosh valley, on which the settlement of Dasu is located at 1920 m. The settlement terrace of Dasu is overlooked by a 300 m higher level.

At the valley outlets massive ground moraine is exposed, which Haserodt (1989) called tributary valley outlet moraines of the High Glacial, but which were classified into the latest Late Glacial with a snow line depression of 600–700 m. After Kuhle (2001) an Indus main valley glacier existed for this valley section as well.

An enormous ice filling of more than 1000 metres must have taken place in the Kutwal and Phuparash valleys, because ground moraine is time and again found high up on the valley flanks, along with strias and polishings from a high glacial ice level. At a Last Glacial Maximum drop of at least 1200 m in the snow line altitude at 3500 m, precisely the large valley basins with a low gradient are reached, so that an exponential increase in the glacier coverage, as described by Kuhle (1988a, p. 587, Fig. 9; 1997, p. 117), was possible. A further indication of a high glacial ice filling, regardless of the geological structure, is the shape and the glacially flattened top of the Darchan ridge, especially in the section from Jutial to opposite Dasu. At the end, these results complete and prove the findings of Kuhle (2001). It has to be pointed out that it was hard to find clear ice margins of the Postglacial period while ground moraine covers whole valley flanks and is also widespread at the lower Haramosh valley. Their very good preparation is an indicator for their relatively young age of Late Glacial.

← *Photo 1.* The glacier end of the Mani glacier at 2700 m is deeply sunk into the GLM moraine. The orographic right postglacial lateral moraine of the Mani (☐) transects the orographic left lateral moraine of the Baska glacier (○) to form an intersection (see Photo 7). In the background, the Haramosh Peak towers to 7409 m. Locality from which the photo was taken: 2730 m, settlement terrace of Gun above the Baska terminal moraine (Figure 1), 35°54′929″ N, 74°50′096″ E. Photo S. Meiners, 13.08.2001.

← *Photo 2.* The lateral moraine valley of the Mani glacier is blocked by garland-like moraines (↓) above the settlement of Kutwal. In the middle is the Kutwal lake, 3200 m. At the time of its maximum postglacial stage, the glacier lapped over the lateral moraine at this point. The internal walls represent post-Postglacial fluctuations in glacier levels. On the opposite side, two avalanche-fed glaciers fed by the Haramosh north side flow into the westwardly flowing Mani glacier. After Wiche (1960) this moraine outburst was due to the Mani glacier giving way to the pressure of the hanging glaciers. Locality from which the photo was taken: orographic right valley flank, 3745 m, 35°53′253″ N, 74°54′495″ E. Photo S. Meiners, 10.08.2001.

→ *Photo 5.* The Phuparash glacier, an avalanche fed glacier, is completely covered by debris. The catchment area altitudes of the south-exposed Phuparash range are between 6500- 6785 m, whereas the south to south-west side of the Malubiting rises up to 7453 m. Parts of the great lateral moraine on the inside have subsided en bloc (↘). On the left side of the glacier tongue, tree stocks point to a relative lack of movement of the glacier (△). 2 km down-valley of the recent glacier end at 2650 m (○), the great lateral moraine comes to an end at 2500 m. Locality from which the photo was taken: valley flank of the Darchan ridge (Figure 1), 3355 m, 35°59′411″ N, 74°46′462″ E. Photo S. Meiners, 16.08.2001.

Photo 3

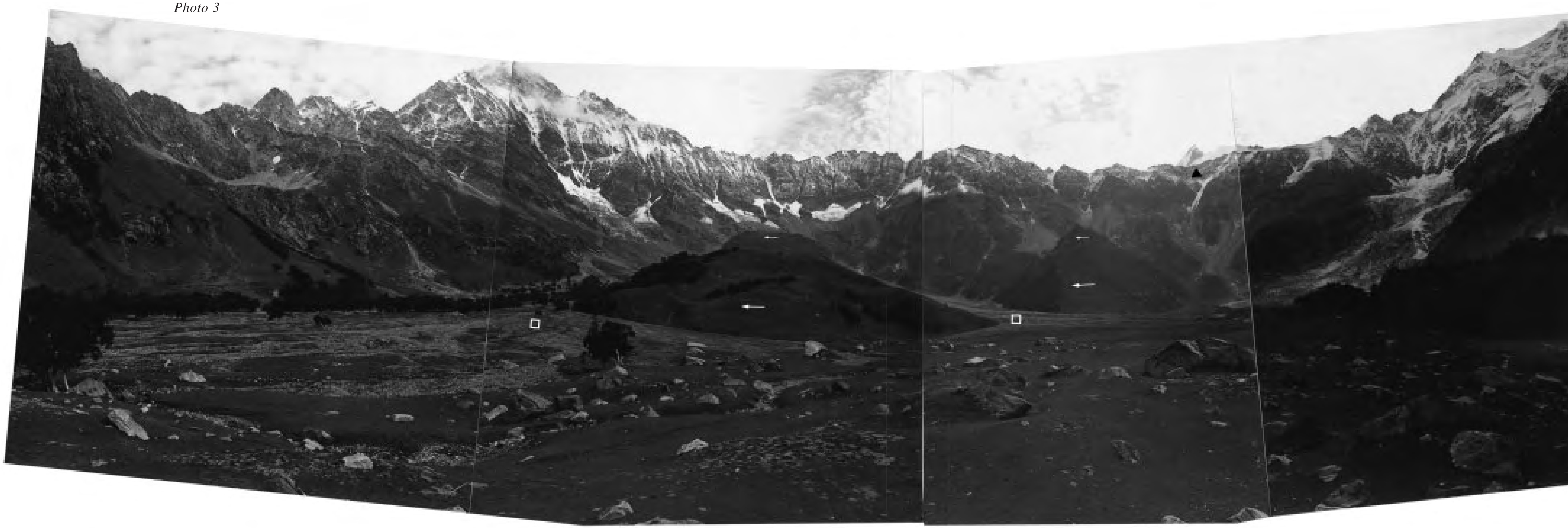
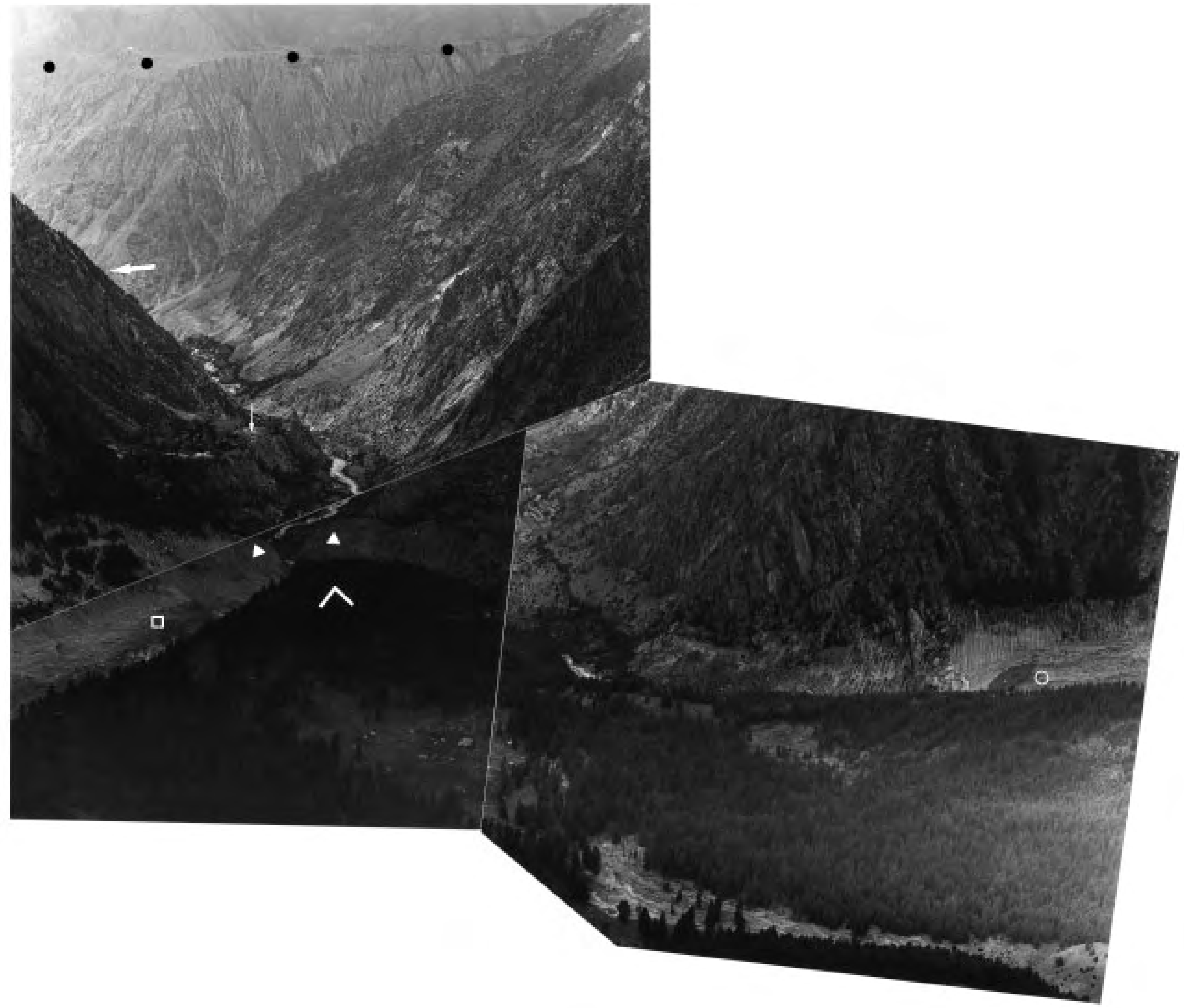


Photo 4

← *Photo 3.* This photo shows the valley head of the Mani glacier, which undercuts the north flank of the Haramosh (see right behind the trees). The 4800 m high Haramosh La (▲) in the centre of the picture is glaciated. Widespread, flat mudflow cones (□) are heaped into the broad lateral moraine valley at 3300-3500 m. The enclosing peaks achieve low altitudes of 5500- 6400 m. Only small flank glaciers have formed below the erosion channels, ending at around 4500 m. The isolated ridges set into the valley head of the valley flank show strias of a prehistorically higher ice level in the ground moraine, which covers the grassy slopes (←) It belongs to the latest Late Glacial stage. Their maximum altitude is 4150 m, so that ice filling was at least 650 m thick. Locality from which the photo was taken: lateral moraine valley floor, 3370 m, 35°54′788″ N, 74°55′022″ E. Photo S. Meiners, 9.08.2001.

