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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

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Abstract: The results presented on the glacio-geomorphological reconstruction of a maximum Ice Age (LGM = Last Glacial Maximum) glaciation in High-Asia concern five test-areas in and around Tibet (Figure 1, Nos. 14, 6, 17, 2, 9, 18, 16). For the E-Pamir plateau and its mountains a covering ice cap is proved; a snow-line (ELA)-depression of 820–1250 m in relation to the present relief has been calculated. The Ice Age snow-line ran at 3750–3950 m asl. In the Nanga Parbat-massif a glacial (LGM) ice-stream network with a snow-line altitude (ELA) at c. 3400–3600 m has been reconstructed. This corresponds to an ELA-depression of at least 1200 m. The lowest ice margin site of the connected 1800–1900 m-thick Indus glacier flowed down to c. 800 m asl. From N-Tibet the author introduces further observations of ground moraines and erratics from a high plateau area he had already investigated in 1981. They provide evidence of a complete inland ice sheet in Tibet. From the S edge of Tibet six large outlet glacier systems i.e. lowest High Glacial ice margin sites of the Himalaya ice-stream network are reconstructed. This is a continuation of the investigations in 1977, 1978, 1982, 1984, 1988 and 1989 between Kangchendzönga in the E and Nanda Devi in the W. In this place probably the lowest glacial glacier end of the Himalaya-S-slope was found at c. 460 m asl at the Dumre settlement, S of the Manaslu. C14-datings from the Tsangpo valley on the S edge of Central Tibet classify the reconstructed Tibetan ice as being from the Last Glacial Maximum (LGM) between older than 48580 ± 4660–2930 and 9820 ± 350 YBP. From this empirical findings and inductive results on the Ice Age Tibetan glaciation are derived deductive conclusions on the interaction of the relief and the snow-line altitude with concern to the ice cover. Modelling by means of those snow-line depressions and estimations of the precipitation provide ideas about surface heights, ice thicknesses and flow behaviour of the ice sheet. The hypothesis of a global triggering of the ice age by the uplift of the subtropical Tibet up to above the snow-line motivates the investigations presented here.

1. Introduction

Figure 1 shows the selected *test-areas*, the glacio-geomorphologic inventory and analyses of which have in part already been published in detail and in part only cursorily without geomorphological and sedimentological details and substantiating photographs, or even have not been published at all. In the *regions selected* here, we have still been waiting for an interpretation sufficient to provide exact evidence. The order in accordance with which the several test-areas have been visited, could not be planned as the author would have necessarily wished, but was dependent on travel possibilities and their costs. For the *reconstruction of the Ice Age glaciation* this order is fortunately insignificant. As recognized by naturalists and biologists of the last century, and then also made clear by the glacio-geomorphologists Penck and Brückner (1901–1909) through the medium of the ‘Glacial Series’, the *arrangement of the positions* of their indicators is of special importance and can *provide evidence* of the reconstruction of *functional systems* – as for instance the Ice Age glaciation of High-Asia and Tibet (cf. Kuhle 1990e;

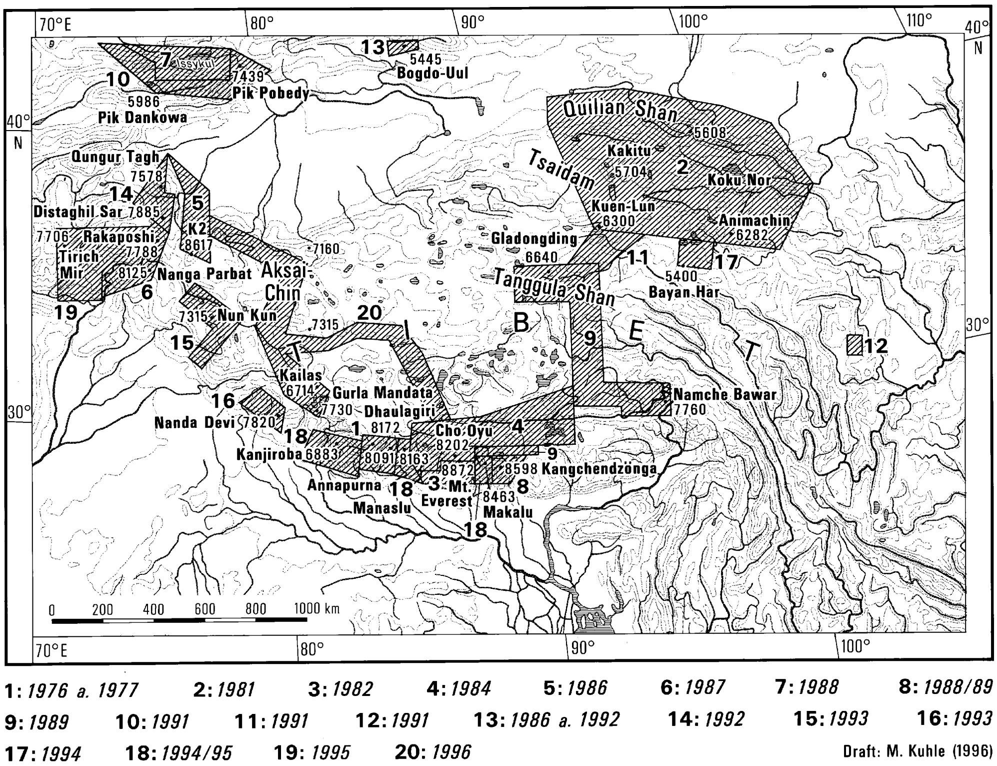

Figure 1. From the here shown areas observed by the author, new findings on the maximum Ice Age glacier cover were put down in this contribution, mainly of the areas 14, 6, 2, 17 and 9.

1991b). So, too, these oberservation- and investigation areas establish, with their *configuration* in and around Tibet, a *macro-regional* arrangement of their positions as regards the *common vanishing point* ‘Ice Age glacier cover of High-Asia’. In the same way, as in *every mountain valley or high-plateau-section*, the indicators as for instance sanders, end moraines, lateral moraines, tongue basins, roches moutonnées, flank polishings, glacier striations, ground moraines, trough profiles, transfluence passes, erratics etc. lie, confined to small areas, in an *unambiguous and typically spatial arrangement* vis-à-vis each other – the reconstruction-results of the different test-areas (Figure 1), consolidated by *ice surfaces and their snow-line*, share a *common system of reference*. This is the *system of the planetary and hypsometric landform change,* in accordance with which the geomorphological characteristics of the *high* latitude zones on earth – as with glacier development – are *repeated* at *low* latitude, but at a *higher altitude* above sea level (in the mountains and on high plateaus). This means that the results from the different regions of High-Asia *either support each other* as far as this is typical where their position is concerned or that they are *excluded* as being contradictory i.e. the time factor does not correspond.

The *internal and external arrangements of the positions* in mind, regional ‘mosaic stones’ of a prehistorical maximum glaciation of plateau sections and mountain-massifs in and around Tibet will be introduced in four chapters. With a fifth chapter concerning *new data* of the Last Maximum glaciation of Tibet, the overall picture of this ‘puzzle’ will be *classified chronologically*. In chapter 6 glacial-climatic models have been derived from the empirical data by means of mathematical deductions.

To provide really scientific, i.e. intersubjective evidence, the photographic images and panoramas with the indicative signatures are *absolutely necessary*. Only with this – in the meantime modern – method can the key function of the *positional arrangement* of the positions be made *absolutely clear* and without misunderstandings to the reader.

2. The Ice Age Glaciation of the East-Pamir (36°40′–39°10′N/74°40′–76°10′E)

2.1. *Some notes on the climate and presentation of the problem*

E-Pamir mediates between Karakorum and Tian Shan-bow (Figure 1, No. 14). Because of its leeward position it is one of the most arid mountain areas of High-Asia. The winter-precipitation of the W-flow is intercepted to a great extent by the Hindukush and W-Pamir. A summer low-pressure-trough leads to monsoonal precipitation caused by the Arabian Sea and the Bay of Bengal, which, however, for the most part precipitate in the S by rising levels of precipitation. Thus, the precipitation on the NE-slope of the Kongur massif (Figure 14), which falls away to the

Tarim basin, is less than 50–100 mm/yr (station Yengisar c. 1400 m asl: 63.5 mm/yr). At 2000–4000 m asl the precipitation increases here to 100–400 mm/yr. Further to the W on the E-Pamir plateau, behind Kongur and Muztagh Ata between 3000–4000 m asl, the precipitation decreases to less than 100 mm/yr (Taxkorgan 3090 m asl: 68.3 mm/yr) and between 4000–5000 m asl it is c. 200 mm/yr. Above the equilibrium line i.e. at more than 5000 m asl, the precipitation might increase exponentially (cf. Shen Yongping 1987; Xie Zichu et al. 1987). To the small amount of precipitation on the plateau we have got to add the subtropical radiation, which causes a high potential evaporation. In summer 10–20°C mean temperatures are reached at 2000–4000 m asl, at 4800–5000 m it is merely 3–6°C. Here, the coldest month has an average temperature of –20°C. The daily temperature fluctuations reach more than 20°C. The long-term annual mean temperature of Taxkorgan (3090 m) is +3.3°C. These are the characteristics of an *arid-continental highland climate* (cf. Kuhle 1990c), where the *daily temperatures partly overlap during the entire year*.

With this climate in mind, two main questions are to be asked for the reconstruction of the glacier cover on the E-Pamir plateau: 1) *How strong* can the glaciation ever have been under such an aridity? 2) Which changes are *caused* by the ice cover in places where the atmosphere is at present heated up by insolation?

2.2. *On the topography and recent glaciation between Taxkorgan and Kungai Kalajili (King Ata Tagh)*

Towards the NE the area falls away to the Tarim basin (Figure 14), to which Kungai Kalajili is most shortly connected. Where the peaks of Muztagh and Kongur rise are found large glacier areas, the outlets of which reach down more than 2000 m *below* the equilibrium line. Whilst Muztagh Ata wears a uniform ice cap of 20–25 km in diametre, the recent Kongur glaciation is orientated according to its three-axis main ridge. Its *dendritic* outlet glaciers reach 17 km in length. The Kaiayayilak glacier flows down to 2820 m (Figure 14). King Ata Tagh is glaciated through 45 km and sends a 23 km-long glacier down into the Oytag valley. The appearance of the glaciation shows that the unfavourable radiation of the N slopes *exceeds* their precipitation shadow.

2.3. *The lowest pre-historical ice margin position in the Oytag valley and its Late Glacial and Holocene glacier history (Figure 14)*

Six km up-valley from the inflow into the Gez valley occurs the lowest High Glacial ice margin position at 1850 m asl. It is preserved in the shape of a 30–60 m thick dumped end moraine (Figure 14, No. 4) and marked by blocks up to the size of a house and a greenish groundmass (Photo 12). This is to be found in all younger moraines up to the recent Oytag glacier at 2750 m asl (Photo 1, Figure 6) (2780 m asl, cf. Pan Yusheng (ed.) 1992, p. 76). The Oytag river, which is cut deeply into the bedrock, exposed the moraine body with its polymict boulders (Photo 11). The moraine shows a characteristic matrix (Figure 2) with a complete mixture of *finest to coarsest* portions of components. A related exposed and thick complex of ground moraines (basal till) (Figure 7) occurs 3.5 km up-valley at 1900 m asl (Figure 14, No. 5; Photo 10). Up to 2270 m asl the thickness of the ground moraine decreases to 5 m (Figure 14, No. 7, Photo 5 □, 6). The coarse-crystalline portions of the bedrock in the catchment area *shift* the fine-grain-peak from the clay- to the silt-fraction. The deep *incision* of the Oytag river is a function of the Late Glacial to the Historical glacier retreat. A *thick glacier infilling* of the two 20 and 25 km-long branches respectively of the Oytag valley belonged to the ice margin position at 1850 m asl. Evidence of this provides the lateral moraine about 3000 m asl,

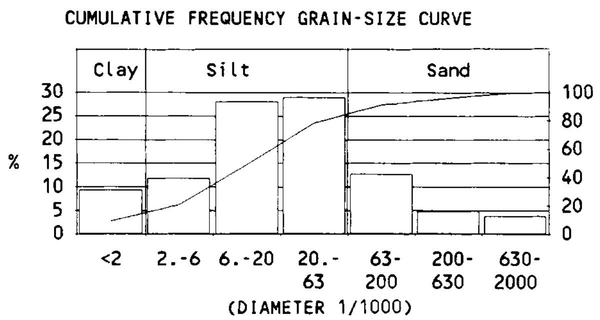

Figure 2. Grain-size diagram of the end moraine (LGM) at 1870 m asl in the Oytag valley (cf. Figure 14, No. 4; Photo 11 ■). Due to the coarse-crystalline catchment area, the characteristic fine-grain peak shifted to the coarse silt. Humus content 2.66%, lime content 9.12%.

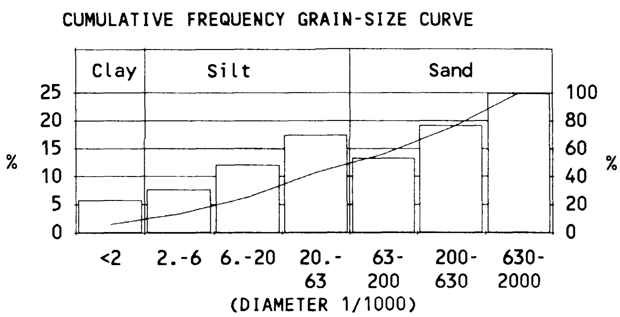

Figure 3. Grain-size diagram of a Late-Late Glacial end moraine of the Oytag glacier at 2130 m asl (cf. Figure 14, No. 7; Photo 6 second ■ IV from the left). Because of the bedrock granites of the Kara Bak Tor, the bimodal course of the curve shifted to the right-hand, i.e. to the sand- and silt-zone (cf. Figure 2). Humus content 2.56%, lime content 8.37%.

reaching up to the right intermediate valley ridge of the southern source branch (Figure 14, No. 6). It is situated 500–700 m *above* the valley floor (Photo 4, 5 ■ 0, 6 ■ 0 on the very left). Corresponding moraine remnants are preserved on the spur between the Oytag valley branches (Figure 14, No. 8, Photo 6 ■ 0, centre of the left half). A thick *ground moraine cover*, attached to the bedrock trough flanks, leads upwards to these moraine ledges (Photos 4–8). In the cross-section of the right-hand Oytag valley branch Late Glacial lateral moraines are preserved in several terraces on both flanks (Figure 14, No. 6, Photos 3–7 ■ I, II, III, IV), so for instance at 250 m above the valley floor (2270 m). The glacier surface levels *of the same age* lie 10.5 km down-valley on the orographic left-hand side (Figure 14, No. 9) some decametres *lower* (Photo 6 right half, 8, 10 I–III), as proved by another glacigenic remnant of a terrace. The youngest Stadium (IV) is absent here. The two or three ice levels preserved in this way are to be classified as belonging to the Late Glacial Stadia I, II and III, which are *widespread in High-Asia* (cf. Kuhle 1986e, 1987c (Table 1)). 0 (Figure 14) marks the Last-High Glacial (LGM) moraines (Photos 4–7, 9) (cf. in contrast Pan Yusheng (ed.) 1992, pp. 76, 78). Those Late Glacial lateral moraine ledges contain up to 10 m-thick *para-glacial* sediments (Photo 6, 7 ●). At the exits of cut-off valleys and valley flank gorges, which drain high basins, the lateral and ground moraine covering is in part cut up to the bedrock (Photos 6, 8 ↓). A *Late-Late Glacial* ice margin position of the Oytag glacier is preserved upwards of the confluence of the two valley source branches at 2130 m asl by means of an end moraine bend (Figure 14, No. 7, Photos 6, 7 ■ IV)). Figure 3 shows the *coarse granularity* of the matrix, oriented from the source material, which indicates the *characteristic* fine-grain peak in the coarse silt (cf. Dreinmanis and Vagners 1971). The ice margin is to be classified as belonging to the Last Pre-holocene Stadium IV, 620 m below the present glacier terminus and an equilibrium line depression of 310 m. In the bank area of the present Oytag glacier it is not possible to define all of the three Neoglacial (V, VI, ′VII) and five Historical ice margin positions (VII, VIII, IX, X, XI) (Table 1) by moraines, which are usually preserved (Photos 1–4). Within the available last 5500 years with a maximum ELA-depression of 300 m, *glacier-specific* oscillations as deflections of *kinematic waves* bound to the steep topography, are probable. They do not provide a generalizable idea of the climate and led to over-

Table 1. Glacier stadia of the mountains surrounding Tibet (Himalaya, Kuenlun, Pamir, Karakorum, Quilian Shan), from the Pre-Last High Glacial (Riß) to the present glacier margins and the pertinent sanders (glaciofluvial gravel fields and gravel field terraces) and their approximate age (cf. Tables 2, 3 and 4)

glacier stadium		gravel field (Sander)	approximated age (YBP)	ELA-depression (m)
-I	= Riß (pre-last High Glacial maximum)	No. 6	150 000- 120 000	c. 1400
0	= Würm (last High Glacial maximum)	No. 5	60 000- 18 000	c. 1300
I-IV	= Late Glacial	No. 4- No. 1	17 000- 13 000 or 10 000	c.1100- 700
I	= Ghasa-stadium	No. 4	17 000 - 15 000	c.1100
II	= Taglung-stadium	No. 3	15 000 - 14 250	c.1000
III	= Dhampu-stadium	No. 2	14 250 - 13 500	c. 800- 900
IV	= Sirkung-stadium	No. 1	13 500 - 13 000 (older than 12 870)	c. 700
V - 'VII	= Neo-Glacial	No. -0- No. -2	5 500 - 1 700 (older than 1 610)	c. 300 - 80
V	= Nauri-stadium	No. -0	5 500 - 4 000 (4 165)	c. 150 -300
VI	= older Dhaulagiri-stadium	No. -1	4 000 - 2 000 (2 050)	c. 100 -200
'VII	= middle Dhaulagiri-stadium	No. -2	2 000 - 1 700 (older than 1 610)	c. 80 -150
VII- XI	= historical glacier stages	No. -3 -No.-6	1 700 - 0 (= 1950)	c. 80 - 20
VII	= younger Dhaulagiri-stadium	No. -3	1 700 - 400 (440 resp. older than 355)	c. 60 - 80
VIII	= stadium VIII	No. -4	400 - 300 (320)	c. 50
IX	= stadium IX	No. -5	300 - 180 (older than 155)	c. 40
X	= stadium X	No. -6	180 - 30 (before 1950)	c. 30 - 40
XI	= stadium XI	No. -7	30 - 0 (=1950)	c. 20
XII	= stadium XII = recent resp. present glacier stages	No. -8	+0 - +30 (1950- 1980)	c. 10 - 20

M. Kuhle 1993

ridings of the moraines. Here, at the NE-foot of the 6800 (6634) m-high Kara Bak-Tor, remarkable intermittent advances derive from *small* climatic impulses and their interference with the *topography*. From this result the at least three lateral moraines (Figure 14, No. 10, Photo 2, 4, V–XI), joining down-valley. The fluctuations of the glacier level at the tongue end, which for a short time have been considerable, point to the extension and frequency of the oscillations and at the same time *unclimatic* characteristics of the *glacier-individuum*. Thus, the right-hand outer bank has been polished and abraded up to the bedrock 40 m above the present ice level (Photo 2 ☗, 4 ☗ on the very right). Above the mountain forest, which is no longer reached, begins in a *sharp line*. The youngest left-hand lateral moraine comes to a corresponding height (Photo 2, 4 ■ IX–X). It marks – as is suggested by the meagre dwarf shrub – an advance during the first quarter of the century (Stadium X or XI; cf. Table 1). A *next-older* (earlier) glacier stadium (IX) reached down to 2550 m asl (Photo 4), which corresponds to a snow-line depression of 100 m. At 2450 m asl lies a *Post Glacial* – or perhaps Post Neoglacial – *rockfall* or landslide (Figure 14, No. 10) which as a result of *glacial undercutting* has come down from the left-hand valley flank (Photo 4 △). Down-valley a *Neoglacial* tongue basin is situated at 2400 m asl, in the build-up of which the Stadia V (Photo 4) and ′VII (ELA depression 175 m) participated. Two Late-Late Glacial lateral moraine sediments (Stadium IV) (Photo 3, 4) rise like stairs on the right-hand side of the recent glacier tongue at about 3000 m asl. Thus, the pertinent snow-line ought to have run above 3000 m. The pertinent tongue basin comes to an end at 2300 m. The outer lateral moraine (IV) has been dated by means of snail shells in a thin loess cover as being *older* than 6000–7000 YBP (personal communication: Prof. Z. Qingsong, Peking, June 6th, 1992) or 6249 ± 85 YBP (Pan Yusheng (ed.) 1992, p. 76).