← *Photo 4.* The Baska glacier fits snugly onto the orographic right side of the valley below the south-east exposed Malubiting, 7453 m, so that the left lateral moraine valley is very broad. Under high debris production, massive mudflow cones are heaped onto the lateral moraine valley floor (▼). The orographic left great lateral moraine (GLM) at 3500 m has been destroyed at its start by a large ice avalanche (→). Part of the firn and ice cover of the steep glacier component of the Malubiting crashed down at high speed parallel to the fall-line and surged over the moraine. The ice masses buried the entire livestock of the village and cost two human lives. Locality from which the photo was taken: Lateral moraine, 3470 m, 35°56′55″ N, 74°53′171″ E. Photo S. Meiners, 12.08.2001.



↑ *Photo 7.* View into the Kutwal valley onto the area of confluence of the Mani (□) and Baska (○) glaciers in the foreground up to the confluence of the Phupharash valley into the Haramosh valley (✓) from an altitude of 4120 m. In the foreground is the wooded intersection (∧) between the Mani glacier on the left and the Baska glacier on the right. While the main level of the great lateral moraine continues down-valley to below Iskere at 2100 m (↓, see Photo 8) particularly on the orographic left side of the valley, a more recent glacial stage (historical) can be identified at 2200 m – on the basis of the gradient of the lateral moraine walls (▲). The ends of the Baska glacier and the Mani glacier are at an altitude of 2700 m. Down-valley, bordering the settlement and farmland of Barche at 2000 m, a round moraine ridge rises abruptly and in isolation from the valley flank (see Photo 11). In the background, the Darchan ridge (●, Figure 1 2) rises to an altitude of 2500 - 2700 m, about 800 – 1000 m above the valley bottom of the Haramosh valley. . As a result of the roundness of this plateau-like ridge and a ground moraine coverage, high glacial ice-filling to above this level is assumed. This corresponds with flank polishings (Photo 11, 9) on the right side of the Kutwal Valley flank above Barche, which prove a prehistoric ice filling up to a height of more than 1000 metres. Locality from which the photo was taken: intermediate valley head Baska/ Mani, 4120 m; 35°54′800″ N, 74°56′146″ E. Photo S. Meiners, 10.08.2001.

← *Photo 6.* Parts of the great lateral moraine (GLM) ridge have subsided to a more recent lateral moraine level, the remains of which at 2600 m are covered by mudflow (▲), which break through the GLM. Here, too, the postglacial or historical GLM moraine achieves a height of 300- 400 m above the valley bottom and corresponds morphologically to the GLM moraine of the Mani und Baska glaciers. Locality from which the photo was taken: orographic left GLM inner slope of the former Phuparash glacier, 2725 m. Photo S. Meiners, 15.08.2001.

↓ *Photo 8.* The contur of the orographic left GLM lateral moraine comes to an end in the central Kutwal valley with a base level of 2100 m at a step in the longitudinal valley gradient, without forming the shape of a terminal moraine. The postglacial lateral moraine wall has already been eroded away by undercutting. The base of the valley filling is made up of a typical ground moraine, which incorporates larger boulders in loose material. The moraine is undercut by the discharge of the left Godeli glacier and the Kutwal river (Figure 1). In the lower part on the orographic right valley flank ground moraine was formed to residual cone-shaped debris accumulations (△), insofar as it has not been washed off polished sections of the valley flank (●). In the background of the valley on the right edge of the picture, the historical to postglacial great lateral moraine of the Mani and Baska glaciers can be seen (↓). Locality from which the photo was taken: orographic left Kutwal valley slope, 2260 m. Photo S. Meiners, 7.08.2001.