2.4. *The Ice Age outlet glacier down from the E-Pamir plateau and its traces in the Gez valley*

The Ice Age glacier margin lay lower than 2000 m asl. Evidence of this provide *lateral moraine terraces* at 40, 80 and 140 m above the valley floor (2000 m). They are classified as belonging to the three sub-Stadia of I (I, I′ and I″) (Figure 14, No. 11; Photos 17–19 ■; Figure 8). 2 km upwards of the Gez valley there are preserved *remnants of lateral moraine* (Figure 14, No. 12; Photo 20, 21 ■ 0), situated in the valley bend at a height of 400–500 m. The thickness of the ice (Photo 16, 17, 19, 20, 21 —— 0), derivable from this, points to a glacier terminus lying 10–15 km down-valley at 1800 m asl, near to the inflow of the Oytag valley (Photos 13–15 □ 0 ■ 0). These moraines (Photo 16 ■) contain metamorphic schist, gneiss and granite. 13 km up-valley, the pertinent ground moraine material (Figures 4 and 5) is exposed at 2180 m asl (Photos 25-27 ■; Figure 14, No. 13). It is at least 12 m thick, tightly packed and covered by a glacio-fluvial gravel body (Photo 25, 27 □). ‘Nests’ of sand and gravel are compressed into it (Photo 25 ▼ ▲). The polymict components are edged, partly rounded and facetted (Photo 25, 27 ▽). In the lower Gez valley, which as a result of the pre-historical glaciation appears remarkably clean and poor in debris (Photo 22), three *bar mountains* (Photo 23, 24 ☗) are preserved, which have been *striated* by the overflowing glacier (Figure 14, No. 12–13). On the orographic right-hand valley flank, 100–250 m above the valley floor, glacial rock polishings on schist have been preserved (Photo 22 ☗). They are covered by moraines with erratic granite blocks (Figure 14, No. 14; Photo 23 | |). Up-valley Schroeder-Lanz (1986, Figures 4 and 5) has already diagnosed lateral- and ground moraines. In this place the valley *widens to a confluence-cauldron*, the floor of which lies between 2180 and 2350 m asl (Photo 27). Extended lateral

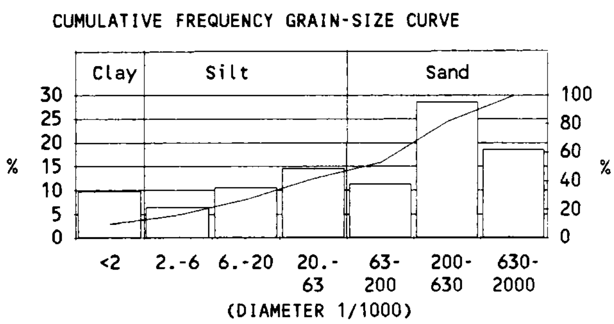

Figure 4. Grain-size diagram of a rather fine-ground ground moraine in the Gez valley (2180 m asl; Figure 14, No. 13; Photos 25, 26 ■ 0–II). The but gently-curved course in the pelitic zone of the peak in the clay up to the fine-sand is characteristic (cf. Figure 5). Humus content 0.18%; lime content 0.74%.

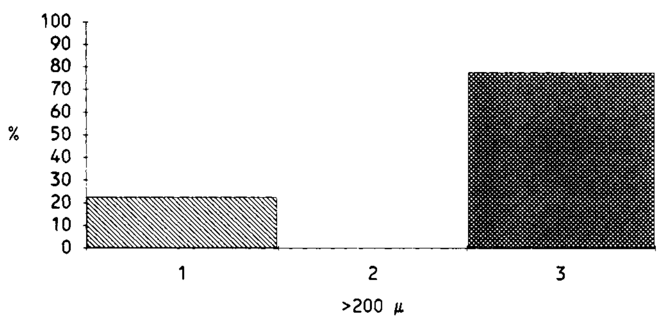

Figure 5. Quartz-grain compositions of the ground moraine matrix of Figure 4. The freshly weathered e.g. glacier-ground grains (1) are attaining a good 22%; the 75% fluvially polished grains (3) can be explained by the subglacial meltwater activities far below the ELA (cf. Figure 4).

moraine- and kame-terraces confirm considerable glacial volumes of ice (Figure 14, No. 14–15; Photo 28). The vertical profile at the military station located there, shows the following characteristics: 10–20 km above the talweg *potholes* have been formed (Figure 14 left-hand of No. 14). The lowest moraine terrace (IV) lies at 2300 m asl; the next one (III) follows at 2380 m asl; at 2500 m asl moraine II continues; then others at 2620 m, 2700 and 2850 m, the three sub-Stadia of I (Photo 28, I″, I′, I). The High Glacial lateral moraines (0) are attached to both valley flanks at a height of 3000–3100 m asl. They provide evidence of an *ice thickness* of at least 800 m (Figure 14 right-hand of No. 3) (cf. in contrast Pan Yusheng (ed.) 1992, pp. 77–79). Orographic left-hand flank polishings are in part covered by *remnants of ground moraines* (Photo 28 ■ segment 4). 2 km away from the Gez main valley, the Kaiayayilak glacier terminates at 2820 m asl (or 2769 m, cf. Pan Yusheng (ed.) 1992, p. 79) at the valley exit (Photo 29, 30 ⇓). In its forefield Historical to Neoglacial moraines are *dovetailed* with Late Glacial lateral moraines (Figures 15, 27). On the spur between Kaiayayilak- and Gez valley run two medial moraines up to 800 m (or 700 m, cf. Pan Yusheng (ed.) 1992, p.80) above the talweg, thus tracing the confluence of the glacial subsidiary streams of the glacier (Figure 14, No. 3–15, Photo 29 ■ I, —— ■ 0). On the orographic left-hand side opposite, the Erkuran valley flows into the Gez valley as a *gorge-like trough* (Figure 14, No. 16, Photo 31). 5 to 6 km upwards of the Gez valley glacial abrasions and polishings on bedrock granites are preserved (Figure 14, No. 17; Photo 32, 33 ◓ ◤ ◥). In this section the talweg runs at 2850 m asl in a *former subglacial meltwater gorge* (Photo 34). Up-valley ice streams from the Kongur-N-flank still reach the wall foot at present. During the Holocene they have accumulated large end moraines in this valley chamber (Figure 14 V left-hand of No. 17; Photo 35 ■ V). Adjacent *roches moutonnées* of an older (earlier) age have been observed (◓). On the left-hand valley side a Late Glacial moraine is preserved (Photo 36 ■ I–IV). Its ridge runs at 3350 m, i.e. 400 m above the talweg (Figure 14, I–IV, right-hand above No. 18). On the right-hand side a *ground moraine rampart* (Photo 35 ■ I–IV) proves the then *overthrusting* of the ice stream of the Kongur-N-slope over the Late Glacial Gez glacier (Figure 14, No. 18). 5 km further up, the Gez valley begins at the NE-edge of the E-Pamir plateau (Photos 37–40). Here, on the orographic left-hand side *glacial polishings of the outcropping edges of the strata* occur up to hundreds of metres above the valley floor (◓). In the place, where the valley flank from the Pamir plateau begins, it is covered by metre- to decametre-thick *ground moraine* (Figure 14, No. 19; Photo 37 ■ 0–I). 500–550 m above the valley floor at 3600 m asl it passes into a lateral moraine terrace (Photo 37, 38 ■ 0–I). The position of the ground- and lateral moraines makes clear that these sediments have been deposited by an at least 550 m-thick *outlet glacier* (Photo 37, 38 ——) of the E-Pamir ice, flowing off steeply from here (cf. in contrast Pan Yusheng (ed.) 1992, p. 80). The ice surface lay at the root of the outlet glacier at 3700–3900 m asl *near to the snow-line* (Photo 38 —— centre). *At early glacial times* the E-Pamir ice has developed from the high massifs of King Ata Tagh (Photo 41, No. 13, 14), Muztagh Ata (Photo 46, 53 No. 2) and Kongur (Photos 42–45, No. 1, 6, 8–12), in the forefields of which the ice joined, when the snow-line dropped and thus, *step by step*, the

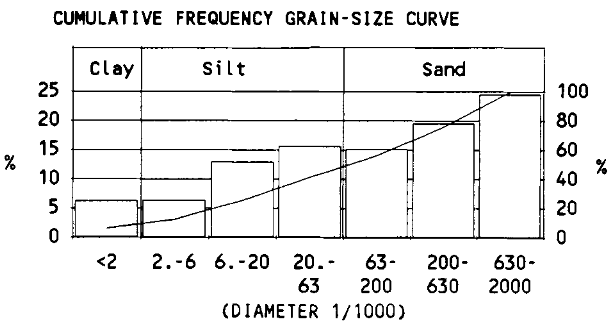

Figure 6. Grain-size diagram of the sub-recent to recent orographic left-hand lateral moraine of the Oytag glacier (Figure 14 below No. 10; Photo 1 ■ X–XII). The sample was taken from an undisturbed primary position on the moraine-crest at 2950 m asl. The material, which has been scoured out of bedrock granites and -phyllites in the catchment area (cf. Figure 7), shows – as a lateral moraine sediment and due to the c. 20 km minor distance transported – a steeper cumulative curve (histogram), which contains more coarse portions than Figure 7. Humus content 5.09%, lime content 10.94%.

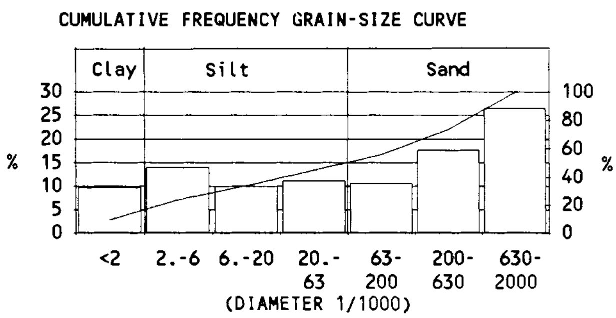

Figure 7. Grain-size diagram of the High Glacial (LGM) ground moraine, located in the Oytag valley upwards at a distance of 3.5 km from the lowest pertinent ice margin position (Figure 2) at 1900 m asl (Figure 14, No. 5; Photo 10 □). Sample taken from a depth of 20 cm at an undisturbed primary position. The material shows the classic course of a bimodal curve as an indicator of moraines; it is built up from finer substrate than the recent lateral moraine of the same catchment area (Figure 6). Humus content 2.66%, lime content 7.92%.

plateau ice cover has been built up. In the course of this the highest catchment areas lost their importance for the glacier feeding and the larger, but less elevated ice surfaces supplied the main quantity. From the beginning of the Gez valley one km upwards of the plateau, 400 m high round-polished rock ridges with a moraine cover have been preserved (Figure 14, No. 19; Photo 38 ◓ left half). They confirm the above-mentioned minimum-level of the pre-historic ice cover of the plateau (Photo 41 ——).

2.5. *Indicators of the pre-historic inland ice cover of the E-Pamir plateau*

In order to register the maximum glacier cover, the glacial sequence of forms ought to be defined in a *reverse-chronological* order. The recent glaciers flow down to the Pamir plateau from Kongur and Muztagh Ata (Photos 54–57; Figures 16, 17), which still rise 2500 m above the ELA (Photos 42–44, 46, 53 No. 1, 2). During the Late Glacial, when the glaciers reached down several hundred metres farther, their tongues have been so much more extended that they merged into a *piedmont-ice*. This was the case on the Kongur-W to SW slope during the Stadia IV and III, and possibly already during Stadium II (Photo 42–45 ■; Table 1). This 'ring of glaciation' is proved by a *hummocky* glacigenic accumulation-landscape (Photo 43, 44 ■) (cf. Pan Yusheng (ed.) 1992, pp. 82/83). The 'moraine rings' of Kongur and Muztagh Ata had contact and the ice streams from the Kongur-SSW slope flowed together with those of the Muztagh Ata-N slope, forming a *parent-glacier* (Photo 45 ■; Figures 18, 19). In the S source branch

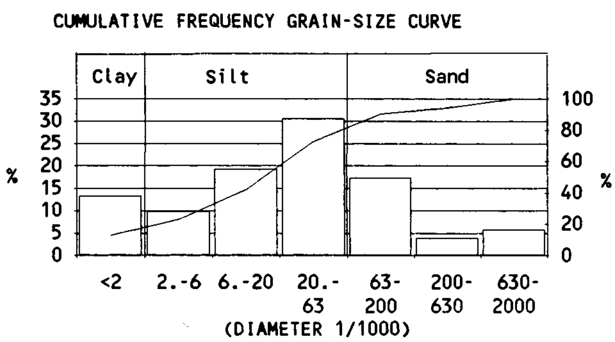

Figure 8. Dislocated moraine material taken from a mudflow fan at 2000 m asl on the orographic left-hand side of the Gez valley (Figure 14 left-hand of No. 11; Photo 17 ◆). The substrate contains a predominance of schist portions, but also coarse-crystalline portions from the bedrock granites and gneisses from the Kongur massif. The bimodal course of the curve with two fine-grain- size-peaks in the area of clay and silt points to a ground moraine matrix. For comparison see Figure 4, 16 km up-valley where, due to the minor transportation distance, the peak of the coarser material shifted to the medial-sand fraction. Humus content 2.88%, lime content 10.16%.

of the Gez valley this *confluence* led to the depression of a *tongue basin* into the 200 m thick moraine basement of piedmont-ices (Photo 45 ■ II–IV, ■ III–IV). The end moraines of Stadium III, which have been formed by this parent-glacier and in addition by a glacier branch directly from the S, from the Muztagh Ata, fringe the three Karakol lakes at 3650 m asl (Figure 14, No. 20; Photo 44 ■ III). 3 to 5 km downwards of the Karakol valley, 100 m above the talweg, a moraine ramp has been pressed into a small left tributary valley (Figure 14, No. 21). Photo 46 (foreground) shows the pertinent ground moraine material, exposed on the Karakol lake (cf. Pan Yusheng (ed.) 1992, p. 83), with free-rinsed erratic granite blocks (■). The ground mass between the polymict blocks (Figure 25) consists of *glacially broken* grains (Figure 26). The Late Glacial piedmont moraines on the W- to SW slope of the Kongur as well as the moraine belt on the WNW slope of the Muztagh Ata (Figure 14, No. 23, 24 and 30; Photos 54–57 ■; Figures 16, 17) *contrasts* with its environment, where this moraine landscape lacks completely (Photo 45 segment 1 ◓; 53 ◓). A section is shown in Photo 46 (◓), where rock ridges and small valleys are *free* of thick moraines. This could give the impression that this Late Glacial end moraine landscape reflects the maximum glacier extension on the E-Pamir plateau. On the exemplary rock ridges of Photo 46 *erratic* granite blocks are deposited on schists which build up the valley divide (interfluve) at 3730–4800 m asl (Figure 14, No. 25; Photos 47–49 ■ | | ↓). They provide evidence that these up to 5000 m-high hills have been overflowed by the High Glacial ice (Photo 46 ——; 53 —— segments 2, 3). Since even the Late Glacial glaciers flowed down to the lowest plateau areas below 4000 m (Photo 42–45 ■ II, III, IV) the *Ice Age* snow-line must have led to a *glaciation*, which *covered the entire plateau*. Due to this *dropping of the ELA down to the E-Pamir plateau* glacial end moraines *are absent*. The ice surface came above the ELA before the marginal outlet-glacier-discharge stabilized the ice level and thus made the plateau an *area of glacial erosion*. Therefore *erratic blocks* occur even at a *great distance* from those high granite-massifs on round-polished ridges (Figure 14, No. 26; Photos 50–52 ↓↓). Round-polished and abraded ridges at the Kongur and Muztagh Ata point to an ice-level at 5000 m (Photos 42–45 ——; 46, 53, 54 ——) and thus to an ice thickness of 1200–1300 m. Further towards the W the peaks, round-polished by the ice sheet, even reach 5450–5550 m. The *small cirques* (Figure 14, No. 27, 28; Photos 58, 60, 66: ○ ○), which were inset there, have been formed by local glaciers at an *up-lifted* Late Glacial snow-line (Stadia I-IV) and in the Early Glacial. On the 400 to 600 m higher plateau section at the Subax pass, W of the Muztagh Ata (Photo 53 ■ ■ on the very right; 58 ■ I–0), lies a level *ground moraine cover* with erratic granite blocks (Figure 14, No. 29; Photos 59, 60, 61 ■ I–0), up to some metres in thickness. Figures 9–12 show the variability of their matrix. This is a ground moraine plate which lacks a ramp, as it is left behind from an *ice-cap, which had priority over the relief*, and which has been flattened on all sides (Photo 58, 62 ——0) (cf. in contrast Pan Yusheng (ed.) 1992, p. 84). At the time of maximum glaciation the plateau areas, situated 400 m *lower*, also belonged to the glacial area of erosion (Photo 53 □ 3–1). This applied all the more for *this higher plateau surface*. Therefore the ground moraine up here is to be attributed to an ice cap (Photo 58 ■ I–0, 62 ■ I–II, 66 and 68 ■ I; Figures 20, 21), still *remaining in the Late Glacial (I)*. The Late Glacial ice flowed down from here to at least 3300 m (Figure 14, No. 31; Photo 63 from ■ 0–II to the right side) both, to the N in the direction of the Karakol lake (Photo 53 from ■ I–0 to the left side) and to the S into the basin of Tahman (Photos 69–71). Two sequences of lateral moraines of 80–120 m in height prove the nearby ice margin (I) Photos 66, 68 ■). This run-off-line of the ice cap is overridden at a right angle by the *younger* end moraine ramps of the *local* Muztagh Ata glaciation (Photos 63, 64 ■ III, 67 ■ II, 69, 71 ■ III–I) to beyond the talweg of the Tahman valley (Figure 14, No. 32; Photo 65 ■ III, II, I). Glacier valleys of the 5568 m-massif provide information on the ELA-depression in the Tahman basin (see below 2.6). Whilst its cirques have been formed by the Stadia II to V, longer *Ice Age valley glaciers* reached the piedmont area about 3200 m asl (Figure 14, No. 33, Photo 69 ■ I; Figures 22, 23). N of Taxkorgan there are preserved *roches moutonnées* in phyllites, which have been dressed in young varved clay (Figure 14, No. 34; Figure 24). These glacial traces at 3000 m asl are to be considered as belonging to the Pre-Last (-Riss) or Last-High Glacial Maximum (LGM) (–I or 0; cf. Table 1). At that time the adjacent Tahman basin was *glacier-covered, too* (Photos 69, 70 ——–I/0) (cf. in contrast Pan Yusheng (ed.) 1992, pp. 84–87).