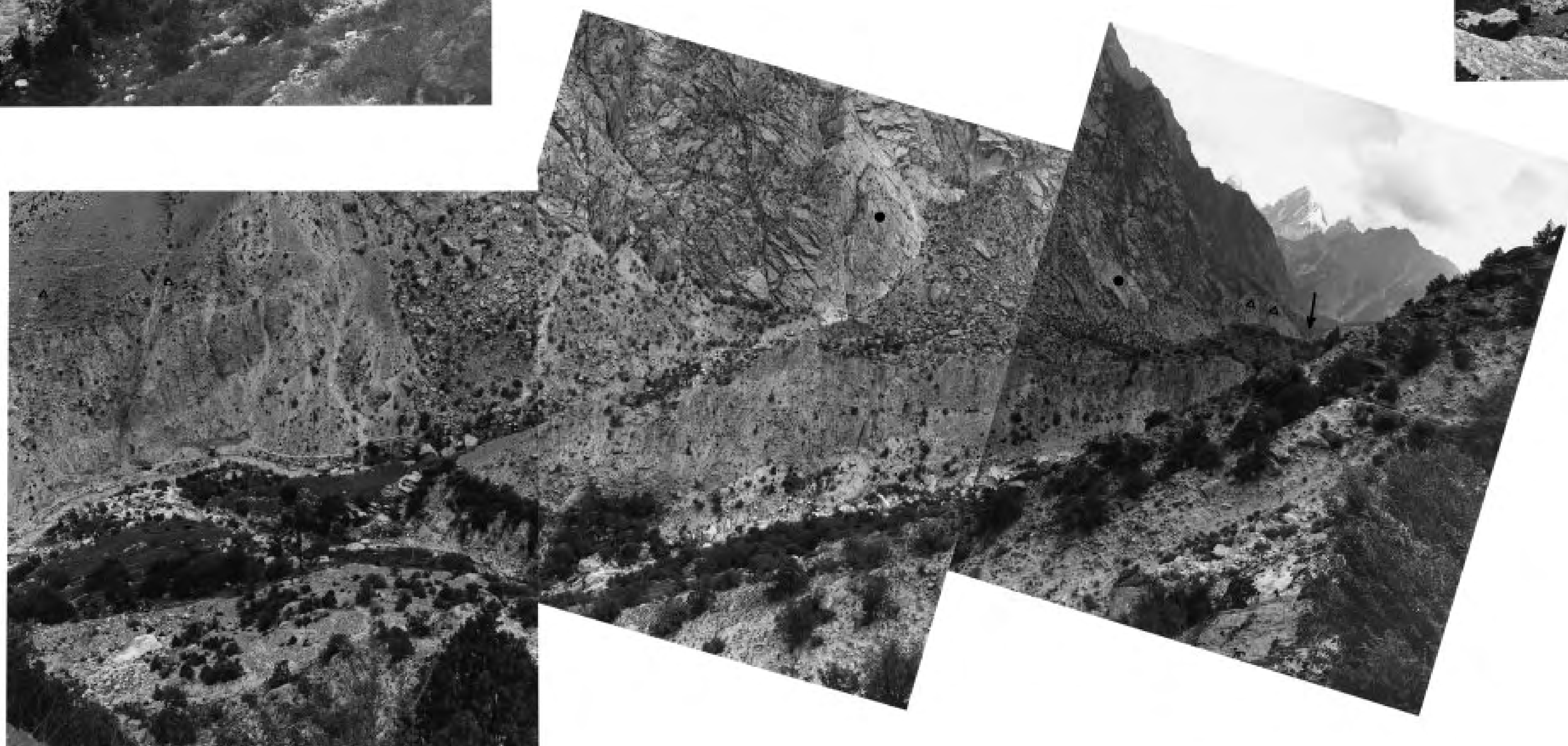


Photo 10

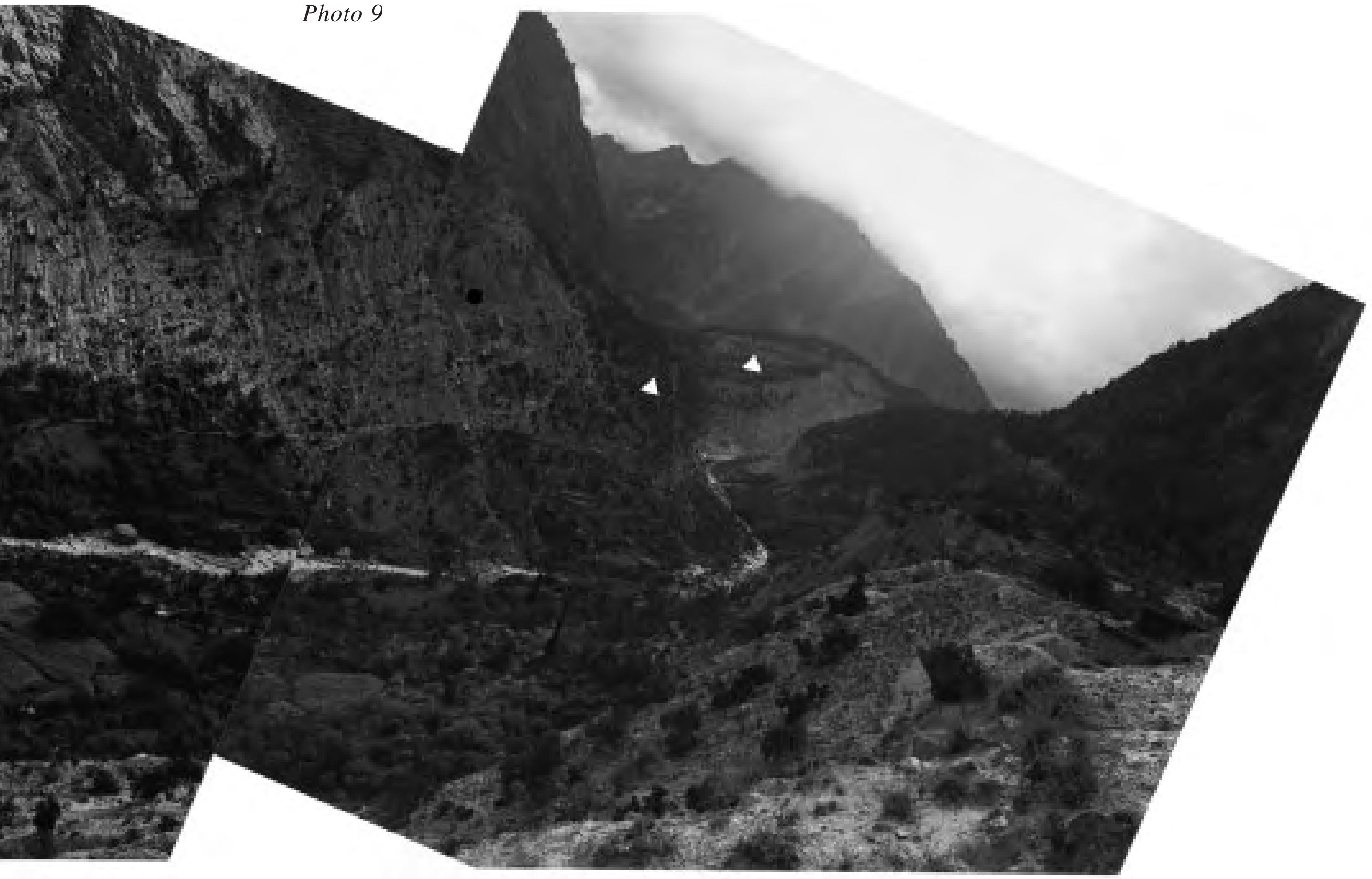
↑ *Photo 10.* The middle to lower section of the Kutwal Valley shows a glacially eroded trough profile. In the background the Darchan ridge towers c. 800-1000 m above the valley floor and in the middle part the moraine remnant (▽) as described at Photo 11 can be seen. The level of the orographic left lateral moraine terrace (– –) down-valley of the locality described in Photo 8 continues again on the valley slope and in part also finds its counterpart on the right side. The old irrigation channel was directed along this depression and often destroyed by slides. The new channel is under construction and has not been built along a natural moraine remnant, which means that it will be even less stable than the old one. Locality from which the photo was taken: on the upper edge of the step in the Kutwal valley on the down-valley end of the ground moraine terrace (Photo 8) , 2400 m. Photo S. Meiners, 8.8.2001.

↓ *Photo 11.* On the valley outlet of the Kutwal valley on the orographic right there is an outstanding feature at 2050 m (▼), covered with ground moraine, which stands out from the valley side with a roughly 80- 100 m high reversal of slope. This is probably a glacially eroded, rounded outcrop of rock, which achieves a height of 300 m above the Kutwal river. This accumulation is neither an end moraine nor yet connected with the left lateral moraine leading into the Haramosh Valley , but should be provisional attributed to the latest Late Glacial period (see Photo 7). Locality from which the photo was taken: orographic left Kutwal valley flank, 2090 m. Photo S. Meiners, 7.8.2001.

↑ *Photo 9.* The Kutwal Valley shows a classical glacigenic trough valley cross-profile. In the background on the right, the most recent neoglacial (VI or VII Dhaulagiri) ice margin of the Mani and Baska glaciers at 2200 m is shown (▲). The lateral moraine terrace on the orographic left Kutwal valley side is the settlement area of the village of Iskere, 2500 m (■), rising up to 400 m above the valley bottom. The orographic right valley flank contains remnants of ground moraine (●). In the background on the left, the Darchan ridge with its glacially eroded flat top can be seen (←). Locality from which the photo was taken: orographic right left great lateral moraine in the Kutwal valley, 2600 m, Photo S. Meiners, 8.8.2001.

→ *Photo 13.* Taken from 1600 m near the bridge below the settlement of Dasu at 1900 m. The latest Late Glacial (IV Sirkung) moraine of Dasu (↘) is linked with the level at the opposite side (↙). The terrace has been overtopped by a ground moraine level on which the settlement Phuchuli was build in an altitude 400 m higher than Dasu. This locality is only 2.5 km away from the Haramosh valley outlet near Sassi at 1500 m. Photo S. Meiners, 7.8.2001.

Photo 9



↓ *Photo 12.* In the lower Phuparash valley up-valley from the settlement of Jutial at 2200 m, ground moraine covers both valley slopes to a high level. A massive moraine accumulation at a 120 m high step in the longitudinal valley profile is particularly well preserved (↓). A late to last glacial ice-filling of this Haramosh partial stream is demonstrated by the ground moraine, which is also to be found further down-valley on the Darchan ridge. Locality from which the photo was taken: orographic left Phuparash valley bottom, 2090 m, 35°56′706″ N, 74°45′208″ E. Photo S. Meiners, 7.8.2001.

↑ *Photo 14.* The valley outlet of the Haramosh valley at Sassi at 1500 m, like that of the Darchan (Khaltaro) valley, is characterised by massive incised ground moraines, through which the Jeep road is also directed. An isolated rock with a flattened surface (foreground) which rises around 200 m above the Indus valley (right side), demonstrates a massive, last glacial maximum ice-filling. In the background at the true right side ground moraine terraces of an Indus valley glacier stand firm against erosion. Locality from which the photo was taken: Jeep road to Dasu, 1700 m. Photo: S. Meiners, 7.08.2001.

References

Dainelli, G. (1922): Studi sul Glaciale. Risultati Geologici e Geografici, Relazioni scientifiche della Spedizione Italiana De Fillipi nell' Himalaya, Caracorum e Turchestan Cinese (1913–1914). Vol. III, Ser. II.

Haserodt, K. (1989): Zur pleistozänen und postglazialen Vergletscherung zwischen Hindukusch, Karakorum und Westhimalaya.– Beiträge und Materialien zur Regionalen Geographie, **2**: 182–233.

Iturrizaga, L. (1999): Typical debris accumulation forms and formations in High Asia.A glacial history-based concept of the origin of the Postglacial debris accumulation landscapes in subtropical high mountains with selected case examples from the Hindu Kush, the Karakoram and the Himalayas.– GeoJournal, **47** (1/2, Tibet and High Asia (V), Ed: Kuhle, M.): 277–339.

Kick, W. (1985): Geomorphologie und rezente Gletscheränderungen in Hochasien.– Regensburger Geographische Schriften, **19/20**: 53–77.

König, O. (2001): Investigations on the Quaternary Glaciation in the Khumbu Himal (Nepal, East-Himalaya).– GeoJournal, (Tibet and High Asia VI, Glacio-geomorphology and prehistoric Glaciation in the Karakoram and Himalaya, Ed: Kuhle, M.): 345–363.

Kuhle, M. (1988a): The Pleistocene Glaciation of Tibet and the Onset of Ice Ages- An Autocycle Hypothesis.– GeoJournal, **17** (4, Tibet and High-Asia. Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 581–596.

Kuhle, M. (1988b): Topography as a Fundamental Element of Glacial Systems. A New Approach to ELA-Calculation and Typological Classification of Paleo- and Recent Glaciation.– GeoJournal, **17** (4, Tibet and High-Asia, Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 545–568.

Kuhle, M. (1989): Die Inlandvereisung Tibets als Basis einer in der Globalstrahlungsgeometrie fuâenden, reliefspezifischen Eiszeittheorie.– Petermanns Geographische Mitteilungen, **133** (4): 265–285.

Kuhle, M. (1991a): Glazialgeomorphologie. Wissenschaftliche Buchgesellschaft, Darmstadt. 213 S.

Kuhle, M. (1991b): Die Vergletscherung Tibets und ihre Bedeutung für die Geschichte des nordhemisphärischen Inlandeises.– Sitzungsberichte der Akademie der Wissenschaften und der Literatur Mainz, Paläoklimaforschung, **1** (Klimageschichtliche Probleme der letzten 130 000 Jahre, Ed: Frenzel, B.): 293–306.

Kuhle, M. (1993): The Pleistocene Glaciation of the Himalaya and Tibet and its Impact on the Global Climate: A Relief-specific Ice Age Theory.– Journal of the Nepal Research Center (JNRC), **9**: 101–140.

Kuhle, M. (1994): Present and Pleistocene Glaciation on the North-Western Margin of Tibet between the Karakorum Main Ridge and the Tarim Basin Supporting the Evidence of a Pleistocene Inland Glaciation in Tibet.– GeoJournal, **33** (2/3, Tibet and High Asia, Results of the Sino-German and Russian-German Joint Expeditions (III), Ed: Kuhle, M.): 133–272.

Kuhle, M. (1997): New Findings concerning the Ice Age (Last Glacial Maximum) Glacier Cover of the East-Pamir, of the Nanga Parbat up to the Central Himalaya and of Tibet, as well as the Age of the Tibetan Inland Ice.– GeoJournal, **42** (2–3, Tibet and High Asia. Results of Investigations into High Mountain Geomorphology, Paleo- Glaciology and Climatology of the Pleistocene (Ice Age Research) IV, Ed: Kuhle, M.): 87–257.

Kuhle, M. (1998): Reconstruction of the 2.4 Million qkm Late Pleistocene Ice Sheet on the Tibetan Plateau and its Impact on the Global Climate.– Quaternary International, **45/46**: 71–108 (Erratum: Vol. 47/48:173–182 (1998) included).

Kuhle, M. (2001): The maximum Ice Age (LGM) glaciation of the Central- and South Karakorum: an investigation of the heights of its glacier levels and ice thicknesses as well as lowest prehistoric ice margin positions in the Hindukush, Himalaya and in East-Tibet on the Minya Konka-massif.– GeoJournal, (Tibet and High Asia VI, Glacio-geomorphology and prehistoric Glaciation in the Karakoram and Himalaya, Ed: Kuhle, M.): 3–290.

Loewe, F. (1924): Die Eiszeit in Kaschmir, Baltistan und Ladakh.– Zeitschrift der Gesellschaft für Erdkunde,: 42–53.

Meiners, S. (1996): Zur Rezenten, Historischen und Postglazialen Vergletscherung an ausgewählten Beispielen des Tien Shan und des Nord-West-Karakorum.– GeoAktuell, **2**: 1–200.

Meiners, S. (1997): Historical to Postglacial glaciation and their differentiation from the Late Glacial period on examples of the Tian Shan and the N.W. Karakorum.– GeoJournal, **42** (2–3, Tibet and High Asia, Results of Investigations into High Mountain Geomorphology, Paleo-Glaciology and Climatology of the Pleistocene (Ice Age Research IV), Ed: Kuhle, M.): 259–302.

Meiners, S. (1998a): Beobachtungen zur jüngeren Vergletscherungsgeschichte im Nordwestkarakorum und zentralen Tienschan.– Petermanns Geographische Mitteilungen, **142** (3/4): 227–232.

Meiners, S. (1998b): Preliminary Results concerning Historical to Post-Glacial Glacier stages in the N.-W.-Karakorum (Hispar Muztagh, Batura Muztagh, Rakaposhi Range).– Scientific studies, **4/I** (Pakistan German Research Project, Culture Area Karakorum, Karakorum- Hindukush-Himalaya: Dynamics of change): 49–69.

Orographical Sketch Map Karakoram Sheet 1. (1990). publ. Swiss Foundation for Alpine Research Zurich, Switzerland.

Roethlisberger, F. (1986): 10000 Jahre Gletschergeschichte der Erde. Verlag Sauerländer, Aarau, Frankfurt am Main, Salzburg.

Wiche, K. (1960): Klimamorphologische Untersuchungen in Westlichen Karakorum.– In: Tagungsbericht und wissenschaftliche Abhandlungen des Deutschen Geographentag Berlin. Vol. 32. S. 190–203; Wiesbaden.

GeoJournal **54:** 451–469, 2001.

Investigations on the Quaternary Glaciation in the Khumbu Himal (Nepal, East-Himalaya)

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Key words: glacial landforms, ice marginal correlation, snow-line calculation, Quaternary

Abstract

Based on geomorphological field work the mapping of former lateral/terminal moraines in the middle segment of the Bhotekoshi Nadi is quite similar to the geomorphological findings of Heuberger (1956: Fig. 2). The deductive calculation of the equilibrium line altitudes is oriented on the reconstructed types of former glaciers. Based on the geomorphological findings of this valley segment the relation of Neoglacial and Late Glacial ice margins of the glaciers of the tributary valleys of the Bhotekoshi Nadi is not conclusive. A post-late glacial maximum snow-line depression of at least 950 m has not obligatory caused an ice fill of the Bhotekoshi Nadi below 3200 m.

Introduction

Bhotekoshi Nadi is situated in the eastern part of the Khumbu Himal at the Himalaya South Slope. The valley is about 30 km long between the Nangpa La Pass (5741 m) and Namche Bazar (2840 m), where it flows into the Dudh Kosi (27°42′ N86°43′ E). The article is mainly dealing with the valley segment between the settlement of Tarnga (4000 m) in the north of Thame and the valley exit of the Bhotekoshi Nadi (Figure 1, Photo 1).

According to the geomorphological relief analyses the arrangements of the positions are placed between selected glacialgeomorphlogical shapes. The arrangements of the positions between the ice margins of the local glaciation of the tributary valleys reaching the main valley are preferred to the desription of the positions of the forms in the tributary valleys. The results of this representation are evaluated concerning the remote glaciation and put into an abstract system of snow-line-calculation. The latter bases mainly on the method of Kuhle concerning the snow-line-calculation, published in 1986 and 1988a.

The results of this article found on field works by the author in March 2000. All photographies were taken by the author during this time. The informations about altitude and locality are taken from the official Nepalese Map 'Namche Bajar Sheet No. 2786 03'.

Owen et al. (1998) give a short survey of the research concerning the Quaternary glacial history of the Khumbu Himal. Heuberger (1956: 353–354, fig. 2) descripes and maps the majority of the moraines described in the following and dates them into the Late Glacial. Kuhle (1998: 5) understands the Last Glacial Maximum (LGM) ice filling of the Bhotekoshi Nadi 'as an outlet glacier of the S-Tibetan ice stream network' (cf. Kuhle 1999: Photo 23). The Bhotekoshi Nadi Glacier, as part of the South Tibetan ice stream network on the Himalaya South Slopes, reached down to 1800 m asl (Kuhle 1988b: 587, Kuhle 1998). Kuhle (1987: fig. 18) calculates for a small catchment area nearby Namche Bazar 'a drop in the equilibrium line of c. 950 m during the last Ice Age', when the corresponding glacier has not shifted on the main-valley-glaciation (c.f. Photo 1). In Heubergers & Weingartners (1985: 79) and Heubergers (1986: 30) opinion the Last Glacial Maximum (LGM) ice stream reached down to the settlement of Tega in the south of Ghat in the Dudh Kosi, which means down to c. 2500 m. Williams (1983) shows ground moraines reaching down to 3500 m linked with an in average 6500 m high catchment area. Williams writes (1983: 209) 'that the average lowest ELA can be estimate quite precisely as about 4250 m' (ELA = equilibrium line altitude) based on the findings in the small and low tributary catchment area of the Dudh Khunda Khola in the north of Ghat, i. e. a snowline depression of 1100 m to 1300 m against the recent snowline altitude. On the basis of soil weathering analysis Bäumler et. al. (1991: 240) postulate 'that the ice of the last main glaciation never reached Lukla' (2800 m asl., c. 400 m above the Dudh Kosi thalweg).

The lower Bhote Kosi Nadi – indicators on the Quaternary glacial history

Thesubu Khola (length: 11 km) flows into Bhotekoshi Nadi as a tributary valley from orographic left in 3320 m. Photo 2 shows the valley exit of Thesubu Khola. From orographic right there is a rampart following the valley exit bending over in the frontal area towards the thalweg to mediate to a rampart with simular dimension and ridge altitude which