2.6. *The course of the snow-line on the E-Pamir plateau (37°50′–39°N/74°40′–75°40′E) during the Last Glacial Maximum (LGM)*

The Ice Age ELA cannot be defined on the plateau itself, but only with the help of *end moraines of marginal outlet- and mountain glaciers*, with which the Oytag- and the Gez glacier must be taken into consideration. The first terminated at 1850 m asl, which at a mean altitude of the catchment area of 6000 m yields an ELA at 3925 m asl (Figure 13). At present the Oytag glacier tongue terminates at 2750 m asl. Its medium catchment area is 800 m higher than that of the Ice Age glacier. Thus an ELA depression of 850 m (6800 – 2750 = 4050 : 2 = 2025 + 2750 = 4775 – 3925 = 850) can be calculated. The *present ELA* runs at 4775 m asl. 850 m is a *minor* drop in the value of the LGM (cf. Table 1). Peulvast et al. (lecture given in 1992) calculated an ELA-depression of only 400 m. Further E, on the S edge of the Tarim basin, ELA-depressions of 1300 m have been noted (Norin 1932; Kuhle 1994a). The lowest ice margin of the Gez glacier lay at 1800 m. The *next recent* glacier terminus at 2820 m (Figure 14, No. 3) provides evidence of an ELA about 5000 m (7200 – 2820 = 4380 : 2 = 2190 + 2820 = 5010) (or 5200–5300 m; cf. Pan Yusheng (ed.) 1992, pp. 80, 82). The altitude of the catchment area of the Gez-outlet-glacier lay at 5700 m. Thus an ELA of about 3750 m (5700 – 1800 = 3900 : 2 = 1950 + 1800 = 3750) can be calculated for the LGM. With that the ELA, which had dropped 1250 m, was *tangential* to the E-Pamir high plateau (Figure 13); Peulvast et al. (lecture given in 1992) has calculated here an ELA-depression of only c. 400 m. There exists an arrangement on the 5568 m-massif (Figure 14, No. 33) to *check* the High Glacial (LGM) ELA on the SW edge

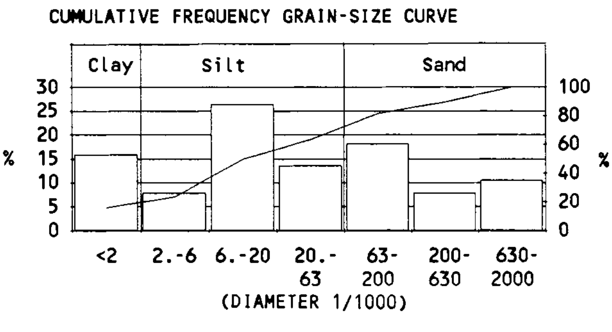

Figure 9. Ground moraine matrix, containing granite erratics of crystalline schists (Figure 14 on the right-hand side of No. 29; Photo 58 right half of the centre), at 4300 m asl on the Pamir plateau. The predominance of the pelite-portion (clay, silt) is obvious. This points to grinding as a result of a heavy ice burden (cf. Figure 10). Humus content 4.73%, lime content 12.81%.

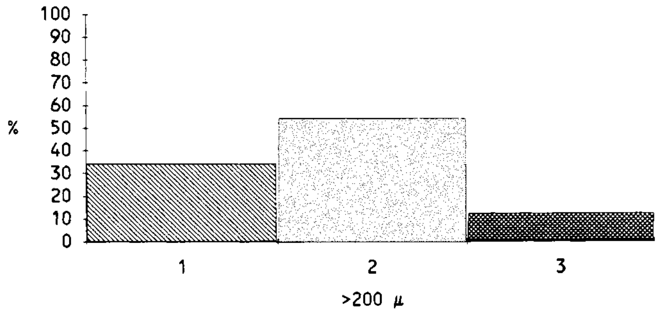

Figure 10. With the help of groups 1 and 2 (freshly-weathered and glacier-broken, what cannot always be differentiated with assurance) the quartz-grain-compositions of the ground moraine of No. 9 prove the predominant influence of the grinding by the hanging ice cover in contrast to the efficiency of the subglacial polishing of the meltwater (3) (cf. Figure 9).

of the test area. At an altitude of the catchment area of about 5160 m the glacier came down to 3200 m, i.e. the ELA lay at 4180 m (5160 – 3200 = 1960 : 2 = 980 + 3200 = 4180). If this ELA-depression of a mere 820 m *does not belong* to Stadium I but to the LGM (cf. Table 1), the basin of Tahman might have been free of ice. Peulvast et al. (lecture given in 1992) found out here an ELA-depression of merely 250–400 m.

2.7. *First conclusion, derived from results which were achieved on the E-Pamir plateau*

Widespread erratics and ground moraines provide evidence of an E-Pamir plateau ice-cap during the LGM (Last Glacial Maximum). Glacial flank polishings and abrasions as well as a gorge-like glacial trough profile occur in the Gez valley. These forms suggest an outlet glacier of 500 m to more than 800 m in thickness, flowing down from the Pamir plateau ice-cap. Similar in thickness was the Oytag glacier, which ran down from King Ata Tagh into the Tarim basin. At c. 1850 m the lowest ice marginal positions were extrapolated from lateral moraines (Gez glacier) or confirmed with the help of terminal moraines (Oytag glacier) on the E-Pamir NE slope. ELA-depressions of at least 850 m in the N and 820–1250 m in the plateau area were confirmed for the LGM. The ELA ran at 3750–3925 m asl; highest ELA values might even have been reached at 4180 m. The ice cover gave rise to the transformation of the E-Pamir plateau from an interglacial heating- to a cooling surface with a dented (concave) course of the equilibrium line.

3. Reconstruction of the Maximum Ice Age Glacier Cover in the Nanga Parbat Massif (35°05′–40′N/74°20′–75°E)

3.1. *Introduction*

In the course of the 'German Nanga Parbat Scientific Expedition 1987' (Figure 1, No. 6) the authors's task was to work on the *glacio-geomorphology* of this massif and to investigate the remnants of its *Maximum High Glacial* relief-filling glaciation. During 1987 his researches were concentrated on the Rupal-Astor valley and its tributary valleys. It was thus possible to work on the southern and eastern slopes of the massif. Furthermore he extended his studies to the northern flank of Nanga Parbat, where he investigated glacier traces in the largest main valley of the entire topography, that is the Indus valley, to which the valleys of the Nanga Parbat N-slope are immediately adjacent and adjusted to its bottom in form of steep hanging valleys. In addition the author has carried out further observations with regard to the history of glaciation in this section of the Indus valley insofar as he has inspected in detail the Rakhiot valley in 1995.

The main peak (8125 m) reaches a height of 7000 m above the Indus valley over a horizontal distance of only 23 km. This *extreme relief energy*, which is important for the maximum glaciation, can be recognized in a similarly succinct way by the difference in height of 3000 m of the upper Rupal Gah valley floor (including the recent Toshain glacier at 4100 m asl) and the Indus valley floor (c. 1100 m asl near the Rakhiot bridge) (Figure 13). In these comments the Historic and Neoglacial, i.e. Post Glacial or Holocene, glacier-history in the environs of recent glaciers or further down-valley, is touched only insofar as a differentiation from older, i.e. *Late- to High Glacial*, glacier events is necessary. Otherwise this study on the Ice Age would escalate

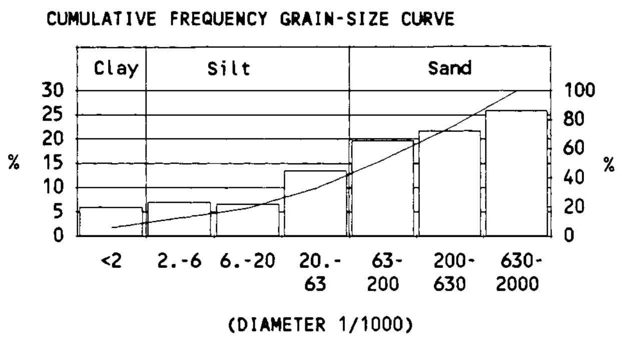

Figure 11. Matrix of the just a few decimetres-thick ground moraine at 3960 m (Figure 14 right-hand side above No. 29; Photo 61) on the E-Pamir plateau. Its insignificant thickness led to an increased scouring of the in situ bedrock with the result of rising coarse-grain-portions (cf. Figure 12). Humus content 1.75%, lime content 6.31%.

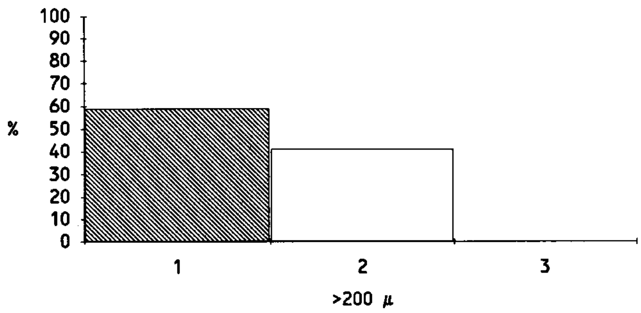

Figure 12. The quartz-grain-compositions of the ground moraine-sample Figure 11 show increased portions of freshly out-weathered components (1) at the expense of the portions of glacier-broken grains (2). A subglacial meltwater discharge cannot be read (3 is absent) (cf. Figure 11).

at the expense of clarity and readability. In this context the author would wish to mention especially the *history of Ice Age research*, recently compiled by Kick (1996, chapt. 5.5, pp. 54–58), which shall not be repeated here. The extensive and fundamental study of Haserodt (1989) including the glaciations of Hindukush, Karakorum and W-Himalaya concerns this investigation of the Nanga Parbat area both in its cartographic perspective and in chapters 2.7 (pp. 199–200), 3 (pp. 205–206) and 4 (p. 208). Due to the limitations of this narrow-local analysis it cannot be discussed generally, though. However, the author will take into account and analyse the immediate points of contact with the *field researches* of Haserodt.

The best way is to begin with the uppermost valley chambers and to describe the valleys' origin with their present glaciers and the preserved glacier traces by following the topography *valley downwards*. For that one should not start in the forefields of the still existing glaciers but at the levels far above them with their now to a great extent ice-free valley flanks up to the *present-day snow-line*. We begin with the upper Rupal Gah.

3.2. *Concerning the maximum ice-filling of the Rupal Gah between Toshe Gali and Chhungphar Gah beneath the Nanga Parbat S-slope*

On the orographic left-hand valley side remnants of *glacigenically-shaped* valley flanks are preserved at a height of 4000–4670 m above the Toshain (Rupal) glacier (Photo 79 □ background). During the Holocene they have been modified down the slopes by *weathering* and *solifluction* (Photo 79 ◤ background). These are remnants of ground moraine ledges, further above lateral moraine ledges (Photo 72 ■ left of the centre, background) and – still further above – polishings, which have abraded the outcropping edges of the strata on the mountain spurs (Photo 72 ◤ left of the panorama centre). They document a former ice level about 4670 m asl (Photo 72 —— left of the panorama centre). The mountain spur slopes, formed between the five recently glaciated orographic left-hand tributary valleys, have been polished back by the former main valley glacier to *facet-like* glacigenic *triangular-shaped* spurs (Figure 28, No. 1–4). On the valley slope opposite, but also down-valley, this former level of the glacier surface is confirmed by glacial flank abrasions (35°10′N/74°27′–30′E; Figure 28, No. 14; Photo 76 ◥ below No 1; 77 ◥ background). Proved in detail, this means: the glacigenic triangular-shaped slope surface, i.e. the abraded mountain spur in the upper Rupal Gah between the upper Toshain glacier and the orographic left-hand joining Mazeno glacier-valley (35°10′N/74°29′E), is preserved glacially *polished* and *abraded* up to 4670 m asl (Figure 28, No. 1). The down-valley orographic left-hand section of the main valley flank (35°10′30″N/74°31′E) following next, is preserved up to the height of approximately 4700 m asl as a freshly polished and abraded intermediate valley ridge spur (Figure 28, No. 2). Up to c. 450 m above the present glacier level of the Toshain (Rupal) glacier decametre-thick material of *ground moraine* has been attached to this polishing-facet. Upwards, at c. 4500 m asl, it ends in a *lateral moraine ledge*, i.e. small lateral moraine-terrace (Photo 72 ■ I–IV). As the former glacier level indicated thereby has dropped about 200 m when compared with the highest glacier level, documented by flank polishings (see above), the moraine edge and the pertinent glacier level are classified as belonging to the *Late Glacial*, i.e. Dhampu-Stage (III) (Table 1) after the author's nomenclature (Kuhle 1982, pp. 150–168; 1986e, pp. 441–452; 1994a, pp. 235–236). A younger Late Glacial glacier stage of Stage IV (Table 1) took part in the build-up of the sections of this ground moraine slope situated still further below (Figure 28, No. 2). – Down-valley there follows a 5230 m-high rock crest, running down to the S from the Mazeno ridge (Photo 72, No. 3), that has also been polished and abraded by the former main valley glacier to a *facetted mountain spur*. Up to 4680 (or 4700) m it shows traces of flank polishing and abrasion (35°10′40″N/74°32′20″E; Photo 72 ◓ right-hand of

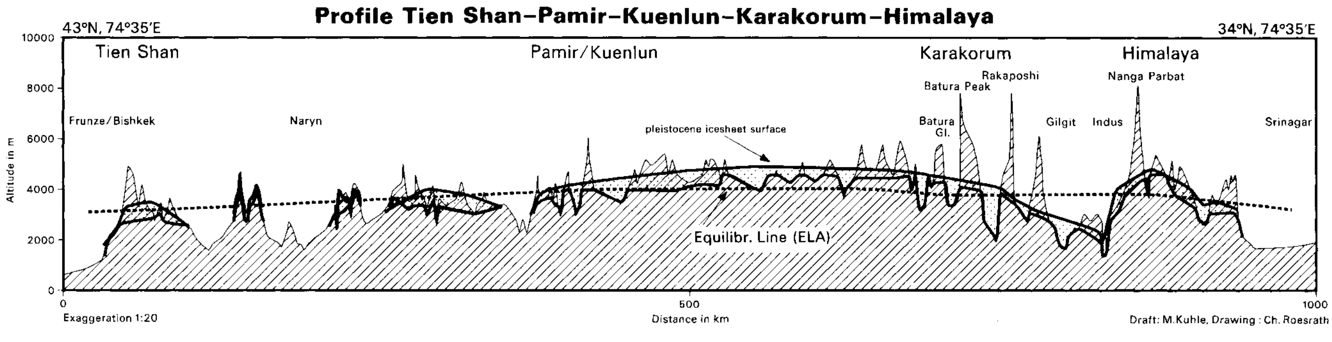

Figure 13. Schematized N/S profile of the Ice Age glacier cover in High Asia with the pertinent course of the equilibrium line. The position of the Nanga Parbat ice-stream network in the south and the Pamir ice between the Karakorum (e.g. W Tibet) and the Tien Shan in the north is obvious.

□ I–IV). Here, too, two *Late Glacial* glacier surface levels which, as measured against the *High Glacial* level have melted down about 300 and c. 370 m, are preserved through lateral moraine ledges (at 4380 m asl = Stage III and at 4300 m asl = Stage IV: see Table 1) (Figure 28, No. 3). All these moraine findings are essential, because they provide evidence of the course of the Late Glacial snow-line (ELA) *above* their deposit level, whilst the older Late Glacial (Stages II and I) and the High Glacial ELA must have been running *below* the pertinent glacier surface. An indication of this is given by the complete *lack* of lateral moraine deposits in their levels. Thus we are in the Rupal Gah in the feeding area of the Early Late Glacial and High Glacial glaciers. The above-mentioned remnants of lateral moraines at 4500 m asl (Stage III) therefore belong to a snow-line about 4400–4500 m and with that to an *ELA-depression* of c. 700–800 m (Table 1). Since the High Glacial glacier level was lying c. 200 m higher, the pertinent snow-line-depression must have come to *well over* 700–800 m. The next downward section of the main valley flank between the tributary valley-glacier, which flows down the 6970 m-peak of the Mazeno crest to the S in direction of the Rupal glacier, and the Shaigiri glacier (Photo 72 second □ from the left; 76 □) has become *glacigenically rounded* up to 4600 or 4650 m asl (35°10′50″N/74°33′30″E; Photo 72 ☗ left, above the second □ from the left). Due to *frost-weathering* and *denudation* processes, e.g. falling rocks or rock-breaking, but also to erosion through snow-melt-water, the lower slope of this glacigenic truncated spur (Figure 28, No. 4) has been dissolved into grooves. Fresh talus cones and debris slopes, which are filled into the small lateral valley of the recent Toshain glacier, make clear, that these events are *Post Glacial* i.e. Holocene to Recent.

Again up-valley, between the Shaigiri- and Bazhin glacier (Figure 28, No. 5–8) there is an orographic left-hand section of the main valley flank, that immediately links the still at present glaciated summit of the Nanga Parbat-massif over a distance of 6.5 km (Photo 72 between □ on the very left and □ on the very right). Whilst today only the Rupal face (Tap) hanging glacier in its direct line of dip flows down to the valley floor of the Rupal Gah at 3580 m asl (Photo 72, second □ from the right), during the Ice Age the mountain flank, rising more than 4500 m, supplied the Rupal Gah with *important* ice masses. From this resulted a *reduction* of the horizontal polishing of the valley glacier flanks in favour of the ground-polishing of the hanging glacier, parallel to the line of dip, by which the high glacial level of the valley glacier has become geomorphologically *blurred*. Nevertheless, there exist forms which represent the former valley glacier-surface (Photo 72 ——, right half; 75 ——). On the mountain spur outwards of the Shaigiri glacier inflow (35°11′N/74°34′35″E), the former flank polishing reaches up to a height of at least 4520 m (Photo 72 ——, left of the centre). To this polishing-line, that of the E adjacent steep hanging valley is adjusted (Photo 72 ○ on the right below No 3; Figure 28, No. 5). Between this valley and the Rupal-face hanging glacier (35°12′N/74°35′30″–74°37′E) the *flank polishings of the main glacier* reach up to c. 4650 m asl. In some places above, moraine material (4680 m asl) with large blocks is preserved upon rock flattenings (Photo 72 ■ above —— on the left below No. 1). This, too, indicates the approximate height of the former ice level (Figure 28, No. 6). At glacial times the flank ice from the Nanga Parbat S-face, above the level of the valley glacier, had split in the two hanging valleys, which thus functioned as *outlets*. In the upper part of the section of the main valley flank concerned, which between these hanging valleys converges in a mountain spur, a small cirque has been shaped (Photo 72 first ○ from the right). Such *subordinated* ‘mountain spur- cirques’ and ‘-nivation funnels’ are to be noted on many orographic left-hand intermediate valley ridges of the tributary valleys (Photo 72 ○). Since they are mostly formed *above* the High Glacial level of the valley glacier, their *initial formation* is to be classified as belonging to the Early- and Late Glacial, i.e. the pertinent course of the ELA was somewhat *higher* than at High Glacial times. Of course they have been shaped during the High Glacial, too. These small glacial concave moulds give evidence of the onset of the *destruction* of High Glacial valley flank-polishings by means of the glacier’s work *itself*, which already started during the Late Glacial (Figure 28, No. 7).