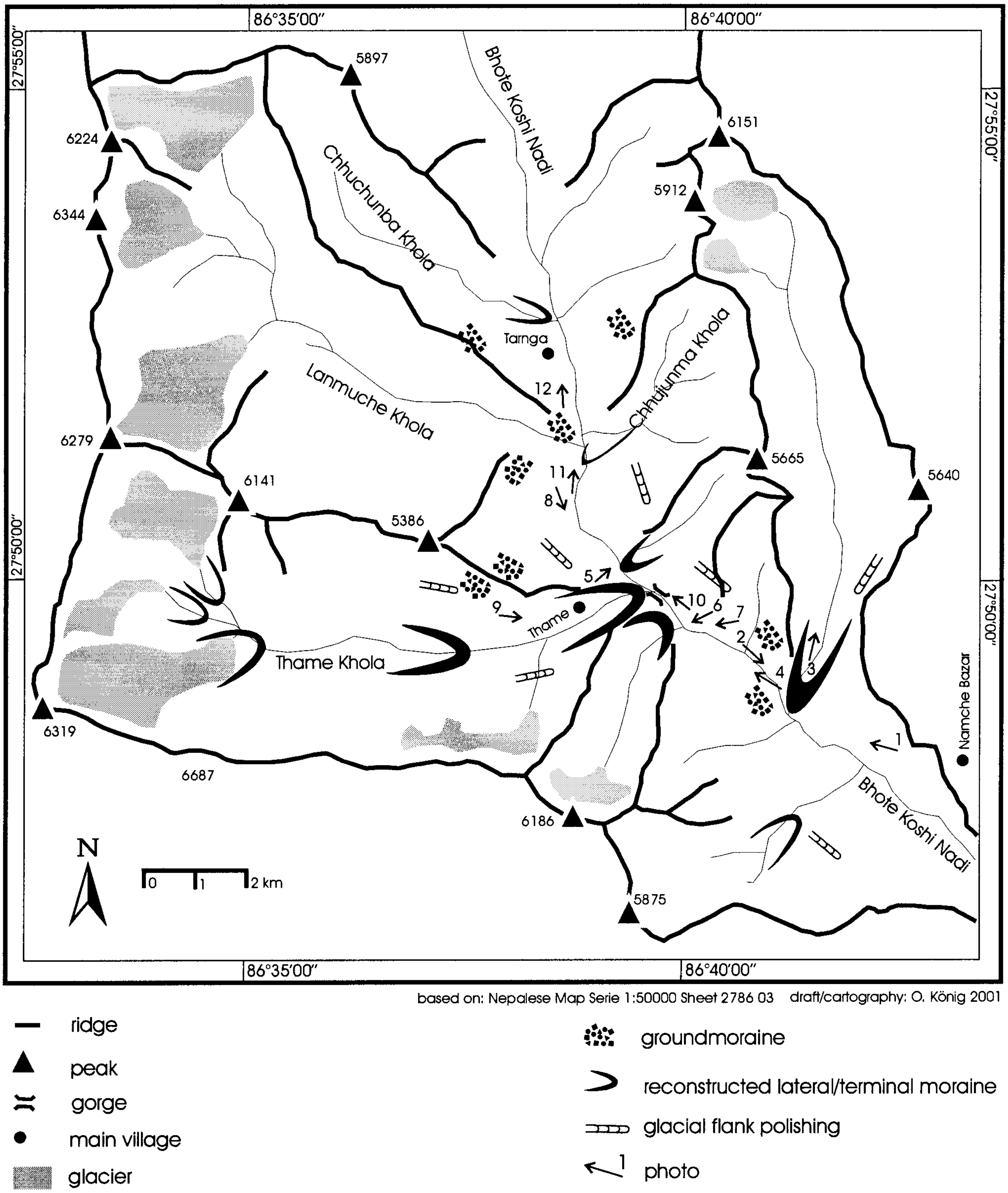


Figure 1. Reconstruction of the former ice extents in the lower Bhotekoshi Nadi (Khumbu Himal).

is situated orographic left of the Thesebu valley mouth. Outcrops of these ramparts show there structure as being composed of glacial prepared and transported sediment. These ramparts described as lateral/terminal moraine pushes far into the main valley. The tongue basin is conserved relatively good and showes that in the point of time of its tongue basin enclosure origin there was no icestream network in the main valley. Supplementary to these findings there are polished areas and glacial shaped parts of the flanks of the Thesebu Khola which support the sumption of an ice filled valley to at least 4000 m. In addition there are indicators of a distinct higher ice fill in the valley (Photo 2, Photo 3).

The run-off of the Bhotekoshi Nadi is pushed towards the orographic right flank because of the described Thesebu Khola lateral/terminal moraine. It runs partly through glacial sediment, which development is not clearly connected with the lateral/terminal moraine of the former Thesebu Glacier (Photo 2, Photo 4) but corresponds with similar sediment in the upper part of the Bhotekoshi Nadi valley. The surface of the Bhotekoshi Nadi moraine is overlayed by debris accumulations. The recent runnoff of the Bhotekoshi River is still undercuting the moraine. The described tongue basin of the former local Thesebu valley-glacier terminates in about 3350 m. The corresponding catchment area reaches a medium height between 5700 to 5800 m. Considering the former glacier-type the equilibrium line must be calculated to 4520 m. The recent local equilibrium line of this catchment area is above 5500 m. Some isolated summits up to 5665 m are scarcely covered by glaciers (Photo 3, Photo 5). The recent glaciers of the neighboring area show, that the snow-line lies between 5350 to 5500 m. The summits being steep and exposed could be the reason for shifting the local equilibrium line above 5600 m. The Thesebu Khola valley glacier ice margin in 3350 m depends to an average snow line depression of about 1100 m in relation to the local equilibrium line in 5600 m and about 830–1000 m in relation to the middle recent snow-line altitude of the whole area studied.

2,5 km up-valley in the Bhotekoshi valley there is a lateral moraine reminder of an orographic right tributary valley reaching down to the valley bottom of the main valley (Photo 6, Photo 7). Both sides of the valley exit of this small tributary valley show lateral moraine reminders depending to a former glacier tongue coming down to 3600 m. The frontal part of this glacier bassin is missing. It is likely that the glacier terminus was nearby because of the form and the direction of the moraine reminders. The position of the glacier tongue to the extend of the glaciers of Thame Khola (c.f. Photo 2) and the potential interaction makes it difficult to interpretate. But it is morphological definite that there were two separated glaciers down to 3600 m at least indicated by two separate lateral moraines (Photo 7).

The highest summit of the catchment area is the Tartikikhla with 6186 m (Photo 8). The Kuangde which Heuberger (1956) takes into consideration is a nearly as high. The middle elevation of catchment area amounts to about 5800 m. The slopes of the valley end above 5000 m are mainly more than 50° steep . Dependent on the potential relief of the former glacier tongue the equilibrium line according to the ice margin calculated in 3600 m lies in 4550 m. With reservations Heuberger (1956) calculates the former snow-line to 4900 m based on the method of v. Höfer; in consideration of the glacier type the result of this calculation seems to be too high (c.f. Kuhle 1988a, Benn & Lehmkuhl 2001: Table 1). Heuberger (1956) shows a late glacial tonque basin being closed belonging to the glacier mentioned above. Photo 4 shows this moraine reminder in position to the moraines of the former Thesebu and Thame glacier tongues. The Thame Khola extends about 12,5 km as an orographic right tributary valley to the Bhotekoshi Nadi. Photo 9 shows the valley exit. The valley end is built by a ridge with peaks between 6100 and 6700 m (middle elevation of cachment area: 6570 m).

Near the valley exit besides the Thame Khola thalweg there are elongated rampart-like forms. These walls of sediment start in about 3860 m being independent of the flanks. The rampart-ridge falls in for a few deca-meters towards the valley exit. Its end is in about 3800 m. The orographic left accumulation pulls towards the opposite flank of the Bhotekoshi Nadi crossing the valley exit of Thame Khola (Photo 8, Photo 10). The right wall ends at the edge of the recent outlet of the Thame Khola, respectively mediates to a very dismembered moraine landscape, being interpretated as a mixture of a platform moraine and a ramp moraine (Photo 6, Photo 7, cf. Kuhle 1991). Both mentioned lateral moraines set up on the platform built by the descriped moraines with is base in 3640 m. The space of the tonque basin between the lateral moraines near the recent surface is filled with mainly glacio-fluvial accumulated sediment. The base is built up with moranic sediment. An edge of the terrace below the settlement of Thame subdivides this area into two levels. This terrace is to be interpretated as a result of a fluvial cut of a tongue basin filling. Its level is in between 3760 m and 3840 m. Upwards 3840 m the valley descent becomes clearly steeper. The influence of the sediment filling equalising the relief disappears. The profile of the valley bottom declines eastwards of 4200 m. The descent leads over to the historical lateral moraines nearby the recent glaciers. The recent glaciers of the Thame khola catchment area do not reach down to 4600 m. Based on morphological and sedimtological results the valley-segment between 4200 m and 4100 m , that means the valley part below of Gokpuche Goth can be interpretated as a former ice margin.

The layers of moraine sediment on the orographical left flank of Thame Khola between Gokpuche Goth and Thame support the assumption of a glaciation in this valley-segment according to the moraine findings at the valley exit (Photo 9). There are flank polishes and glacial sediment relicts in upper parts on both flanks of the Thame Khola showing the valley was filled higher with ice of older glacial stades in accordance to findings in the main valley. The ice accumulation area of the Rolwaling Glacier joins westwards with the Thame Khola glacier catchment area (Teshi Lacha La: 5730 m). At present the ablation tongue of the Rolwaling Glacier reaches down to 4550 m calving into Tsho Rolpa (König, 1999, Meiners, 1999). Geomorphological analyses in the Rolwaling Khola indicates a neo glacial dated ice margin at 3800 m downvalley the settlement of Na (Meiners 1999: 367) and complementary the finding for the Thame Khola valley exit moraines.

Some decametres north of the above mentioned narrow gorge (Photo 10) there is a platform terminal moraine based on the valley floor of the Bhotekoshi Nadi. This terminal moraine is situated at the valley outlet of a small orographic left side tributary valley (Photo 5). It is about 3 km long starting in 5665 m. At the valley mouth (at about 3800 m) a changing incline of the valley botton leads over to a platform of loose material which is clearly separated from the incline of the main valley. Up-valley of the described accumulation glacial undercutting forms, polished rock surface and rounded parts of the valley flanks helps to interprete the platform as being glacial. The base of this glacigenic form is cut by the Bhotekoshi Nadi River in 3650 m. The related outcrops clearly shows moraine material which is genetically attached to the platform moraine. The latter one marks an ice margin of a former glacier between 3700 m to 3800 m and an increasing platform shifts the ice margin in a higher position. The catchment area is recently no glaciated. The medium height is about 5400 m (Photo 5, Photo 9).

Following the main valley upwards one reaches the valley outlet of the Lammuche Khola (Photo 11) 2,5 km north of Thame. It is an orographical right tributary valley of the Bhotekosi Nadi. The morphology of the valley confluence of the Lammuche and the Bhotekosi Nadi Khola presents glacial sedimented loose material, which is undercut by the recent drain and partly overwork by the 1985 morine dammend lake outburts flood (Vuichard & Zimmermann 1987, Cenderelli & Wohl 2001).

There are moraines of at least three catchment areas to differ morphologically: beside the mentioned valleys there is the Cchujunma Khola which is a tribute valley from the orographic left of the Bhotekoshi Nadi. Photo 11 shows lateral moraine remnants added at the valley outlet in about 4050 m to follow the descent of the main valley. Without reaching far into the main valley these moraines describe an ice margin in c. 3950 m. They overlay older moraines depending to the glaciation of the main valley chamber as a part of an ice stream network. These older groundmoraines reach beyond the valley outlets of both tributary valleys (Photo 12). The genesis of the talus cones of this valley is linked quite close to the accumulation of moranic sediments in higher flank-segments (c.f. Iturrizaga 1999).

Considering the findings in this segment of the valley it is difficult to define the position of the ice marginal of one of the three involved glacier-catchment-areas. The glacier coming out of the catchment area (medium height 5500 m) of the Chhujunma Khola would be canaliesed in the lowest quarter of the valley and therefore being typed as a flank glaciation. A glacier alike has reached down to 3950 m. A comparable ice margin is assumed for the bigger area of glaciation in the Lanmuche Khola (medium height of the catchment area about 6350 m). Photo 8 shows the main valley segment in around 1,5 km north of the Thame Khola mouth without findings of ice margins being jounger than the described moraine of the Thame Khola in this segement of the Bhotekoshi Nadi. There is only one valley segment to place potential ice margins of former Lanmuche and Chhujunma glaciers being the same age or jounger than the Thame moraine. It is about 1 km south of the valley outlets of the tributary valleys. Their potential length is therefore easy to calculate. The end of the glacier in the main valley has then been above the mentioned valley confluence, that means above 4000 m. The corresponding equilibrium line can be calculated in 5070 m in Lanmuche Khola and in nearly 4600 m in Chhujunma Khola.

Results

The summarised description of glacial-geomorphological forms in the middle Bhotekoshi Nadi proofs ice margins of glaciers depending to the tributary valley glaciation in the main valley. The corresponding glacier in the main valley can not have gone beyond the ice margins of the tributary valleys when they were developed. That means they are not attached to the LGM (Heuberger 1985, 1986 and Kuhle 1988a, 1998). The morphological findings indcating the former Thame Khola Glacier and the former Thesebu glacier show in particular that there has been no confluence of the Bhotekoshi Nadi glacier with the ones of the tributary valleys at the valley bottom at the period of their origin.

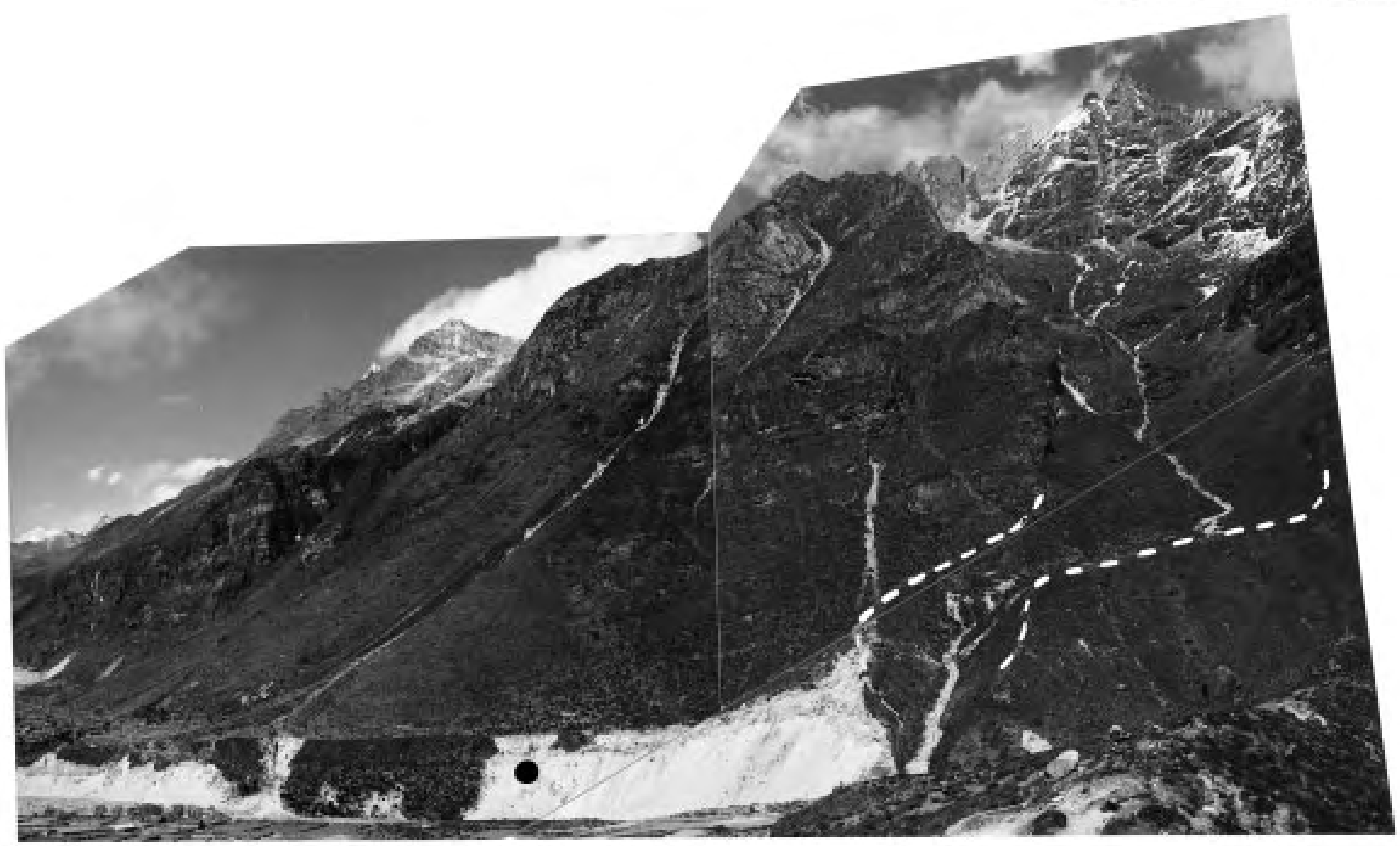
The recontructed former Thesebu Khola, Thame Khola and Lanmuche Khola glaciers are classified as firn hollow glaciers in transition to firn basin glaciers. The remaining glaciers mentioned are classified as flank glaciations or avalanche basin glaciers (dependent on the proportion of the equilibrium line sinking into the relief). The medium equilibrium line of the reconstructed ice marginals of the latter glaciers was between 4500 and 4600 m – these findings are attached to late glacial advances (c.f. Meiners 1999). The same with the Thesebu Glacier and the flank glaciation or rather the cirque glaciation of the orographical right flank of Bhotekoshi valley westwards of Namche Bazar (Photo 1, compare Kuhle 1987: fig. 18). The equilibrium line of the reconstructed Thame and Lanmuche Glacier was on an average of 5060 m clearly higher. That leads to a problem in classification being illustrated at the Thame Glacier in relation to the Thesebu Glacier. An equilibrium line depression in the catchment area of the Thame Khola down to the described Thesebu Khola glaciation (snow line about 4500 m) could not enlarge the Thame Glacier beyond the valley outlet of the Thesebu valley in the Bhotekoshi Nadi because of the described Thesebu terminal moraine. This difficulty arises because of the distinct higher catchment area of the Thame Khola compared to the Thesebu Khola. It is intensified by the negligible horizontal distance of the valleys, especially the valley exits. Concerning to a snow-line depresssion of about 900 m the late glacial glacier level of the Lanmuche Khola and the Thame Khola would have reached clearly below the down-valley attached moraines. But the morphological findings deny that.

↑ *Photo 1*. The picture presents the lower part of the Bhote Koshi Nadi. Panbuk Southpeak (6757) can be seen in the background. The thalweg of the Bhote Koshi Nadi running for 3 km deeply, that means gorge like, in the rock. The orographic right flank of this valley segment being exposed towards the east is slightly glaciated and rises up to 5800 to 6000 m (cf. Kuhle 1987: fig. 18). North of the valley mouth of the Thesebu Khola (– –) the morphology of the valley bottom changes noticable (Photo 2, Photo 4). ● marks the Thame Khola valley exit moraine complex (c.f. Photo 9). A Late Glacial ice level of the Bhotekoshi Nadi part of the ice stream network was probably located in c. 3700 m, that means c. 600 m to 800 m above the nowadays valley floor (—, c.f. Kuhle 1987: fig. 19 for indicators from the opposite flank). (The picture was taken from a point 500 m westwards from Namche Bazar looking to NE from 3520 m).