Between the Rupal face hanging glacier (Photo 72 □ second from the right) and the adjacent Bazhin glacier to the E (Photo 72 □ right-hand) the highest Ice Age glacier surface, proved by *flank polishing and abrasion*, reached up to a height of 4500 m (Photo 72 —— right quarter; 74, 0 —— left third) (35°12′38″N/74°36′40″E). Adjoining rock-polishings to the E (Photo 72 ☗ on the right), partly superimposed by *ground moraine* (■ right quarter above), reach up to c. 4400–4460 m asl (——, right quarter above ■) (35°12′40″N/74°37′10″E; Figure 28, No. 8). Beyond and down-valley of the Bazhin glacier (for its history see Table 2), in elongation of the junction of the Bazhin-valley with the Rupal Gah, a *classically* polished glacier valley-flank is preserved (Photo 72 ◥ ◥ on the very right; 79 ◤ on the very right; 74 ◥ second from the right; 80 ◤). Moreover, the grooves inset in this place permit a superimposed *ground moraine* (Photo 72 ■ on the very right; 80 ■), which breaks off in some distance of the ice scour limit (Figure 28, No. 9), to be recognized. The Ice Age glacier level ran down in a repeatedly bent course from the Nanga-Parbat-Silver-Saddle-Rakhiot-Peak-SE-face (which falls away from 8125 to 7070 m asl; Photo 72, No. 2) to the left from a height of 4650–4600 m (35°14′15″N/74°39′E; Figure 28, No. 10) via 4500 m (35°12′55″N/74°39′20″E; Photo 72 —— on the very right; 78 —— on the very left) up once more to c. 4550 m asl (35°14′N/74°41′33″E) to the junction of the Chhungphar-valley (Gah) (Figure 28, No. 11; Photo 74 —— right-hand of the centre) with the Rupal Gah (Photo 82 —— bold). This at present still relatively heavy-glaciated tributary valley (Photo 72 □ on the very right; 78 □ right; 79 □ foreground) supplied the Ice Age *Rupal ice-stream network* with an *important* firn flow from the Nanga Parbat massif (see below 3). Before looking at the reconstruction of its level, the glacial traces of flank polishings and abrasions on the orographic right (S) valley side of the upper Rupal Gah ought to be introduced in order to complete those of the orographic left one (see above). Above the Toshain-glacier, on the rock faces of the 6325 m-peak- NE-spur, flank polishings reach up to 4800–4750 m asl (35°08′N/74°29′E; Figure 28, No. 12; Photo 72 —— right-hand of No. 6; 76 —— below No. 2; 79 —— right-hand of No. 6). This level of the *ice scour limit* is proved by some merely decametres higher preserved traces of the firn flow level beneath Toshe Gali (5122 m asl) and also by those, the remnants of which one can find in the whole Rupal-valley head (Figure 28, No. 13). The ice scour limit on the 5950 (5971) m-peak-N-face, opposite of the Mazeno valley-inflow (35°07′40″N/74°31′30″E; Figure 28, No. 14; Photo 76 below No. 1; 77 and 79 below No. 6), was running at about 4700 m. In the area of the junction with the right side valley, facing the Shaigiri-valley, which is still at present filled with a c. 7 km long valley glacier, remnants of *polished cavettos* (grooves) at 4650–4700 m asl (35°09′N/74°33′25″E; Figure 28, No. 15) are preserved. On the large, steep face of the 5950-m-peak (Photo 72, No. 5) in the catchment area of this tributary valley the exposition of which changes from E to N, indicators of a former glacier level are lacking, whilst on the left flank *freshly preserved* glacier polishings do occur (35°08′N/74°33′40″E; Figure 28, No. 16). A *highest former* ice surface level can be evidenced by traces of the glacier margin in massive-crystalline rocks between 5150 and 4670 m asl in a subordinate small hanging side valley on the orographic right (35°08′30″N/74°35′40″E; Figure 28, No. 17; Photo 73 ——) beneath the 5584 m-peak (Photos 72, 73, No. 4). *Early Late Glacial* lateral moraine deposits are lying here up to c. 4450 m asl (Figure 28, No. 18).

From the junction of that right-hand tributary valley down the Rupal valley, a series of mountain spurs, which by glacial polishings have been formed into *classical triangular-shaped* valley flank-facets can be recognized. These glacigenic *truncated* slopes (35°10′08″–38″N/74°35′–39′40″E) reach up to max. 4450 m (Photo 76 ↘ ▲ below and to the left of No. 3; 74 ↙; 77 ↘ ▲ to the left of No. 6; 79 ↘ ▲ to the left of No. 6). In places, the pertinent lower slopes show a covering of *ground moraine* and Late Glacial lateral moraine (Photo 74 ■ on the right; 77 ■ on the left; Figure 28, No. 19).

Between 35°10′38″N/74°39′40″E and 35°10′50″N/74°40′35″E (Figure 28, No. 20) remnants of the glacigenic triangular-shaped *valley flanks-facets* and form-ruins, slit by groove-formation (Photo 76 ▲ from the centre to the left-hand edge; 78 ▲ left half), do continue until their acute upper angles join the crest of the Rupal ridge, that is the intermediate valley ridge to the Chhichi Gah – a larger ESE-tributary valley – at a height of 4000 m (Photo 79 ▲ and —— from the centre to approx. the left- hand edge). Probably, though, the *High Glacial ice scour*

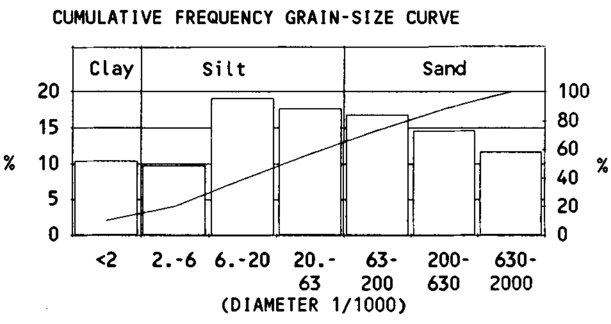

Figure 15. Late Glacial material of lateral moraine of Stadium IV at 2700 m asl in the orographical right-hand forefield of the recent Kaiayayilak glacier (Figure 14, No. 3; Photo 29). The ground mass shows very well-balanced portions of the fine-grain spectrum. The proportionally great portions of clay and silt are characteristic; both the peaks of the bimodal course of the curves are in the clay (weakly developed) and silt, whilst the sand portions decrease with an increasing grain-size. For morphometry cf. Figure 27.

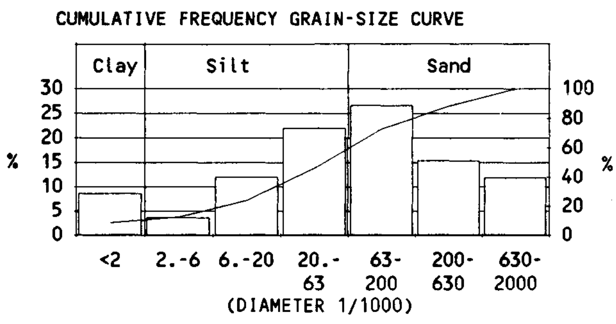

Figure 16. Sub-recent ground- i.e. end moraine on the edge of a Muztagh Ata W glacier (Figure 14, No. 30; Photo 55 ■ XI–XII); according to the minor age of the moraine and its altitude at 4530 m asl, the humus content at 0.72 % is very small. This sample with its classic bimodal course of the curve (two fine-grain-size-peaks) serves for comparison with the samples from the area of the High Glacial moraines of the E-Pamir plateau. For morphometry (form-analysis) of the quartz grains of this substrate see Figure 17. Lime content 3.7%.

limit i.e. the level of the ice-stream was lying at about 300–500 m higher, which is evidenced by the Rupal valley flank opposite (see above). The glacial polishings of those upper slopes, however, seem to be *completely* destroyed (Photo 79 below 0 —— on the left). This applies especially to the out-cropping edges of the stratum of the more than 15 Ka ice-free metamorphic rock surfaces, which, bound to the clefts, have been forcedly shifted backwards by frost weathering. Further down the main valley, the Rupal ridge dipped up to 3310 m asl beneath the ice surface (35°10′50″N/74°40′35″E–35°13′40″N/74°43′20″E; Figure 28, No. 21; Photo 79 —— left third; 82 —— thin, on the right). Nevertheless, it shows no rounded feature, but is sharpened today. This goes back to *Late Glacial* glacier polishing of the still joining Rupal- and Chhichi valley glaciers, at a level, which had dropped *beneath* the ridge level. So this is the result of Post High Glacial scouring.

Down the Rupal ridge, in the valley chamber of Tarshing, the Ice Age Chhichi firn-stream joined the Rupal parent-glacier (Photo 79 —— near to the left-hand edge; 82 —— up to the left-hand edge). The recent 6 to 8 km long glacier infillings in the Chhichi Gah catchment area – the 5860 m-peak-ESE-glacier, the Ghughuol- and Dodhar-glaciers – only just reach the main valley floor 16 km above this confluence with their *deepest* down-flowing tongue (Figure 28, No. 22; Photo 82 left □).

Besides smaller *High- to Early Late Glacial* cirques and nivation funnels (‘Karoide’) in the affected lower section of the orographic right flank of the upper Rupal Gah (Photos 78, 79 ○) there is connected in this N-exposition a larger *cirque* with a still existing snow-infilling (35°10′20″N/74°38′30″E; Figure 28, No. 23; Photos 78, 79 ○ on the left below No. 4) and a short hanging valley with a cirque glacier N of the 5584 m-peak (Figure 28, No. 24; Photo 72 left-hand edge below No. 4). Forming a bay-like curve to the S, the Ice Age firn stream surface passed into the two large concave moulds, which interrupt the right Rupal valley flank. This can be evidenced by *polishing lines* at a height of 4350–4450 m (Photo 72 —— on the very left; 78 —— to the left of 0; 79 —— above ○).

3.3. *Proofs of a highest Ice Age glacier surface level from the lower Rupal Gah to the Astor valley up to the junction of the Parishing Gah on the E-side of the Nanga Parbat group*

Flowing down at present from the 9 km long ESE-flank of the Nanga Parbat-massif between Rakhiot-peak (7070 or 7074 m) and Chongra-peak (6830 m) (Photo 83, No. 1; 2 = W Chongra), the three subdivided glacier streams of Chongra (No. 1, 2, 3) and the Chhungphar glacier (Figure 28, No. 26), which terminate in a joint ablation area, i.e. a joint glacier tongue (for its history see Table 2) (Photo 82; 83 □), have *roughened* and *dissected* the polished rock faces that had become extensively polished by the Ice Age glacier (Photo 82 ☗ second from the left). This is the orographic right flank of the Chhungphar Gah, where glacial rock *polishings and abrasions* on the spur 4 km eastwards of the Rakhiot-peak are arranged from 4650 to 4550 m asl, providing proof of a connected former glacier level (35°15′–15′40″N/74°41′E; Figure 28, No. 25; Photo 82 —— bold). Between this and the above-mentioned locality (see 2) on the same valley flank in the confluence area with the Rupal Gah (35°14′N/74°41′33″E) at 4550 m asl, the flank polishings are *interrupted* by a former cirque (Photo 82 right ●), presently covered with debris, and five grooves with their small source funnels. Nevertheless, the polishings are clear with

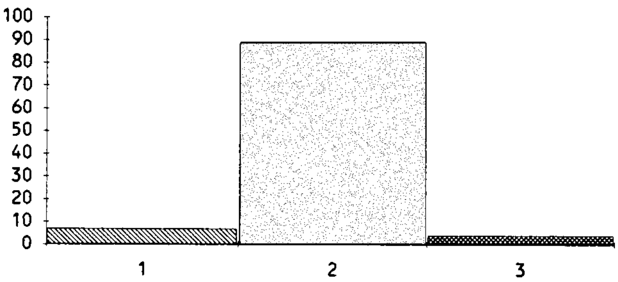

Figure 17. Quartz-grain compositions of the moraine matrix of Figure 16. The content of the freshly-weathered grains (1) lies at 7%; the 89%-proportion of grains, which are ground by the glacier, is typical of ground moraines of semi-arid cold glaciers (2); accordingly, the content of fluvial-polished grains (3) is small (4%) at an altitude of this glacier of a mere 500–700 m below the ELA.

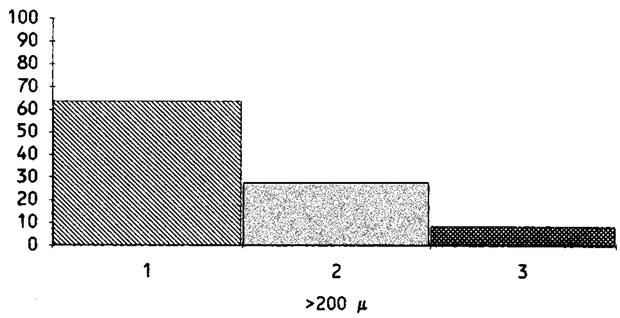

Figure 18. Quartz-grain compositions of the matrix of the ground- to end moraines in Figure 19. The content of the freshly-weathered grains (1) lies at 63.8%. This points to a short distance of transport from the bedrock raw material. The proportion of the glacially ground grains (2) is 27.6%, that of the grains, polished by subglacial meltwater (3) is 8.6%. This portion is relatively small, because it concerns a moraine position far from the talweg (Photo 45 ■ III–IV in the foreground).

Table 2. Samples for radiometric dating (C14) with their localities and thus detailed description in the area under investigation in 1987 and 1995: Nanga Parbat and Rakaposhi regions (Figure 1, No. 6; Figure 28 between No. 25 and 26 and 8 and 9; cf. Table 1). Laboratory analysis: M.A. Geyh, Lower Saxony State Office for Soil Research, Hanover, Germany. (Cf. Table 3 of Central S-Tibet: Nyainquêntanglha and Namche Bawar regions; Figure 38)

sample nr.	sample material	taking of the sample	sample depth	sample location	sample environment	conv. ^{14}C-age (YB 1950)	^{14}C-content (in % modern)
30.08.87/1	wood	out of moraine	0,1m	35°15'N 74°43'E Nanga Parbat Chhungphar-Chongra glacier 3180m asl	innermost orogr. left moraine of Chongra glacier vegetation: juniperus sp., cupressus sp.	215+/-115 stadium IX or stadium X little ice-age	133,6+/-0,9
30.08.87/2	wood	out of moraine	0,1m	35°15'N 74°43'E Nanga Parbat Chhungphar-Chongra glacier 3180m asl	highest, oldest moraine of Chongra glacier vegetation: juniperus sp., cupressus sp.	255+/-75 stadium IX	96,8+/-0,9
06.09.87/3	wood	out of lateral moraine	0,1m	35°12'N 74°39'E Nanga Parbat Bazhin glacier 3656m asl	orogr. left lateral moraine sample taken at anorganic layer vegetation: juniperus sp., cupressus sp.	125+/-60 stadium X little ice-age	98,4+/-0,8
15.09.87/5a,b	wood Juniperus trunk ⌀25 cm	out of lateral superficial moraine	0-1m	36°12'N 74°34'E Rakaposhi Minapin glacier 3420m asl	orogr. left lateral superficial moraine; pulled by the recent glacier out of the former lateral moraine	280+/-50 stadium IX	96,6+/-0,6

M. Kuhle 1988

respect to their *upper limit*. On the left-hand flank of the Chhungphar valley, that is the W-exposed rock slope of the Tarshing ridge, *perfectly* preserved glacial flank polishings occur up to a height of 4600 m (Photo 81 left ▲; 83 ▲ ▲ ▲ ▲ ▲ in the centre; Figure 28, No. 26). They at most come to an end 70 m below the 4676 m-high Sharsingi peak in an upward direction (35°16′39″N/ 74°44′40″E; Photo 81 —— below No. 1). In places, metre- to decametre-thick remnants of *ground moraine* are preserved on the lower rock face (35°17′10″N/74°43′35″E, 3700 m asl; Photo 83 fifth ■ from the left). Though the structure of bedding and resistance of the bedrocks of this mountain flank in very differently declining outcrops of the stratum is in part extraordinary *irregular*, the whole valley flank from the bottom to the ridge shows strikingly *well preserved* glacier polishing and abrasion. This provides a conclusive indicator for the youthfulness of this shaping, i.e. its *Late*- or at most *Last High Glacial* (LGM) age. This polishing line (Photo 81; 83 —— on the left) runs on the pertinent valley cross section, 1300 m above the surface of the recent Chhungphar glacier, at 3300 m asl (Photo 83 □). Thus it proves an ice thickness of *at least* 1400 m – yet probably more than 1600 m – at a corresponding thickness of the recent ice stream of 100 m to more than 300 m. Down-valley, in the area where the Chhungphar Gah joins the lower Rupal Gah, on the flank of the Rampur ridge (35°16′–14′40″N/74°45′40″–47′30″E), *extensive* glacial polishings occur on the orographic left-hand side up to the 4004 m high summits of this mountain ridge (Photo 83 fourth and fifth ▲ and above ——). In places there are even preserved remnants of a *ground moraine cover* (35°14′55″N/ 74°46′05″E and 35°14′20″N/74°47′36″E; Figure 28, No. 27). East of the Rampur Eck (3884 m), the ridge, which extends downward to a height of 3175 m asl, has been totally overflowed and at a considerable thickness from the Rupal subsidiary stream. Accordingly it has been left *round-polished* (Photo 81 ▲ ▲ on the right with ——; 83 second to fifth ▲ from the right) and with a *partial* moraine cover (Figure 28, No. 28). – The already-mentioned subsidiary stream of the Chhichi valley (see 2) joined the Rupal glacier from the SSW, i.e. from exactly the other valley side from that of the Chhungphar subsidiary stream. Traces of forming, which provide evidence of the *maximum level* of the Rupal glacier, are preserved on the orographic right-hand valley side, i.e. on the flank of the 4720–5099 m-high Chhichi ridge, over a distance of 16 km – from the recent tongue of the Dodhar glacier to the valley head – between more than 4200 m and *at least* 3770 m (35°06′–12′40″N/ 74°44′25″E; Figure 28, No. 22–29; Photo 82 ▼ ▼ —— on the left). However, this does not exclude the fact that the glacier level was even lying about 200–500 m higher *without* forming or leaving behind geomorphological traces. The indicator of the level, located at 3770 m asl m, mentioned above, is a remnant of a lateral moraine terrace (Figure 28, No. 29; Photo 82 ■ II) on the NW-ridge of the Chhugam peak (4066 m). Due to its altitudinal position in relation to the snow-line – to have been formed it had to lie *at least* somewhat *below* the ELA – this lateral moraine remnant is to be classified as belonging to the surface of the ice-stream network, which had already dropped during the *Late Glacial*, i.e. perhaps to the Taglung Stadium (II s. Table 1). This – as shown, too, by the more than 800 m higher glacier level on the other side of the Rupal Gah, opposite this confluence of the subsidiary streams – actually

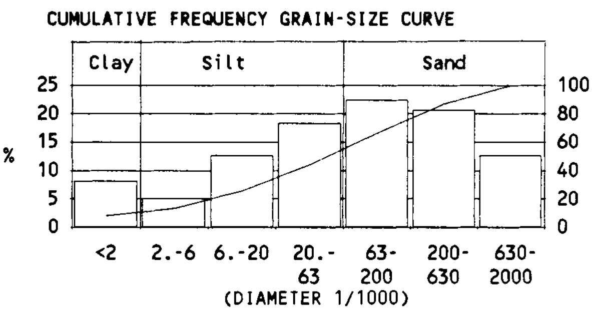

Figure 19. Matrix of Late-Late Glacial ground- to end moraines from the N-flank of the Muztagh Ata at 4250 m asl (Figure 14, No. 22; Photo 45 ■ III–IV in the foreground). The typical grain-size composition of the material is similar to that of the sub-recent ground- and end moraines in Figure 16. This is also partly a result of the corresponding bedrock raw material. Due to the older age and the deeper location, however, the humus content (2.71%) is significantly higher. For the quartz-grain composition of this sample see Figure 18. Lime content 8.44%.