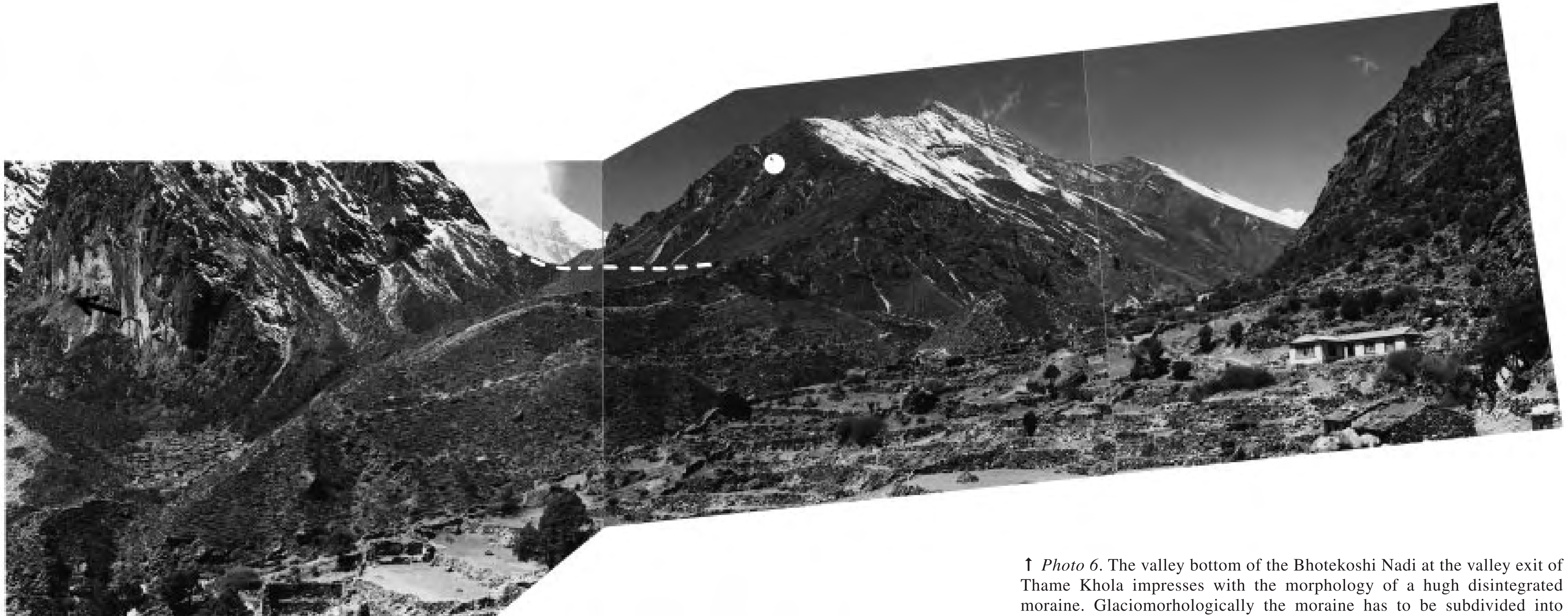
↑ *Photo 2*. Shows the valley exit of the Thesebu Khola, an orographic left tributary valley to the Bhothekoshi Nadi. The lateral moraines of a former glacier tongue basin join both sides of the valley mouth (– –). They start at about 3480 m. Moranic sediments can be found down to at least 3320 m where the recent runoff in the main valley is eroding the glacial sediments.
Upvalley the Thesebu Khola lateral moraine the loose sediment shows a mixture of the fractions clay to boulders with a peak of the frequencey curve in the sand fraction. Therefore it seems unlikely that this sediment is accumulated exclusivly fluviatil. The described sediment is not part of the lateral moraine of the Thesebu Khola Glacier but a sediment which is accumulated against the outside of the lateral moraine (→). On the right there is a moraine terrace seen which proofs a former ice fill of the main valley (○). In the area around the valley exit the orographic left flank of the Thesebu Khola is glacially rounded. It seems rather likely that the glacier level had been up to 4000 m (—).
The picture was taken standing in about 3520 m, looking towards south east, i. e. downvalley the Bhotekoshi Nadi.

← *Photo 3*. The position on the described Thesebu Lateral Moraine (Photo 2) in the orographic left makes it possible to look into the Thesebu Khola out of 3460 m. The summits in the background are around 5600 m high without remarcably recent glaciation (c.f. Photo 5: The east slopes of the 5665 m peak are part of the catchment area of the former Thesebu Glacier with the steep summit being without glaciation.) In the longitudinal profile of the valley the rock threshold runs for about 1,5 km between 3800 and 4400 m vertically. The recent thalweg passes below the position in a few decametres distance. Boulders embbeded in a matrix of sand and clay are to be seen (○). The cross profile of the Thesebu Khola has the shape of a U-shaped glacier valley with over-steepened flanks of the solid rock. (– –) marks flank polish in about 4400 to 3900 m which are probably High- to Late-Glacial. Further up in the valley indicators for a higher ice level can be found (— in 5200 m).

→ *Photo 4*. The Bhotekoshi Nadi segment between the valley mouth of the Thesebu Khola and Thame Khola is covered with hugh accumulations of loose material, which are eroded by recent runoff. The settlement of Thamu (○) is built on a fluvial debris accumulation with moranic material influence (Iturrizaga 1999,: fig. 4 d), which base on an older groundmoraine. There are parts of fluvial sedimented material inside the moraine. The right as well as the left flank is covered with moraine material to a large extent. Glacial polishing and triangular abrasision forms as well as prominent slope-changes in the longitudal profile can be estimated as an indicator for an ice fill of the Bhotekoshi Nadi during the LGM. × marks the relict of a lateral moraine bound on a former glaciation of a steep tributary valley in the South of the Thame Khola valley exit. The moraine is barely reaching the main valley (Photo 7).



← *Photo 5*. The picture shows part of the orographic left flank of the Bhotekoshi Nadi opposite to the valley exit of the Thame Khola.
The summit to the right is 5665 m high. The peak as well as the flank are without glaciation, i.e. the local equilibrium line of this W-exposed catchment area arise above 5600 m. A platform moraine with a ridge at 3800 m is joining the valley exit of this tributary valley (– –). The recent runoff of the main valley is eroding the moraine. Upvalley there are fluvial accumulated terraces on the outside of the platform moraine in the main valley (○). This can be estimated as a time sequence in the developement of the fluvial accumulation in relation to the glacial sediments. The latter are older.



↑ *Photo 6*. The valley bottom of the Bhotekoshi Nadi at the valley exit of Thame Khola impresses with the morphology of a hugh disintegrated moraine. Glaciomorhologically the moraine has to be subdivided into different glacier advances. It has been intensly cutted through fluvial processes. The orographic right lateral moraine as to be seen in Photo 9 is marked (– – –). The moraine-complex is genetically bound on the former glaciation of the Thame Khola. The area of this valley-segment is influenced by the glaciation of a small tributary valley , resp. the resulting forms of accumulation and erosion (→, c.f. Photo 7).
(○) marks ground moraine reminders at about 4200 m on the orographic left flank of the Thame Khola. The moraine reminders can be explained only by an ice fill of the Thame Khola up to at least this level. (The Photo position is at 3520 m nearby the settlement of Thamu looking towards north-west).

← *Photo 7*. The picture shows a valley segment of the Bhotekoshi Nadi between the valley exit of Thame Khola and the settlement of Para. The orographic right lateral moraine at the valley exit of the Thame Khola documented in Photo 9 and Photo 6 is to be recognized. In the middle of the picture is the thalweg of the Bhotekoshi Nadi (at about 3500 m) which is eroding among other things the lateral moraine below the orographic right side of a small tributary valley and undercut a triangular shaped erosion form build up of typically moranic sediment (○, c.f. Photo 4: x). The orographic left lateral moraine - corresponding morphographic and as well as morphological - lies below the valley exit of Thame Khola (– –).The ridge of the mentioned lateral moraine of this nameless tributary valley lies between 3640 and 3700 m The base reaches down to at least 3500 m. The house-sized boulders embedded in the clay matrix are impressing (→). (—) marks the orographic right side remnant of the Thame Khola moraine complex.

← *Photo 8*. The orographic left lateral moraine at the valley exit of the Thame Khola (– –, cf. Photo 9) „jammed" the Bhotekoshi Nadi and shifted the base of erosion for at least 250 metres higher in the upvalley part of the main valley. The background of the picture shows the catchment area (6186 m) of the nameless valley (○) which flows into the main valley from the orographic right, just nearby the Thame Khola (Photo 7). (×) marks the exposed platform moraine which development belongs to the glaciation of a further nameless tributary valley (Photo 5). The moranic material shown in the foreground is probably part of a moraine of a former local glaciation of the Lanmuche Khola. The line (—) points the polish-border to support the assumption of the Bhotekoshi Nadi has being filled with ice up to 4200 m at the minimum in former times. So the ice level must have reached above the valley exit of the Thame Khola (– –).
The valley bottom is dominated by polymictic sediment of the clay-fraction to boulders (edge-length with more than 6 m are quite often to be found). The position is about 1,3 km north of the settlement of Thame, a few deca-metres below the valley bottom at about 3840 m.

↓ *Photo 9*. The valley exit of Thame Khola which is a tributary valley of the Bhotekoshi Nadi. The picture was taken from a position at 4100 m looking eastwards. At the left is the well-known monastery of Thame. The both lateral moraines at the valley exit (– –) enclose a glacifluvial filled tongue basin of a former glacier, which ends at about 3700m. Whereas the (—) marks the ice level lying higher in the valley-crossing-profile between 4200 and 4400 m (c.f. photo6: ○). The talus cones at the right-hand site are to be interpretated as moraines being redeposited because they do not have a suficient catchment area (c.f. Iturrizaga 1999: fig. 13). (→) points the position of the gorge as shown in Photo 10.

↑ *Photo 10*. North of the segment where the thalweg of the Thame Khola joins in the run-off of the Bhotekoshi Nadi becomes very narrow. The river of the main valley erodes the solid rock gorge-like about 20 to 25 m deep. At 3640 m it runs below the main-valley flank. On the left-hand site an outcrop of glacigenic sediment is to be seen (○) which belongs morphogenetically to the orographic left of the lateral moraine valley being at the exit of the Thame Khola (Photo 9). Major parts of the left main valley flank are overworked by fluvial processes reaching higher than the border between the solid rock and the moranic material at the opposite flank (×). Therefore the former run-off has been higher than the superior ridge of the gorge. The deep incision is very likely not attached to a glacier or moraine dammed lake outburst floods but rather bound on the erosion of a subglacial meltwater stream (c.f. Kuhle 1991, Zimmermann et. al. 1986). The Bhotekoshi Nadi has been blocked by the Thame Khola Moraine at least up to 250 m (c.f. Photo 8).

↑ *Photo 11*. The Photo shows the valley confluence of the Lamnuche Khola with the Bhotekoshi Nadi at about 3940 m. On the right hand-site the left flank of the Bhotekoshi Nadi is to be seen, on the left hand-site the valley exit of the Lamnuche Khola. The recent run-offs out of both valleys cut into the moraine-like sediments in different levels. There are lateral moraines of the Chhujunma Khola bending inwards and shows a local glaciation of this small catchment area (– –). The line marks a glacier level glacier at about 4200 m to 4300 m (—, c.f. Photo 8).

→ *Photo 12*. The wide open valley segment of the Bhotekoshi Nadi nearby the settlement of Tarnga (○) join directly above the narrow segment of the main valley (documented in Photo 11). The settlement of Tarnga covers 1 km between 4000 m and 4040 m asl. on a glacifluvial and fluvial plain area which depends morphologenetical on the valley narrowness in the confluence of the Bhotekoshi Nadi, the Lanmuche and the Chhujunma Khola. North of Tarnga the lateral moraine reaches out of the Chhuchunba Khola down to the middle of the main valley bottom, i.e. down to about 4080 m (X). The catchment area of the Chhuchunba is separated by a 4800 m high ridge from the Lanmuche Khola. The valley exits are separated by a summit of about 5000 m. The foreground shows slopes covered with moraines (→) which pass into fluvial accumuled sediments nearby the valley bottom. The recent run-off cuts into these forms. Triangular abrasion forms as well as polished and glacially rounded parts of the flank proof the evidence of an ice level above 5000 m (—). They are indicators for an ice fill of the Bhotekoshi Nadi during the Last Glacial Maximum (LGM).

It would have been an ice fill of the Bhotekoshi Khola below the valley exit in the late High Glacial to Late Glacial. The in the text mentioned catchment areas should be interpretated as parts of an ice stream network. This is proofed by glacially overworked flanks and ground moraine reminders. The level of such an ice stream network has been in the valley segment dealed with between 5300 m up-valley and 4000 m down-valley, i. e. c. 800 m above the valley floor at the confluence of the Bhotekoshi Nadi and the Dudh Kosi. Large parts of its surface are attached to the accumulation area of the former glaciation.

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References

(1996): Namche Bajar. His Majesty's Goverment of Nepal, Survey Department. Topographical Map. Map 2786 03. Scale 1: 50000.

Bäumler, R.; Zech, W.; Heuberger, H.; Weber-Diefenbach, K. (1991): Investigations on the intensity of weathering of soils developed from glacial and fluvioglacial deposits and their relationship with the history of the landscape in the Mt. Everest region.– Geoderma, **48**: 223–243.

Benn, D.I.; Lehmkuhl, F. (2000): Mass balance an equilibrium-line altitudes of glaciers in high-mountain enviroments.– Quaternary International, **65/66**: 15–29.

Cenderelli, D.A.; Wohl, E.E. (2001): Peak discharge estimates of glacial-lake outburst floods and "normal" climatic floods in the Mount Everest region, Nepal.– Geomorphology, **40** (1): 57–90.

Heuberger, H. (1956): Beobachtungen über die heutige und eiszeitliche Vergletscherung in Ostnepal.– Zeitschrift für Gletscherkunde und Glazialgeologie, **3**: 349–364.

Heuberger, H. (1986): Untersuchungen über die eiszeitliche Vergletscherung des Mt. Everest-Gebietes, Südseite, Nepal.– Göttinger Geographische Abhandlungen, **81** (Internationales Symposium über Tibet und Hochasien vom 8.–11.10.1985, Ed: Kuhle, M.): 29–30.

Heuberger, H.; Weingartner, H. (1985): Die Ausdehnung der letzteiszeitlichen Vergletscherung an der Mount-Everest-Südflanke, Nepal.– Mitteilungen der Österreichischen Geographischen Gesellschaft Wien, **127**: 71–80.

Iturrizaga, L. (1999): Typical debris accumulation forms and formations in High Asia.A glacial history-based concept of the origin of the Postglacial debris accumulation landscapes in subtropical high mountains with selected case examples from the Hindu Kush, the Karakoram and the Himalayas.– GeoJournal, **47** (1/2, Tibet and High Asia (V), Ed: Kuhle, M.): 277–339.

König, O. (1999): Preliminary results on the last high-glacial glaciation of the Rolwaling Himal and the Kangchenjunga Himal (Nepal, East-Himalaya).– GeoJournal, **47** (1/2, Tibet and High Asia (V), Ed: Kuhle, M.): 373–384.

Kuhle, M. (1986): Schneegrenzberechnung und typologische Klassifikation von Gletschern anhand spezifischer Reliefparameter.– Petermanns Geographische Mitteilungen, **130**: 41–51.

Kuhle, M. (1987): Subtropical Mountain- and Highland-Glaciation as Ice Age Triggers and the Waning of the Glacial Periods in the Pleistocene.– GeoJournal, **14** (4): 393–421.

Kuhle, M. (1988a): Topography as a Fundamental Element of Glacial Systems. A New Approach to ELA-Calculation and Typological Classification of Paleo- and Recent Glaciation.– GeoJournal, **17** (4, Tibet and High-Asia, Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 545–568.

Kuhle, M. (1988b): The Pleistocene Glaciation of Tibet and the Onset of Ice Ages- An Autocycle Hypothesis.– GeoJournal, **17** (4, Tibet and High-Asia. Results of the Sino-German Joint Expeditions (I), Eds: Kuhle, M.; Wang Wenjing): 581–596.

Kuhle, m (1991): Galzialgeomorpghologie. Wissenschaftliche Buchgesellschaft, Darmstadt: 213.

Kuhle, M. (1998): New Findings on the Inland Glaciation of Tibet from South and Central West Tibet with Evidences for its Importance as an Ice Age Trigger.– Himalayan Geology, **19** (2, The role of the Tibetan Plateau in forcing global climatic changes, Ed: Tandon, O.P.): 3–22.

Kuhle, M. (1999): Reconstruction of an approximately complete Quaternary Tibetan Inland Glaciation between the Mt. Everest- and Cho Oyu Massifs and the Aksai Chin. – A new glaciogeomorphological southeast-northwest diagonal profile through Tibet and its consequences for the glacial isostasy and Ice Age cycle.– GeoJournal, **47** (1–2, (Results of Investigations into High Mountain Geomorphology, Paleo-Glaciology and Climatology of the Pleistocene), Tibet and High Asia (V), Ed: Kuhle, M.): 3–276.

Meiners, S. (1999): The history of glaciation of the Rolwaling and Kangchenjunga Himalayas.– GeoJournal, **47** (1–2, Tibet and High Asia (V), Ed: Kuhle, M.): 341–372.

Owen, L., A; Derbyshire, E.; Fort, M. (1998): The Quaternary Glacial History of the Himalaya.– Quaternary Proceedings, **65**: 91–120.

Vuichard, D.; Zimmermann, M. (1987): The 1985 catastrophic Drainage of a moraine-dammend lake, Khumbu Himal, Nepal: Cause and Consequences.– Mountain Research and Development, **7** (2): 91–110.

Williams, V.S. (1983): Present and former Equilibrium-line Altitudes near Mount Everest, Nepal and Tibet.– Arctic and Alpine Research, **15** (2): 201–211.

Zimmermann, M.; Bichsel, M.; Kienholz, H. (1986): Mountain Hazards Mapping in the Khumbu Himal, Nepal, with Prototype Map, Scale 1:50000.– Mountain Research and Development, **6** (1): 29–40.