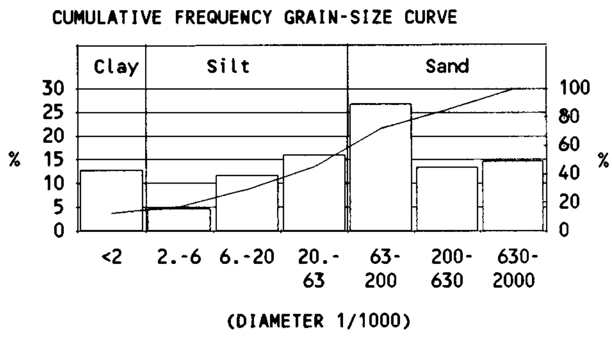

Figure 20. High- to Early-Late Glacial ground moraine at 3630 m asl on the E-Pamir plateau in the WSW foreland of the Muztagh Ata massif (Figure 14, No. 32; Photo 63 ■ 0–II on the right-hand in the foreground; Photo 62 ■). The bimodal course of the curve is clear; due to the massive-crystalline, i.e. coarse-grained source material (granite, gneiss) the right-hand fine-grain-peak shifted from the area of coarse silt to that of fine sand. With respect to this source rock the clay-portion (almost 13%) is very high. This corresponds to the matrix-type of ground moraines insofar, as the portion of glacier-broken grains is substantial (cf. Figure 21).

suggests a *High Glacial* level, lying many hundred metres above. At still lower altitudes above the valley floor, there are preserved remnants of lateral and *ground moraines*, bound to separate Late Glacial glacier surface horizons (Figure 28, No. 29). However, in this place they are overlying the easily-weathering outcrops of the stratum of the metamorphic bedrocks of the Chhugam flank (Photo 83 ■■ on the very left top) which *broke off* extensively, so that they have been almost completely *dislocated* i.e. cleared out. Down-valley the Chhugam ridge and the also glacially polished Rampur ridge, i.e. downwards the Rupal Gah, the Astor valley joins from the right (S) (35°10′–11′N/74°45′42″–48′17″E). It is glacially polished on both flanks up to a height of 3500–3600 m. Between the inflow of the Astor river and the Bulashbar Gah, connected to the right, too, on the orographic right side the abrasion and polishing of the flank extends to a *polish line* at an altitude of 3800 m asl (35°11′30″N/74°49′30″E; Figure 28, No. 30). This is the N-face of the 4695 m-high Bulashbar-massif. Above that glacially polished flank today a cirque terrace with five small glaciers is connected. – In the valley chamber of Bulashbar, where the Rupal and Astor rivers merge in the big Astor river and the continuation of the Rupal Gah – now called Astor valley – goes into a right-angled bend to the N, on the right-hand side beneath (N) the Bulashbar inflow glacial flank polishings and *abrasions* reach up to *at least* 3700 m asl (35°13′30″N/74°52′20″E; Figure 28, No. 31). One km down-valley a main valley cross-profile, divided in two parts, begins. Its upper very wide section manifests the shape of a *trough valley*, whilst the lower section of the cross-profile, which abruptly sets in with a marked upper edge, has the shape of a narrow V-valley (Figure 28, No. 32). This shape allows it to be recognized that it came into being *syngenetically* with the glacial trough by means of *subglacial meltwater*. The 400–600 m-deep, V-shaped incision of the gorge (35°14′38″N/74°50′10″E) proves a surface of the ice-stream network, which – from a little further up-valley – since the Middle-Late Glacial (since c. Stage II or III, cf. Table 1) was lying *below* the limit of the snow-line. Therefore *subglacial heavy erosive* water, which was confined, and because of that running off very fast, could concentrate here. On top of the *round-polished* valley shoulder, on the right-hand above the gorge cut, *ground moraine material* is deposited at 3150 m asl. Where the orographic right-hand side valley from the area of the Deosai plateau, i.e. the Das Khilin or Das Khirim Gah, which according to Oestreich (1904) was glaciated during the Ice Age, flows into the Astor valley, the valley chamber i.e. the basin of Gurikot begins. It was run through from the glacier stream of the main valley and has additionally received glacial supply from the tributary valleys. Thus, local glacier ice, flowing down from the 5718 m-massif of the Deosai mountains (Photo 86, No. 1), which still *today* shows up to two km-long cirque-glaciers (Photo 86 ●●) – connected by Das Khilin Gah in the S (to the right of the detail, shown in Photo 86) and the steep hanging valley, joining at the settlement of Finah, in the N – had priority for the supply from the Rupal-Astor glacier. Consequently, the level of the older surface between 4000 and 4400 m asl has been completely shaped by *glacial ground scouring* to a landscape of polish undulations and depressions (Photo 86 ▲ ▲ above the centre), on which besides remnants of ground moraines are also deposited Late Glacial *local moraines*, featuring terminal moraine slopes (35°20′N/74°51′E; Figure 28, No. 33; Photo 86 ■■ above). But also the from the left, i.e. from W joining valleys, as Gurikot Gah and Bulan Gah, which, too, still at present have small cirque-hanging-glaciers and are reaching catchment areas of 4915

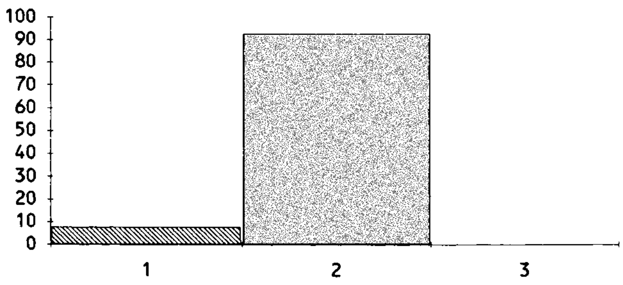

Figure 21. The quartz-grain composition of this sample of a ground moraine (Figure 20) shows a portion of 7.5% of freshly out-weathered components (1) and an extreme dominance (92.5%) of the portion of glacier-broken grains (2). This corresponds to a high overburden pressure of more than 1000 m thickness of the E-Pamir ice. Because subglacial meltwater was not effective (3 is absent), cold-based ice is to be assumed.

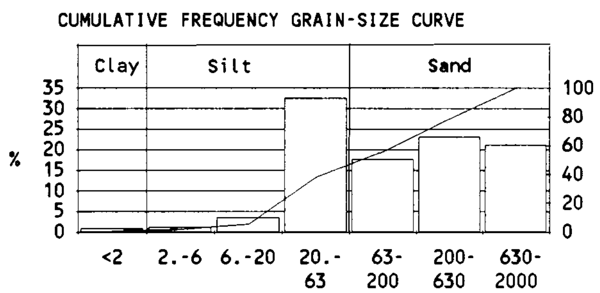

Figure 22. High- to Early- Late Glacial ground moraine at 3200 m asl on the W-margin of the basin of Tahman in the NE foreland of the 5568-m massif (Figure 14, No. 33; Photo 69 ■ right-hand side). Due to the local moraine supply from the 5568-m massif, built up from granite, the matrix is strikingly coarse. Humus content 2.16%, lime content 7.57%. Cf. Figure 23.

and 5150 m, provided the main valley glacier with up to 15 km-long tributary streams. In the basin of Gurikot itself, the recent valley floor of which lies in the talweg area about 2200 m, there are preserved remnants of a ground- and lateral moraine cloak up to 3025 m asl (35°16′25″N/74°52′E), featuring an extended orographic right-hand terrace, S of Kine Das. They, too, are preserved on the right-hand side in the *shape of a kame*, S of the Danal pasture, which has been *undercut* by the Astor river and is exposed 200 m (35°18′20″N/74°52′E; Photo 86 ■ below, right-hand corner) up to c. 2700 m asl, 500 m above the talweg (Figure 28, No. 34). An actual detritus cone is adjusted to the *kame-terrace* (Photo 86 ▽). Similar old *Late Glacial* moraine remnants on the left-hand valley side make up the settlement-terrace of Partabgarh at 2700–2750 m asl (Figure 28, No.

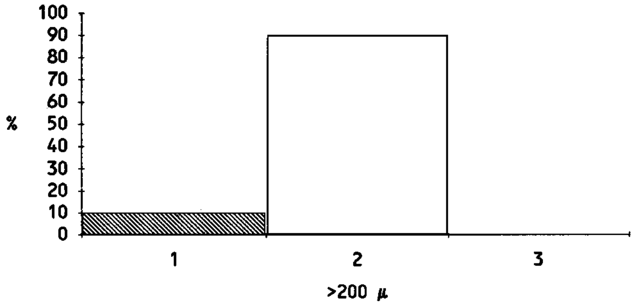

Figure 23. Quartz-grain composition of the ground-moraine sample in Figure 22: 10% of the grains are freshly-weathered (1); 90% are glacier-broken grains (2), suggesting ground moraine or till. Glaciofluvial reshaping is absent (3 = 0%).

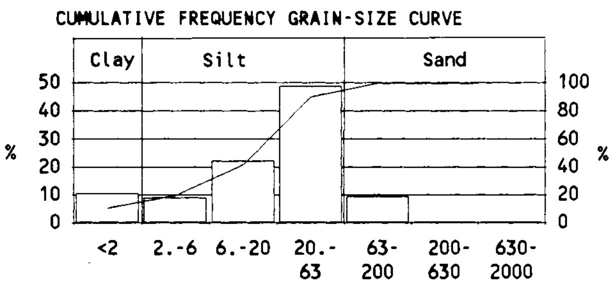

Figure 24. Varved clay, covering an older glaciated knob at 3000 m asl N of Taxkorgan (37°51′30″N/75°12′E; Figure 14, No. 34; right-outside of Photo 69). If this is glaciolimnic material of an ice-dammed lake of the last High- or Late Glacial (LGM = 0 or I) depends on whether this older glaciated knob proves a glacier cover of the northern margin of this area of the Tahman basin in the Last or Pre-Last High Glacial (LGM = Würm or Pre-Last GM = Riß, i.e. 0 or -I). The bimodal course of the curve with two fine-grain-size-peaks confirms, that this varved clay is out-washed moraine material, probably ground moraine, which is rich in matrix. Humus content 3.25%, lime content 13.83%.

35). However, all these levels, giving evidence of a *maximum pre-historic thickness* of the main valley glacier of a little more than 750 m, remain nearly 1000 m below the High Glacial glacier level (cf. Photo 85 —— medium-fine on the right signifies the level of the Late Glacial Stadia I–II). This is proved by traces of *polish lines*, e.g. on the orographic right-hand side above Danal at 3650–3750 m asl (35°19′N/74°53′E) and even on crumbling, unstable outcrops of the strata (Photo 86 ◓ below the centre, white; Figure 28, No. 33–35). On the left Astor valley flank between the valley widening of Gurikot and the Astor settlement at the junction with the Sachen (Rama) valley, there are preserved remnants of polishing and abrasion and *truncated spurs* (polished triangular slope facets), stretching between hanging valleys, which extend to an *ice scour limit* of 3500–3750 m at the three localities 35°16′45″N/74°48′25″E, W of Dumussar, 35°18′35″N/74°49′30″E, W of Hilbiche and 35°20′30″N/74°49′27″E, on the Bulan-ridge westwards above Idgah (Figure 28, No. 36 and 37).

We now turn to the valley chamber of Astor and its catchment area. First the Ice Age reconstructions of the glacier level of the Rama (Sachen) valley, which still at present is filled with the 9 km long Sachen glacier (Photo 84 ☐☐), will be introduced. In its right flank there existed a *glacier ice transfluence* (Figure 28, No. 38) over the 4086 m-high pass (Photo 84 ↘ on the very left) into the Bulan valley, adjacent to the S. This is proved with the help of polished and abraded slopes and their *ice scour lines* on all N- and SE-facing mountain flanks, showing outcropping edges of metamorphic rock and schist of the 4967 m-peak in the upper course of the Bulan ridge (Photo 84 —— in the left-hand third). Whilst this scour line is running a mere 200–270 m above the recent Bulan glacier surface (Photo 84 ☐ on the very left) (35°18′32″N/74°46′40″E) at 4500–4600 m asl, it is much higher on the other mountain side, that is 500 m above the present Sachen glacier level at 4100–4200 m (35°18′45″N/74°45′15″–45″E; Figure 28, No. 39). Corresponding to this the ice level was running on the orographic left-hand side of the Sachen valley flank – which can be estimated by *glacial undercutting* and partial polishing – at an altitude of c. 4500 m far in the W, i.e. next to the valley head (35°20′18″N/74°43′35″E; Figure 28, No. 40, 41), and about 4000 m asl on the most easterly rock spur immediately northwards opposite that 4967 m-peak (35°20′14″N/74°45′40″E; Photo 84 —— centre). At 3650–3700 m asl the *polish line* runs on the orographic left-hand side down-valley of the recent glacier tongue end (35°21′35″N/ 74°47′20″E; Photo 84 —— bold on the right) and leaves the Sachen (Rama) valley flank in the direction of the Astor main valley at the only just *round-polished* point 3593 m on the Nanga Parbat-map 1:50,000 from 1936 (35°22′35″N/74°49′05″E; Figure 28, No.

42) eastwards below the Rama-Eck (Photo 85 —— 0 on the very left). From here the Ice Age Rama glacier branch has merged with its surface into the Astor parent glacier stream *without any steps* (cf. the comments on the glacial level of the Astor glacier above). Over a distance of 7.5 km from the immediate forefield of the Sachen glacier with the single settlement of Rama, down to the Astor village in the valley exit, there is shaped a stepped, *Neoglacial to Late-Late Glacial* (cf. Table 1) landscape of *dumped end moraines* (Photo 84 ■■ right-hand quarter; 85 ■■ in the middle- and foreground), the also *preserved lateral moraine ramparts* of which rise up to point 3106 m (Figure 28, No. 43; Photo 85 ■ III–IV) and fall away towards the Astor main valley floor (35°22′20″N/74°50′40″E). However, one cannot rule out that Early-Late Glacial to High Glacial ground moraines also exist in the underlying bed. The features and materials preserved on the surface, though, are younger, i.e. laid down later (Photo 85 ●●). The recent Sachen glacier tongue is extraordinarily stable. This is confirmed by the end-moraine inset, projecting towards the tongue-ice, which exists unchanged (Photo 84 \) since the Nanga Parbat-map has been mapped in the year 1936 (Figure 28, No. 44). The reason for this stability is that the recent snow-line is running *across the steep wall* of the glacier catchment area, i.e. the Gr. Chongra Peak-E-face (Photo 84 below No. 1), so that its small historic up- and down movements have led to such *small reductions i.e. expansions* of the nourishing area, that it was only enough for *level fluctuations* of the tongue surface, but *not* for oscillations of the ice margin. However, during the Neoglacial to Late Glacial the ELA dropped to the *gentle sloping* area of the Sachen (Rama) valley floor. This caused an extreme surface gain of the nourishing area and led to that marked advance, which built up the Neo- to Late Glacial landscape of dumped end moraines and lateral moraines mentioned (Photo 84 ■■ right quarter; 85 ■■ fore- to middleground), up to the Astor main valley. The nearly *horizontal* highest orographic left-hand Late Glacial course of the lateral moraine (with point 3106 m, see above; Photo 85 ■ III–IV) – still recognizable in its original form – points to a *simultaneous* existence of an Astor parent glacier in the underlying bed, upon which had been pushed the nearly horizontally elongated Sachen glacier of that time (Figure 28, No. 42–43, III–IV).

In the further junction area of the Sachen valley, i.e. in the valley chamber of Astor, on the orographic right-hand side a very *large moraine remnant* of the main valley glacier is preserved, which stretches to the orographic left-hand mouth-spur of the Parishing Gah and the lateral moraine-like ridge of which rises up to 3400–3200 m asl (35°21′35″–32″N/ 74°52′35″E; Figure 28, No. 45; Photo 85 ■ I–II). This is c. 200–300 m too low to put it together with the *polish lines* identified at 3600 m asl (see above) down- and up-valley (see below 4) in the High Glacial and address it as indicator for the *highest* prehistoric glacier level. The level of the ice surface, however, as evidently a *Late Glacial* lateral ice margin, already comes close to this glacier level and has to be classified as Ghasa- or Taglung Stage (I or II). A further, little lower and therefore *younger-Late Glacial* surface level of the main glacier, can be identified by an about 200–250 m lower lateral moraine terrace (about 3000–3150 m asl; Photo 85 ■ below I–II), which is attached to this moraine slope in a downward direction (probably Dhampu- or Sirkung Stage III or IV; cf. Table 1). Its level *corresponds* as well with the up to 3100 m asl rising lateral moraine, situated to the W and opposite (point 3106 m, see above; Photo 85 ■ III–IV) in the exit of the Sachen valley, as with the *Late Glacial* age.

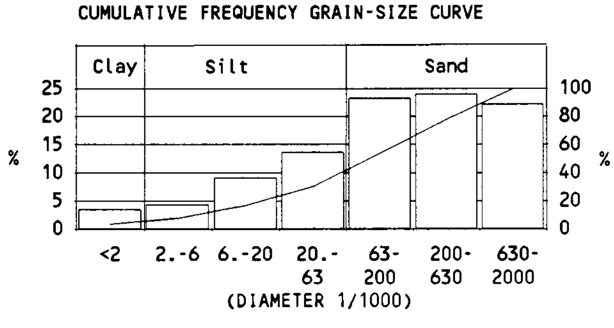

Figure 25. Matrix of ground- and end moraine of the Late Glacial (Stadium II–III) from a source area, rich in granite and gneiss. This is shown by the substantial portions of sand (3650 m asl; Figure 14, No. 20; Photo 46 ■). Humus content 0.97%; lime content 1.74%. Cf. Figure 26.

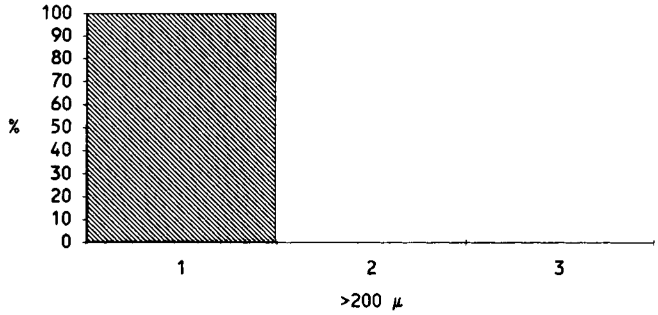

Figure 26. The morphometric diagram of sample Figure 25 shows 100% of group 1 (freshly-weathered grains). In fact, no difference from group 2 (glacier-broken grains) – as is characteristic of ground moraines – can be clearly recognized. Thus, these 100% apply to both group 1 and 2.

3.4. *Traces of a highest Ice Age level of the Astor glacier and the dimensions of its tributary glaciers between Parishing Gah and its inflow into the Indus valley on the NE face of the Nanga Parbat massif*

The at present *still* glaciated catchment area (Photo 85, No. 1–2; ○○) of the Parishing Gah, which drains the SW-slope of the Deosai mountains between the massifs at 5435 m and 5718 m, has provided the Ice Age Astor parent glacier with an additional *tributary* stream from the E (Figure 28, No. 43; Photo 85 —— small). Two other hanging glaciers of the orographic right-hand side joined the Astor glacier from the Gare Gah and its NW parallel valley from 4834–5004 m (or 5010 m, Ruartl Peak) high catchment areas – at an *orographic* snow-line, which at that time had dropped to c. 3500 m (Figure 28, No. 52, 53; Photo 85 left of No. 2) – clinging with their inwards bending tongues to the right-hand side of the main glacier, the surface of which was lying between 3400 and 3600 m in this place (see below). The adjoining, also *subordinate* tributary streams from the right-hand side were supplied by the Dichil Gah – with its source branches Salibur Gah and Das – and by the Burdish Gah from the NE from 5435 m and 4883 m high catchment areas (Figure 28, No. 46–48; Photo 85 ○ on the very left; 84 No. 3), which in places still show today some glacier ice and a 1.7 km-long hanging glacier on the Ruartl-N-slope (Figure 28, No. 46). Down-valley of the valley heads, which are composed of *cirques* (Photo 84 ○○ on the right-hand edge), this steep course of the *V-shaped* valleys is marked by *classic* glacial flank polishings (Photo 84 ➘ left-hand below No. 3 and —— fine), which especially is the case with the Dichil Gah (Figure 28, No. 47). Over a confluence step, which has a *U-shaped* cross-profile with an incised *glaciofluvial* gorge, the Burdish Gah is connected with the Astor valley (Figure 28, No. 48). The last orographic right-hand and somewhat larger subsidiary stream was the Ice Age Shaltar glacier. At least five N- to W-facing mountain flanks, extending up to more than 5000 m, belonged to its catchment area, which at present still sends down at least two 2 and 3.4 km long hanging glaciers in a NW direction. Here, the recent *orographic* snow-line runs at 4700–4800 m asl. The N-slope of the Burdish ridge especially shows preserved glacial *polishings* up to a high elevation, so that for this subsidiary stream *ice thicknesses* of 800–1000 m in the middle and lower valley can be confirmed (Figure 28, No. 55; Photo 87 below ○).

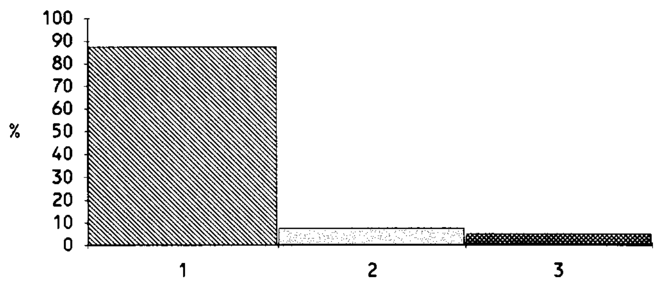

Figure 27. Quartz-grain compositions of the lateral moraine matrix of Figure 15. It is always difficult, to distinguish the groups 1 (freshly-weathered or frosted) and 2 (glacier-broken grains). In any case, more than 90% belong to these two groups (1 and 2), which is typical of short transport distances from this side valley, today still glaciated, and at the same time provides evidence of the glacier transport. The 5% of group 3 (polished, fluvial) indicate a deposit with the help of meltwater, i.e. far below the ELA. This confirms at the same time the at most Late Glacial age of the moraine, which has been already sedimented at a substantially raised snow-line.

On the orographic left-hand side, down the main valley of the Sachen valley, the Harchu and Mamocha Gah provided the Astor glacier with somewhat more *important* subsidiary streams. With six source branches in all, the for the most part more than 5000 m (max. 5345 m) high Mamocha-Lichar-Peak-crest (Chongra-crest), running down to the north from the Rama-crest, was connected by means of these subsidiary glaciers as a larger *glacier nourishing* area to the NE-rim of the Nanga Parbat massif. The largest recent ice stream, the more than 4 km long Lotang glacier, flows down to 3600 m and proves an *orographic* snow-line at merely 4350 m asl. A moraine inset between the two valley branches of Lotang- and Little Lotang glacier reaches point 3864 m (NP-map 1:50,000) and provides evidence with its vertical-distance from the valley bottom of the middle Harchu Gah of a *pre-historic thickness* of the Harchu glacier of c. 650–800 m (Figure 28, No. 49). In the junction area of the Harchu and Mamocha subsidiary streams, the *surface level* of the Astor main glacier was lying at least at 3300–3400 m asl (Photo 84 and 85 —— medium-bold and fine), i.e. its ice was c. 1300 m *thick*. On the orographic left-hand side, down the main valley, the Dashkin Gah joins with its steep talweg from the ENE-facing flank of the Lichar-Peak at 3800 m. Above there was lying the *nourishing* area of a hanging-glacier, which flowed down from the 4760 m-high N-summit of the Lichar-Peak. Where the talweg – which was brought about *subglacially* by meltwater – starts, it has merged into the ablation area, i.e. a little lower, because this talweg in the meantime has been moved to a higher level by *backward* erosion. The glacier tongue reached the *surface* of the Astor glacier at about 3300 m and still might have accompanied the parent-glacier some kilometres down-valley, before it came to an end. Where the talweg of the Dashkin Gah and its three stream-bearing slope ravines, leading down to the settlement of Mushkin, situated to the NNW, set in, the *snow-line*, i.e. the Late-Late Glacial ELA once ran, that means *shortly* before the deglaciation. The *High Glacial* orographic snow-line ran some hundred metres lower at c. 3250–3150 m asl.

The section of the left-hand Astor valley flank, which mediates to the Indus valley, is connected in a NW direction. It is difficult to decide exactly, how far down these slopes of the Doian ridge have been glaciated on its own. Be that as it may, from the flat glacial slope depressions between the top of Khoijut (4323 m) and the mountain-ridge-point Hattu Pir (3127 m) (Photo 91 ■ left-hand of 0) there flowed down a *not over-thick* flank ice which, during the maximum glaciation with separate pointed ice tongues, probably reached the Astor glacier surface lying between c. 3250–3100 m asl (Figure 28, No. 62, 64).

In the following the traces of the Astor *parent-glacier* outwards of the Parishing Gah inflow will be introduced: on the orographic right-hand side the first glacially *back-polished*, classic triangular slope facet outwards of this side valley inflow reaches up to c. 3600 m asl (35°23′42″N/74°51′52″E), giving evidence of a maximum glacier level at this altitude (Figure 28, No. 50). Immediately westwards on the opposite valley side, a corresponding *flank polishing facet* reaches up to an altitude of 3350 m; its *totally* intact, ravine-free, preserved N-section up to c. 3000 m bears a *ground moraine layer* (35°23′40″N/74°49′12″E; Figure 28, No. 51). Upwards of the Gare Gah inflow, moraine remnants are preserved on the right valley side up to the same altitude. They are preserved, however, only on the upper half of the here also triangular-shaped slopes, whilst the lower section has been *undercut* by glacial flank polishing. Nevertheless, the highest remnants of flank polishing occur even above the moraine covering up to c. 3250 m asl (35°24′38″N/74°51′11″E; Figure 28, No. 52). In the junction area of Gare Gah and its northern parallel valley, the rock spur, lying between these valleys, has been *polished round* and *backwards* by the Astor glacier c. 900 m upwards from the talweg of the main valley to at least 3000 m (35°25′30″N/74°50′23″E; Figure 28, No. 53). Due to this it forms with the N adjoining polished slope surface a *connected straight line* of the valley walls, which can be observed as a classic feature in glacier valleys, especially in the Karakorum. Accordingly striking is the disproportion of the – because of the main-glacier's *back-polishing* – small, narrow inflows of the side valleys to the upwards much wider real valley bowls (35°26′32″N/74°50′53″E, side valley upwards of No. 52 and 53). Further down, where Dichil Gah and Burdish Gah join, the intermediate valley spur between these side valleys has been *polished backwards*, too. It is preserved polished up to c. 2400 m asl, i.e. 550 m above the Astor talweg (35°30′20″N/74°46′42″E). Adjacent on both sides, the niche, which was formed by these inflows in the right-hand main valley flank, has at the same time been lined by still existing *ground moraine* up to a height of 2400 m (Figure 28, No. 54). The inflow of the Shaltar Gah, too, shows this *striking feature* of a main glacier flank polishing (Figure 28, No. 55; Photo 87 ➘ ➘), which stretches very *abruptly*, i.e. sharp-edged, over the side valley cross profile and is characteristic for glacial mountain forms. Here likewise a ground moraine remnant is preserved, which was either deposited from the main- or from the tributary-glacier (35°33′N/74°44′E; 1850–2250 m asl; Figure 28, No. 55). Between the junction of Gare Gah and Burdish Gah, on the right-hand valley side of the Astor valley, there can be observed over a horizontal distance of approximately 10 km (35°25′30″–29′38″N/74°47″–49′40″E; Figure 28, No. 56) an up to 3400–3500 m asl reaching (cf. also Photo 90 ——), relatively *cohesive* and little reworked flank polishing. The Late Glacial flank polishing, which can be diagnosed as better preserved, merely reaches up to 2600 m asl (cf. also Photo 87 ——). Pre-historic *thicknesses* of the main glacier about 1500 m in the *High* Glacial (LGM), i.e. 600 m in the *Late* Glacial in the valley cross profiles at the settlements of Harchu or Luskum, can be

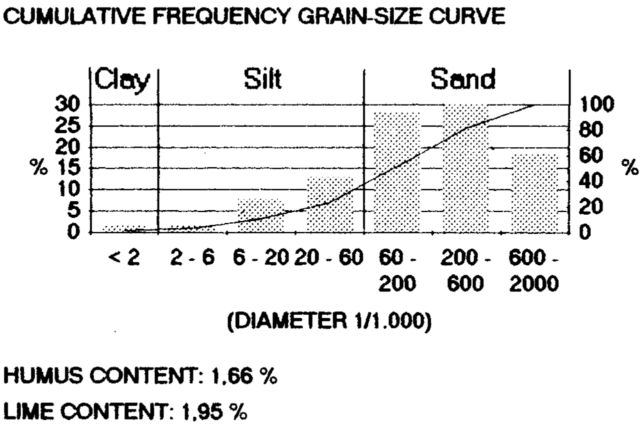

Figure 29. Grain-size diagram of the end moraine i.e. medial moraine N below the Nanga Parbat N-wall (locality: 'Large Moraine'; 4540 m asl; taking of the sample from a depth at 7 cm; Figure 28 right-hand below No. 67; Photos 110 ■ black; 102 IV centre, black; 99 IV; 96 ■ on the very left; 92 right-hand of ■), taken from a non-dislocated (primary) deposit on the upper edge of the inner moraine slope. The moraine has been developed, modified and glaciofluvially reshaped since the youngest Late Glacial (Stadium IV). Its matrix is relatively coarse (to a large extent sandy), which can be explained by the short transport distance of the glacier of a mere 2 km and the glacier feeding by ice-avalanches, which took place further upwards (Photo 93 ■ = location, where the sample was taken). In addition, the bedrock granite of the Nanga Parbat wall produces coarse-grained moraine. Furthermore there exist limestones in the glacier nourishment area. The humus content has been selectively developed by dwarf scrub cushions of the alpine meadow vegetation – which is very poor at this altitude – in the course of millennia (probably since the Neoglacial) (cf. Figure 30).

derived from the two ice levels. A more significant layer of moraine-material is preserved on the up to c. 3000–3100 m verifiable glacial flank polishings between the junctions of Burdish Gah and Shaltar Gah. In parts it has been *covered* by talus slopes (at 35°31′35″N/74°45′E; Figure 28, No. 57). – Between the inflow of Shaltar Gah and that of the Astor valley into the main valley of highest order, i.e. the Indus valley, the right-hand Astor valley slopes have been *dissolved* rather heavily by ravines and *reworked* by crumbling in the glacigenically steepened areas (Photo 90 ▼), but nevertheless remnants of *flank polishings* (Photos 87 and 90 ➘ always in the left half) are evident up to c. 2900 m (35°33′30″N/ 74°43′E). In the lower parts of the slopes, moreover, in places concrete-like and therefore resistant *relicts* of ground moraine are preserved (Figure 28, No. 58; Photo 87 ■ and 90 ■ on the left). Down-valley of the already mentioned flank polishings, from the

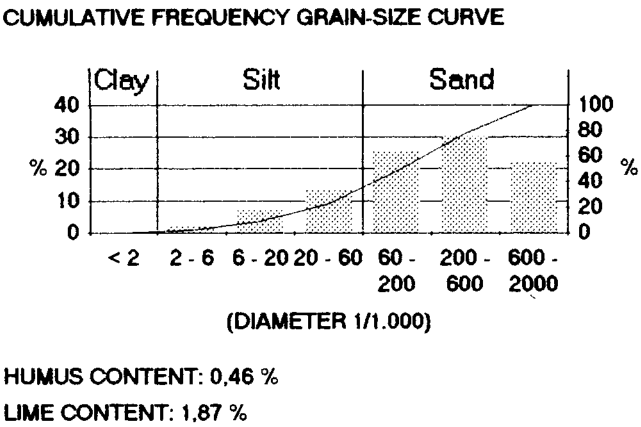

Figure 30. Sample from the same moraine as in Figure 29, but from the upper edge of the inner moraine slope c. 0.8 km further to the NE, taken from a depth at 8 cm from a primary deposit between large, edged granite blocks (4545 m asl; Figure 28 right-hand of No 67; Photos 110 ■ black; 102 IV, centre black; 99 IV; 96 left-hand of ■ on the very right; 92 left of the left-hand IV). This matrix is still somewhat poorer in clay (nearly free of clay) than the adjacent sample (Figure 29). Thus no fine grain size peak (in the sense of Dreimanis and Vagners 1971; Dreimanis 1979) can be noted. In this place (as in Figure 29) a striking shift of the coarse-grain peak to the right-hand, i.e. to the sand fraction, can also be observed. In comparison and contrast to ground moraines this is on the one hand typical; on the other hand it argues in favour of a catchment area with coarse-crystalline bedrock (granite in this case) and avalanche-feeding of the glacier (here from the Nanga Parbat N-wall). Obviously the post-glacigenic frost weathering, which ought to have ground the grains further, was also of a minor – if not without any – effect for the position of the coarse-grain peak. This becomes evident in comparison with the much older, i.e. High Glacial moraine materials of the samples Figures 36 and 37, because those show exactly the same pronounced peaks in the same middle sand fraction. The insignificant humus content is due to the altitude of the locality, where the sample was taken, which is nearly free of vegetation.

position where on the orographic right-hand side in the direction of the intersection with the Indus valley flank the inclination of the slope decreases, the lower slopes have been developed extensively in the *ground moraine* material (35°34′40″N/74°41′30″E; Photo 88 ■). Here, the Astor river (Photos 87–90 ⇓ and ⇓) has cut through the some metres to *decametres* thick ground moraine (Photo 89 ■; 88 ■ below) to the bedrock (Photos 88, 89 ●), so that the manifold *interlockings* of developed ground moraine with a later collapsing by out-melting and slope-processes as well as inserted *gravels* of *subglacial* meltwater-outwash (Photo 89 ○) are exposed over a distance of more than 100 m. In spite of many small *crumblings*, glacial rock roundings – reaching at least 2800 m upwards – are still visible in the crystalline bedrock schists of the upper slopes (35°35′N/74°40′35″E) (Photos 88, 89 ▲ below ——). As a consequence of the *weathering and crumbling* of these orographic right-hand rock slopes, which is bound to the *clefts*, there were built up Post Glacial talus-cones and -slopes (Photos 88 and 89 ▽), which are adjusted to Ice Age ground moraine slopes (Photo 88 and 89 ↙ ↘) (Figure 28, No. 59).

As one moves upward from the Astor valley-exit the orographic left-hand flank with respect to its indicators of the valley glacier, one should first mention the partly collapsed deposits of *ground moraine* from 1250 up to 1950 m asl, diagonally above the Ramghat Pul (-bridge) (35°34′N/74°40′E). Their thickness reaches some decametres (Photo 90 ■). Much further above, on the summit-spur of Hattu Pir, still more *moraine* sediments are preserved (Photo 91 ■ left of 0). Though the rock-belt, situated in between, shows traces of *flank polishings* (Photo 90 ➚), these are to a great extent erased and *superimposed* by denudation of the wall. On the other hand, very well preserved polishings of the outcropping edges of the strata on the undercut slope section remained, where the Astor river does a nearly right-angled N-bend, 1 km up-valley (Figure 28, No. 60). They reach almost up to the top of Hattu Pir (Photo 91 ➘ small, left-hand side in the background). Attached to this *polish flank*, the Astor glacier has left behind about 1000 m above the talweg and from there reaching up a further c. 200 m *huge* ground moraine deposits. They are *exposed* and gullied by ravine-rinsing (Photo 91 ■■ on the top right), so that they at once catch one's eye as a light-coloured complex high above the valley talweg (35°32′50″N/74°40′30″E; Figure 28, No. 61). Hereby an Ice Age glacier *thickness* of 1500 m can be confirmed in this Astor valley cross-profile (cf. Photo 91 ——0). – A few hundred metres further up-valley, a decametre-thick *ground moraine* cover (Photo 91 ■ on the very right), which further down is superimposed on the *polished* valley face with outcropping edges of the strata (Photo 91 ▲ small, fourth and sixth mark from the right), and which from below is in the process of backwards erosion, covers the *glacial* erosional forms. Further up-valley to the S, it passes into far more than 100 m-thick *ground*- and *lateral* moraine complexes (Photo 91 ■■ further to the left) (35°32′30″–32″N/74°40′30″–42′30″E; Figure 28, No. 62). The nature of the moraine, as well as its *minimum* thickness, can be diagnosed in detail along the deep slope ravines, which lead down from the Muskin forest and the fields of the settlements of Doian and Mang Doian (Photo 91 ■ black). The *High* Glacial, i.e. the glacier level running at *maximum* altitude, can be reconstructed and proved well with the help of the *upper margin* of these ground moraine- i.e. lateral moraine remnants from c. 3300 m down to 3100 m asl on the Hattu Pir close to the Astor valley exit (cf. Photo 91 ——0). 250 to 300 m lower, these upper areas of the orographic left-hand ground moraine have been *undercut* in the way of a polish line by the *Early-Late* Glacial valley glacier margin of the Ghasa Stage (I) (see Table 1), so that this nearly parallel running, dropped Astor glacier level is preserved, too (cf. Photo 91 —— I). Further up-valley there is preserved orographic left-hand *flank polishing* opposite of the Shaltar Gah mouth on the rock spur between Doian and Turbaling up to 3050 m (35°31′30″N/74°43′E; Figure 28, No. 63). Another alternation of glacial rock polishing and *ground moraine* cover can be proved by the concave left-hand course of the flanks of Mushkin and Turbaling. However, due to its *vague* demarcation as one moves upward, caused by the shaping of the local hanging glacier in the Lichar Peak NNE-flank (see above), which had a *blurring* effect, it cannot be applied for the determination of the valley glacier level (35°29′N/74°44′E; Figure 28, No. 64). A further *polished* orographic left-hand rock spur is connected up-valley between the settlements of Mushkin and Dashkin, opposite the Burdish Gah mouth (35°30′N/74°45′40″E). This at its base 4 km-wide polished area ends in the *polished spur-top* at 3193 m and with this 1400 m above the Astor valley talweg. Between 2150 and 2800 m asl it is partially covered with remnants of *ground moraine* on both sides of this spur (Figure 28, No. 65). The two accumulation *terraces* between Dashkin and Luskum, c. 100 to 350 m above the talweg, concern Late – and Post Glacial glacial and *glaciofluvial* activities. They give no evidence for the maximum glaciation of the valley. – The last, orographic left-hand valley section to be discussed stretches up-valley up to the locality opposite the Gare Gah mouth. It is the area between the Dashkin and Harchu settlements with the inflows of Dashkin-, Mamocha- and Harchu Gah, where the local side valley- and hanging glaciers due to their high catchment areas rising on average more than 5000 m have reworked the traces of the main valley glacier level beyond recognition. Since these local glaciers have been *superimposed* on the main glacier when they were flowing in, only the in this place here and there preserved *glacial flank abrasions* on out-cropping edges of the strata up to 2850 m asl, c. 850

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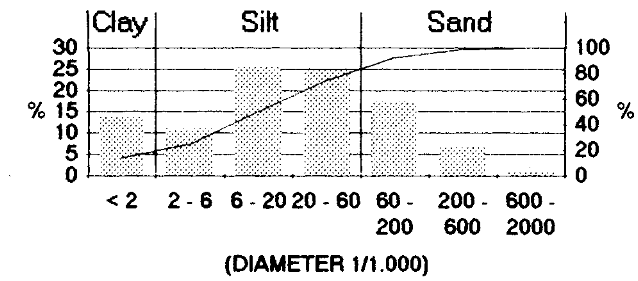
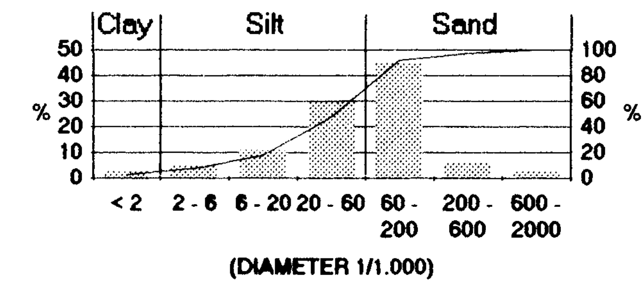


HUMUS CONTENT: 7,56 %
LIME CONTENT: 1,47 %

Figure 31. Ground mass of the orographical left-hand Late Glacial lateral moraine (Stadium III) in the Rakhiot valley (4370 m asl; Figures 28, No. 69; Photo 96 III, on the left), c. 370 m above the recent surface of the Ganalo glacier. With 14% clay, the typical fine grain size peak is very well developed. This points to a lateral moraine, built up from portions of ground moraine (basal till). Also the broad coarse-grain peak in the middle- to coarse silt, which twice reaches 25%, and the heavy drop in the sand portions prove the important glacigenic trituration of the matrix in spite of the short transport distances from the glacier source (cf. Figure 28). The portions of humus, which near to the surface are high, result from the complete cover of meadow vegetation.

CUMULATIVE FREQUENCY GRAIN-SIZE CURVE



HUMUS CONTENT: 13,24 %
LIME CONTENT: 1,84 %

Figure 32. Ground mass of the medial moraine of the Early Neoglacial (Stadium V) between the W Rakhiot- and the Ganalo glacier (3970 m asl; Figure 28, No. 68; Photos 102 below No. 3 between ▼ and □; 96 V and V, fore-ground). The drop in the middle- and coarse-sand portions in contrast to the silt-fine-sand peak is striking. This proves the grain-size-gap between the matrix and the pebble- to block-fractions, characteristic of moraines. This gap still persists from the end moraines up to the glaciofluvial gravel fields. It is conspicuous, however, in that it lacks in the normal fluvial sediment. The very important humus content at a depth of 10 cm reflects the very luxuriant vegetation cover at this altitude.

m above the recent talweg, are attributable to the Astor parent-glacier (35°26′23″N/74°47′30″E; Figure 28, No. 66; cf. Photo 84 —— medium-bold and fine).

3.5. *Reconstruction of the Maximum Glacial glacier filling in the Rakhiot (Raikot) valley as representative of the Nanga Parbat N-face*

To register the former ice filling of this classic hanging valley (Photo 94, 96, 102, 107, 110) – *today* supplied with the 15 km-long Rakhiot glacier – below the semi-circle stretching c. 19 km between the Ganalo peak (6606 or 6601 m) and Chongra peak (6830 m) and rising continously up to the *more* than 6160 m asl N-flank of the Nanga Parbat massif (Photos 92 and 99 No. 3 to No. 2), the ice of which was *concentrated* in this valley, one has to begin with the so-called ‘Large Moraine’ (NP-map of 1936) at the valley head (Figure 28, No. 67; Photo 105, 107, 110 ■ left-hand below No. 1; Figures 29, 30). It rises up to 4559 m asl, i.e. 100–150 m at its upper root (Photo 92 ■ right half; 93 ■ left half) and, down-valley of the moraine, up to 800 m (Photo 94 ■ centre; 96 ■ on the right) above the *recent* glacier surfaces, which are almost lining it. So this concerns a rather large, i.e. 3.5 km extending, prehistoric as well as recent *medial moraine* complex (site of its culmination: 35°18′20″N/74°36′E; Photo 92 behind the large block with the person). With its down-valley roof-like ramp form (Photo 99 //) and its lee-side areas, also built up from *glaciofluvial* material (Photo 94 □), it shows the characteristic features of an *ice marginal ramp* (IMR/Bortensander) (cf. Kuhle 1990a). Besides the primary source branches of the Rakhiot glacier that come from the Rakhiot firn (Photo 99 in the background between No. 1 and 2) and the immediate N-face (Photo 99 on the left below No. 1), it is the Ganalo glacier (Photo 99 and 102 □) – today (1995) *no longer* reaching the main glacier – , which together with the W Rakhiot *wall-foot* glacier (Photo 94 above □, 96, 98, 99 and 102 ▼) frames the ‘Large Moraine’. The in 1995 slightly advancing Ganalo glacier thereby no longer follows its *original* direction down to the Rakhiot main glacier, but comes into contact with the E-parallel situated Rakhiot wall-foot glacier (Photo 96 ▼▼), which also *advances* with a comparatively bulging tongue (Photo 98 ▼) and is only just a few decametres away from the confluence with the Rakhiot main glacier (Figure 28, No. 68; Photo 97 and 102 ▼). W of the Ganalo glacier, beyond the sub-recent and recent *lateral valley* below the spur point 4585 m on the S Jiliper peak NE edge, there occur stepped Ice Age *lateral moraine* remnants. The lower moraine level is lying at 4180 m asl in the pertinent valley cross profile, c. 180 m above the *present-day* Ganalo glacier surface (35°19′43″N/74°34′34″E) and is to be classified as being *Late Glacial* (Photo 96 IV to the right of No. 7; 102 IV on the right). The same applies to the *highest* moraine shoulder on this orographic left-hand valley flank spur of the Rakhiot valley at 4370 m, 370 m above the recent ice surface (35°19′43″N/74°34′17″E; Figure 28, No. 69; Photo 96 III on the left; Figure 31). The *lower* one of these two moraine levels best corresponds to that of the ‘Large Moraine’ (cf. Photo 96 ■ IV on the very left; 102, IV and IV), so that its higher elevation (4559 m) can be *reduced* to its more up-valley position. According to this, both moraine deposits are to be classified as Late Glacial. This means at the same time, that the more highly rising ‘Large Moraine’ has been accumulated approximately up to the pertinent *snow-line level*. The ELA at 4500 m asl, belonging to *this* moraine generation, in comparison with the *recent* orographic snow-line at 4900 m asl has decreased by only c. 400 m, which classifies the moraine generation as belonging to a *Late-Late Glacial* glacier stage, probably to Stage IV (Sirkung-Stage in Table 1). The *higher* orographic left-hand remnant of a lateral moraine terrace (4370 m) ought consequently to be referred to as the most up-valley moraine remnant of an ELA level about c. 4400 m asl – i.e. as pertinent to a *snow-line depression* of c.

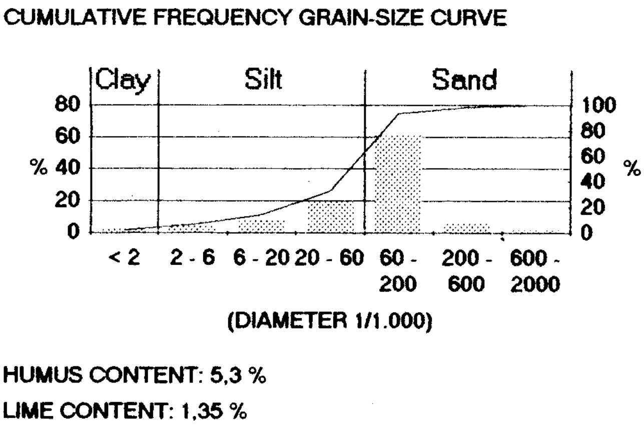
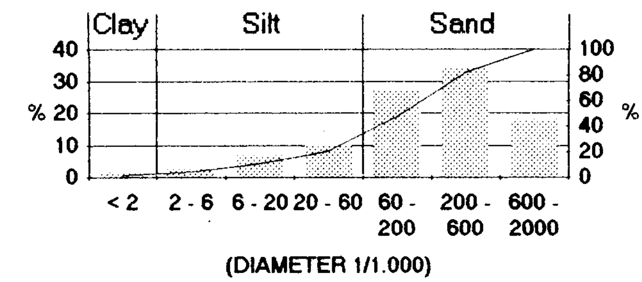


Figure 33. Orographical left-hand Late Glacial lateral moraine matrix (Stadium IV) from a depth of 15 cm at a primary deposition (3830 m asl; Figure 28, No. 72; Photo 102 IV, foreground). The vegetation cover, which has been developed up to the forest and has therefore reached its climax-stadium (probably for millennia), can be noted by the relatively great humus content. The predominance of the sand is a reminder of the matrix of samples Figures 29 and 30, which are of the same age. However, the difference is, that in this coarse-grain peak the portions of coarse sand are completely absent and the portions of medium sand are virtually lacking at a mere 6%. This is due to the c. twice greater transport distance by comparison with the coarse-crystalline bedrocks (Nanga Parbat granite) (cf. Figure 28; compare the locality of No. 67 to that of No. 72). There follows a relatively steep increase of the cumulative curve due to the glacigenic trituration of the coarser grains being in progress. The striking deflection of the curve above the coarse silt might result from the crystal-size spectrum of the bedrocks in the catchment area.

500 m – as a somewhat older, at most Middle-Late Glacial (Dhampu Stage III) moraine remnant, but probably still belonging to an advance of the Sirkung Stage (IV). On the orographic *right-hand* side of the Rakhiot valley there is preserved a *corresponding* level of a lateral moraine kame-terrace below the Buldar notch at 4380 m asl, which has an edge of 1 km in length (35°19′30″N/74°38′E). It is situated in the pertinent valley cross profile c. 480–500 m above the Rakhiot glacier surface (Figure 28, No. 70; Photo 92, 94, 99 III, 96 III on the right). – The *younger Late-Late Glacial to Holocene* glacier margins joining in the direction of the glacier are documented by the moraines of the ‘Fairy Meadow generation’ (Photo 101 □, ■, ■ IV–′VII) – as they will be called here – which are much closer to the ice (Stage IV to ′VII, see Table 1) (Photo 94 IV; 96 IV–′VII; 99 and 102 IV, V–′VII; 95, 97, 100 and 103 V–′VII; Figures 32 and 33). The still *less* striking moraines along the margins (Photo 99 VII-XI; 103 XI) and in the forefield of the Rakhiot glacier (Photo 104 VII–XI), which still often have *ice-contact*, are Post Neoglacial, i.e. younger than c. 2000–1700 YBP, which means that they are *Historic* (Stage VII–XI, cf. Table 1).

For the understanding of the *maximum* ice filling of the valley and its distance from the *Late-Late Glacial to Neoglacial* glaciation, we would like to discuss the ‘Fairy Meadow-generation’. Today (1995) the Rakhiot glacier terminates with a rather *steep* tongue front (Photo 104 ▼; 105), which is ready for an *advance*, at 3200 m asl and with this only c. 20 m higher than at the time when the 1936 map had been mapped. The orographic left-hand *lateral- to dumped end moraine* (Figure 34), upon which is situated the ‘Fairy Meadow’ locality (Photos 101 and 110), reaches in some knolls up to 3306 m asl (Figure 28, No. 71) and thereby a *thickness* of the moraine material of more than 400 m (Photos 104, 105, 106 and 110 IV–′VII). This is the *height*, at which those moraine culminations (Photo 101 ■) lie above the valley talweg. The succeeding deposits in the lateral moraine sections of the Rakhiot glacier situated further up-valley belong to this moraine generation: on the orographic left-hand side the up to 3900 m high moraine complexes (Photo 97 and 102 V–′VII) in the *confluence area* of the Ganalo glacier (35°19′44″N/74°35′E; Figure 28, No. 68; Photo 96 V; Figure 32) and immediately opposite, on the orographic right-hand side, the *corresponding* c. 3800–3850 m-high beginning of a lateral moraine, down-valley of the upper undercut slope of the Rakhiot glacier (35°20′18″N/74°35′55″E; Figure 28, No. 72; Photo 96 IV–′VII), but also up-valley of this undercut slope (Figure 28, No. 70; Photo 94, No. IV in the background). From here, on both sides down-valley of the *recent* ice stream, these lateral moraine tracks are covered with a *forest* of birch, ash and then conifer in the *climax stage* from approximately the timber line downwards (Photo 95 and 103 above V–′VII; 102 V on the right). For instance, the forest around the ‘Fairy Meadow’ (Figure 28, No. 71; Photo 101, 106 from IV–′VII to the right; 111 IV–′VII) and beyond, on the glacier’s other side (Figure 28, No. 73; Photo 104 between IV and V), is composed of more than 300 year-old conifers and ashes. The immediate ‘Fairy Meadow’ moraine complex comes to an end down-valley along the talweg at 2550 m asl (Photo 110 to the left of IV–′VII; 104 to the right of IV–′VII near to the edge of the photo; Figure 34).

CUMULATIVE FREQUENCY GRAIN-SIZE CURVE



HUMUS CONTENT: 1,08 %
LIME CONTENT: 4,1 %

Figure 34. Ground moraine matrix on the orographic left-hand side in the region of the ‘Fairy Meadow Generation’ (c. 2610 m asl). The sample was taken at a depth of c. 50 m from the base of an exposure wall, undercut by the river. (Figure 28 left-hand of No. 76 and right-hand of ′VII; Photos 110 and 106, behind IV–′VII; 105 on the left below and down-valley of IV–′VII; 104 on the right below and down-valley of IV–′VII near the right- hand edge of the picture). Although this moraine material with concern to its granite portions (which stem from Nanga Parbat) has overcome a transport distance of 13–14 km, the greatest portion of the increase of the cumulative curve lies in the area of the sand-fraction, i.e. the coarse grain peak of the matrix culminates in the medium sand. Clay and fine- silt with portions of c. 2–3.4% are of far less importance. These characteristics point to an important admixture of material, which has been taken up only somewhat up-valley and which as far as this place has been only insignificantly triturated. That means, that they imply a local moraine. It concerns a small-scale change of the substratum, which occurs rather frequently in the case of mountain moraines. The high content of limestone, which is unusual in Nanga Parbat moraines, points to that, too. The concave deflection of the curve in the coarse silt, as well as its convex deflection in the sand (here in the coarse sand), is already known to us through Figures 29, 30, 32 and 33 from moraine deposits further up-valley. Here too, the gap of the psammites at the transition to the pebbles and blocks is significant. The age of the matrix is unsure: it might belong to Late Glacial ground moraine (Stadium IV) as well as to Neoglacial ground moraine (V–′VII) with dislocated older moraine portions (which again have been taken up). The very high content of humus, however, which is unusual at this great sampling depth, argues in favour of the second case.

It continues, however, on the orographic right-hand side with a *lateral moraine terrace* (Photo 110 and 113 IV; 114 and 117 IV; 111 and 112 IV background), rising up to the 2828 m point and after further 2–2.5 km down-valley as merely a *moraine ledge* up to the Rakhiot gorge 2 to 2.5 km outwards of the Tato settlement (Figure 28, No. 74; Photo 115 IV; 114 IV black, on the very left). At Tato there set in further pertinent and now also orographic left-hand *moraine remnants*, which, too, reach the gorge route (Figure 28, No. 75; 115 ■), and then – due to the increasing steepening of the valley wall – gradually cease completely. The *deepest*, denudation and crumbling on the gorge flanks so far still surviving ground moraine remnants (Photo 116 IV, 117 IV on the left) are situated on the orographic right-hand side on a very steep wall ramp about at most 200–230 m above the talweg at c. 1980 m asl (35°27′28″N/74°36′16″E). Consequently, the Rakhiot glacier tongue of the *latest Late Glacial* Stage IV (Sirkung Stage, see Table 1) reached down up to c. 1700 m asl (35°27′40″N/74°35′45″E; Photo 117 ▼). So it terminated 1500 m below the *present glacier* end at a *horizontal distance* of only 3.2 km from the talweg of the Indus valley and merely 550 m above it (Photo 116 ▼). R. Finsterwalder (1938, p. 172) was the first who has recognized this glacier stage in the Rakhiot gorge, in the Tato Gah, though he determined its precise lowest ice margin site as being somewhat higher, i.e. at 1900 m asl and with this a little further up-valley. In addition he *did not* think it to be Late-Late Glacial but High Glacial.

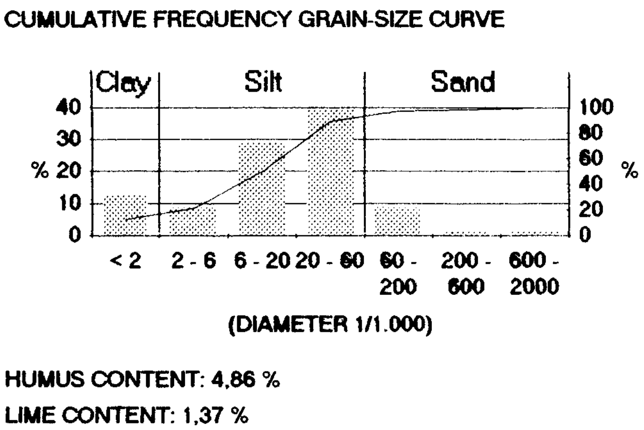


Figure 35. Classic ground moraine diagram from the orographical left-hand valley shoulder, locality: 'Bezar Gali', in the confluence area of the Rakhiot valley (Tato Gah), about 1300 m above the valley talweg (3822 m asl; depth of the sample: 15 cm; Figure 28, No. 81; Photos 94 above the fifth ▲ from the left; 96 right end of —— black; 102 —— right end; 111 ■ on the left; 110 ■ on the left; 107 ■ 0 in the foreground on the very left and on the very right). The columnar diagram shows the characteristic bimodal arrangement with two peaks in the clay and coarse silt. Though granite blocks are incorporated, the entire sand-grain portions amount to only 10%. This is an indicator of heavy glacigenic trituration.

On either side of the Rakhiot valley remnants of flank *polishing and abrasion* in the shape of *rounded* rock ribs and spur ridges insofar have missed the frost weathering which has taken place since the deglaciation, as they still allow the clear diagnosis of having been shaped glacially. This applies along the right-hand valley flank in the form of a most inwards glacially *abraded triangular slope* up to an altitude of 4150 m (35°21′N/74°36′27″E; Photo 99 ◥ below No. 6, ▲ to the right below No. 6; 96 ▲ below No. 6; 102 ▲ ▲ on the left; 107 ◥ to the right below No. 2; 105 ◥) that is 850 m higher than the present Rakhiot glacier surface (Figure 28, No. 72). On a second, somewhat more outward *glacial triangular slope facet*, the preserved polishing reaches to only just below point 4175 m (35°22′50″N/74°36′22″E; Figure 28, No. 73) up to the same altitude and with this about 1000 m higher upwards than the position, which holds the recent glacier end in the valley talweg of this valley cross-profile (Photo 110 ▲ second mark from the top right and —— above; 101 ▲ on the left; 100 ▲ —— on the left). Again down-valley, a polished slope with a *polish line* of c. 3950 m (35°23′42″N/74°36′29″E; Figure 28, No. 76; Photo 96 ◤ and —— on the left below No. 6; 107 ▲ below No. 2 and —— fine; 99 ▲ below —— fine on the very left) stretches over a distance of 2.5 km to an altitude of 3740 m asl (35°25′22″N/74°37′04″E) down to the valley exit (Figure 28, No. 77; Photo 113 ——; 111, 114, 115, 117: 0 ——; 106 —— on the left). In the pertinent valley cross-profile the *Ice Age thickness* of the Rakhiot tributary stream reached nearly 1300 (1290) m. On the left-hand valley flank the *glacial rock rounding* comes up to at least 4350 m asl (35°21′20″N/74°33′46″E; Figure 28, No. 78). With its upper margin it is located in this valley cross profile only just 850 m above the recent valley glacier surface (Photo 106 —— on the right; 104 —— on the left; 102 —— to the right of No. 7; 94 —— on the left; 99 ◥ and —— on the very left). Down-valley a *rounded rock shoulder* is evidence of an Ice Age valley glacier infilling up to an altitude of 4030 m (35°22′42″N/74°33′26″E; Figure 28, No. 79; Photo 99 —— on the very left and ◥ below on the right; 104 —— left and below ▲ on the right; 105 ◤ on the very right). In this valley cross-profile with an ice thickness of about 910 m it proves an *ice thickness* of c. 1000 m, recorded by *flank polishings* on the orographic right-hand valley side (see above; Figure 28, No. 73). 2.6 km down-valley at the N end of the Jalipur ridge, *rock flattenings* in the form of *polished slopes* reach from 3300 m up to c. 4000 m asl (35°24′15″N/74°33′32″–34′25″E; Figure 28, No. 80; Photo 107 and 109 ◤ on the very right; 110 ◤ second from the right). The last down-valley reference to the *minimum* altitude of the High Glacial Rakhiot glacier level is on the orographic left-hand valley side on the 3822 m-high valley shoulder E of Bezar Gali (Figure 28, No. 81; Photo 99: 0 ——; 96 —— centre to the right; 102 —— on the very right). Between c. 3700 and exactly 3822 m asl *ground moraines* are preserved here with an *outline extension* of c. 750 × 450 m (point 3822 m: 35°25′23″N/74°33′48″E; Photo 110 and 111 —— on the left; 107: 0 ■, ■ 0). When passing it, *erratic granite blocks* could be mapped (Photo 107, 108 ↓), which travelled here from the valley head, i.e. Nanga Parbat, and which show extensions the size of a head, up to those of really large components with a longitudinal axis of *several metres*, 'swimming' in isolation from each other in a more or less clay- or silt-bearing ground mass of the moraines (Figure 35). One part of the erratic blocks is rounded at the edges and the other part is *better rounded*. The portions of coarse components and boulders in relation to its matrix are *very small*, which is a feature typical of ground moraines. The ground moraine cover has been spread by the glacier over the relief of the *rounded knob* (Photo 108 ☗) of this valley shoulder with its likewise slightly hilly surface (Photo 107 ■ 0 in the centre and ☗ above). The shape and nature of its surface were only insignificantly reworked by solifluction and *not at all* by fluvial processes, as for instance rill rinsing. The very rare, here nowhere else realised phenomenon of a ground moraine complex of this sort, which lies *high and far away* from any slope debris (cf. Photo 107 left and right third; 108) and has remained from the Ice Age, can be reduced to the existence of the valley shoulder at 1400 m *above the talweg* of the Rakhiot valley with its extended area. This finding is the more significant, as the groundmoraine on the valley shoulder, which confirms a 1400 m *ice thickness*, is only 8.4 km away from the Indus valley talweg (Figure 28, No. 82) and ca. 6 km from the inside width profile of the Indus valley, which suggests an *important glacier thickness* in the Indus valley during the High Glacial (Photo 110 —— bold; 111 —— on the left). While the *Late-Late Glacial* end of the Rakhiot glacier reached down into the Rakhiot valley exit of the Tato Gah up to 1700 m (see above Figure 28, No. 75; Photo 115–117 IV), the *High Glacial* Rakhiot glacier still had a thickness of 1400 m c. 6 km away from the valley exit. It was situated with its *surface* more than 2000 m higher than that younger glacier end (Photo 110 and 111, cf. —— 0 with IV). By this comparison and the *difference in height* of the High Glacial glacier surface lying at least at 3822 m (Photo 111 —— on the left) to 1150 m asl on the Indus (Photo 118, river in the valley bottom) at a horizontal distance of *only* 8.4 km, a considerable *backflow* of the ice from a very thick Indus glacier (cf. Photo 118 —— on the left) into the adjoining Rakhiot valley becomes evident (Photo 118 —— on the right). As for this reason reconstructed and explained in detail, the Ice Age Rakhiot glacier from the valley head (Figure 28, No. 78) up to the ground moraine surface on those valley shoulder (Figure 28, No. 81) had only a *slight slope* with a difference in height of at most 500 m (from e.g. 4350 m to 3822 m asl) over a distance of 8 km along the valley axis (Photo 94 —— on the left; 96 —— centre). If this slope were to be *elongated*, the surface of the subsidiary stream at the junction with the Indus glacier would still lie *at least* 3300 m high, i.e. 2150 m *above* the Indus valley talweg. Assuming, however, a *confluence step* on the glacier surface – normally this is *small* with large ice-stream nets *only* some hundred metres below the snow-line -, which is surmounted by an ice fall, as it can be observed in E-Greenland, there is still left a *High Glacial glacier thickness* of the Indus valley of c. 1800–1900 m (Photo 111 —— fine). Accordingly during High Glacial times a 1400 m-

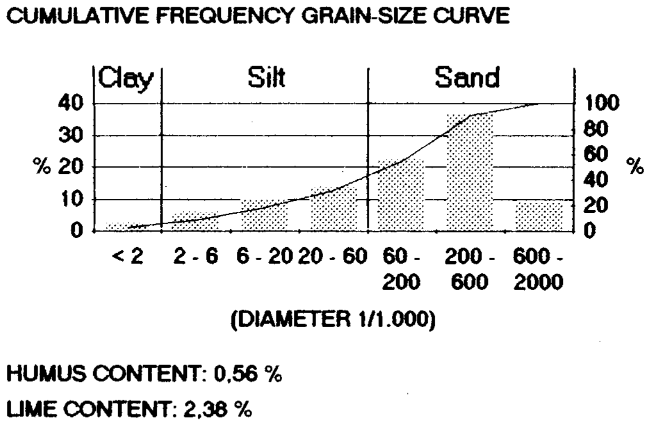


Figure 36. Ground moraine matrix of the Indus valley bottom in the confluence area of the Bunar valley, which leads down from the Nanga Parbat WNW slope (35°24′N/74°19′E; c. 1160 m asl; sampling depth: 13 m (at the exposure wall); Figure 1, No. 6; Figure 38 W (left-hand) of Nanga Parbat; Figure 13: Indus; Photo 122 ■ right-hand). The ground mass of this moraine, into which are incorporated erratic granite portions, is strikingly coarse: the peak of the columnar diagram culminates in the psammites (middle sand). There are contained just 2.5% of clay. The cumulative curve (histogram) rises continuously and without deflection over the silt up to the sand. This fits the important compaction of the micro-fabric und the related minor pore volume. In particular those ground moraines which have been transported over rather long distances under great thicknesses of ice, show a perfect mixture of the grain-sizes of pelites and fine-psammites. This coordinated and very well-balanced proportion of the grains not only develops when the sedimentation by the transporting glacier is occurring, but already during the trituration underneath the ice. Thus the proportion of the mixture is established as a function of the occurrence of the greatest possible distribution of the forces on the grains and the reduction of the internal frictional resistances. The content of humus is small, but nevertheless it argues for a ground moraine deposition down here in the Indus valley as recently as the Late Glacial (Stadium I or even II), because there was absolutely no growth of plants during the extreme ice infilling of this region at High Glacial times.

thick Rakhiot subsidiary stream of about 26 km in length was *immediately connected* with the ice-stream network of the Indus glacier system as a further *nourishing area* besides of the Astor subsidiary stream system, the lowest located relief section of the Indus (Photos 94, 96, 110, 111, 118). Further field work datings, which support this observation, are to be discussed in chapters 3.6. and 3.7.

3.6. *Traces of the High Glacial glaciation in the Indus valley between the junctions of Astor- and Rakhiot valley on the Nanga Parbat N-face*

In the valley exit the *at least* 1500 m-thick Astor glacier (Photo 84 —— fine and medium-bold; 88-90 ——) was attached to the valley flanks with its surface up to an altitude of about 3100 m (Photo 91 ——0) (see chapter 3.4). Between the orographic left-hand locality of the ice level concerned on the mountain spur top of Hattu Pir (3127 m; Photo 91 ■ left of 0 and 118 ▼) and the mouth of the Tato Gah, i.e. Rakhiot valley (Photo 118 right half in the foreground), stretches the flank of the Indus valley in a 12 km-long orographic left-hand course (Photo 118 centre, between ◤ and ◤). It is in the valley chamber of the Lichar settlement in the *undercut* slope area of the Indus redirection from S to W, that a flank *abrasion and polishing* of the valley glacier,

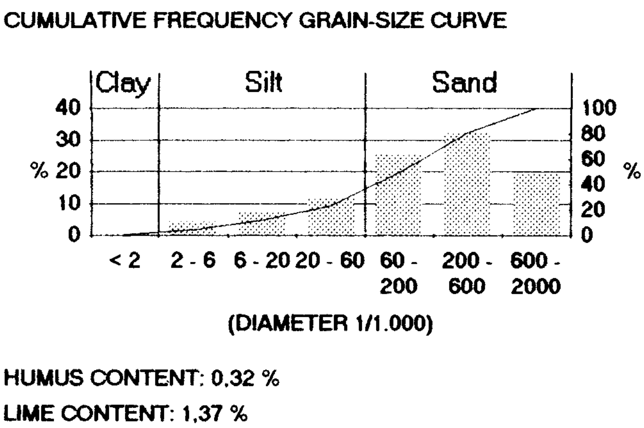


Figure 37. Lowest moraine occurrence in SW High-Asia in the middle Indus valley (35°26′N/74°08′E, c. 800 m asl (or 750–900 m asl); sampling depth: 0.35 m (excavation); Figure 13: Indus; Figure 38 SW (left-hand below) Nanga Parbat; Photo 132 →). Just in the same way as the other ground moraine of the Indus glacier (cf. Figure 36), the matrix shows a coarse-grain-peak in the middle sand and virtually no clay portions. The course of the cumulative curve is not quite as steady as that of Figure 36. This is due to the increasing admixture towards the valley glacier end of residual detritus from the valley slopes and thus the increasing production of local moraine. The humus content, which in relation to this minor altitude above sea level is strikingly small, proves the very scarce plant-cover of this SW marginal regions of High-Asia during the High Glacial.

which intensively undercut the rock and kept it steep, led to a characteristic asymmetry of the *trough*. Since the deglaciation c. 13–15 Ka ago, the overlays of *ground moraines* still existing in remnants – corresponding to the significant gradient of the undercut slope – but also the smoothing of the bedrock have been eroded, i.e. *truncated* extensively by a combination of the processes of rill rinsing and mass movement in the form of *crumbling away*. The highest moraine remnants reach up to 2500 m asl (35°33′N/74°40′E; Figure 28, No. 83; Photo 118 on the left below ▼) and are covered in many places with *autochthonous* frost debris in the shape of a slope. Below c. 1700 m asl, i.e. at the lower 500 m of the slope above the Indus, the several decametres thick cloak of *ground moraine* above the bedrock (Photo 118 ■■ black, centre, background) from the Astor- to the Rakhiot junction is scarcely interrupted or only by little extended rock ribs, valley wall pillars and precipices with *glacial smoothings* (e.g. Figure 28, No. 84, 35°33′30″N/74°39′E; Figure 28, No. 85, 35°32′45″N/74°39′E; the largest rock area even stretches down to the river: 35°31′30″N/74°38′12″E; Figure 28, No. 86; Photo 118 below the black ■■). Remnants of glacial abrasion and polishing are *preserved* on the orographic left-hand flank of this Indus valley section in the W-flank of Hattu Pir up to an altitude of c. 3000 m (35°32′23″N/74°39′48″E; Figure 28, No. 87), and this to the extension of c. 1 km parallel to the slope (Photo 118 ◤ centre in the background). 2 km further down-valley there is up to an *ice score limit* at 2950–3080 m a polished slope surface (35°31′20″N/74°40′07″E; Figure 28, No. 88) westwards below the 3437 m-saddle (Photo 118 on the right below ▼). At 3100 m a *horizontal glacially shaped score* is preserved SE above the settlement of Lichar in the Khoijut NW flank (35°30′15″N/74°39′30″E; Figure 28, No. 89; Photo 118 ↘ to the right of ▼). S of the Lichar Gah inflow, above a steep and therefore forcedly *crumbling* triangular-shaped valley wall facet, there has been observed a flank polishing area, *covered* with some ground moraine, which *flattens* a mountain spur from the direction of the Indus valley (2870–3100 m asl; 35°28′36″N/74°38′17″E; Figure 28, No. 90). Between the two localities mentioned last, the influx of the Lichar subsidiary stream into the Indus parent glacier occurred (Photo 118 between the two white ■, centre of the background). Still today there is in the valley head below of the 5053 (5021) m high Lichar Peak with an initial width of 2 km, a 1 km-long hanging glacier facing NW. It reaches down to somewhat below 4600 m and evidences an orographic ELA at 4800 m asl. With the High Glacial *snow-line depression* of at least 1200 m the end of the Lichar glacier would have been appeared about 2000–2200 m lower, i.e. at 2400–2600 m asl, if it had not already joined the Indus glacier above, at the level of 2950–3100 m (see above) and had not laid down

Table 3. Samples for radiocarbon dating (C14) from the Nyainquêntanglha-massif (Figure 1, No. 9 above; Figure 38 on the right- hand below the Tangula Shan; Figure 40 Transhimalaya) and the Namche Bawar (or Namcha Bawa; Figure 1 No. 9; Figure 38). These datings concern Neoglacial to Historical glacier positions and deposits (cf. Table 1) in Central S- and E-Tibet (cf. Kuhle 1991d, pp. 229/230, Figures 43, No. 19 and 42) (cf. Table 2 of the W border of Tibet: Nanga Parbat and Rakaposhi regions; Figure 38)

sample nr.	sample material	taking of the sample	sample depth	sample location	sample environment	δ^{13}C [‰]	conv. ^{14}C-age (YB 1950)	stadium (stage)
13.8.89/2 L-Hv 17667	turf (peat)	exposure of a gravel terrace	0,35 m below surface	30°20'30"N/90°35'E Nyainqêntanglha SE-slope 5200 m asl	outwash no. - 6 connected with terminal moraine	-22,7	165 +/- 90	Younger Dhaulagiri-stadium X
12.9.89/1a L-Hv 17665	tree trunk	exposure of moraine	several m below surface (10 m above 12.9./1b)	29°37'N/95°00'E Namche Bawar W-slope 3850 m asl	lateral moraine 100 m below modern glacier tongue	-23,2	215 +/- 65	Younger Dhaulagiri-stadium IX
12.9.89/1b L-Hv 17664	tree trunk	exposure of moraine	several m below surface (10 m below 12.9./1a)	29°37'N/95°00'E Namche Bawar W-slope 3840 m asl	lateral moraine 110 m below modern glacier tongue	-24,5	265 +/- 65	Younger Dhaulagiri-stadium IX
12.9.89/1c L-Hv 17666	tree trunk	exposure of moraine	several m below surface (30 m below 12.9./1a)	29°37'N/95°00'E Namche Bawar W-slope 3820 m asl	lateral moraine 130 m below modern glacier tongue	-25,1	60 +/- 60 (^{14}C content[pmc] 99,3 +/- 0,8)	Younger Dhaulagiri-stadium X-XI
12.9.89/1d L-Hv 17663	tree trunk	exposure of moraine	several m below surface (40 m below 12.9./1a)	29°37'N/95°00'E Namche Bawar W-slope 3810 m asl	lateral moraine 140 m below modern glacier tongue	-25,0	200 +/- 70	Younger Dhaulagiri-stadium IX
18.9.89/6 L-Hv 17662	ash	exposure of moraine or kames	6 m below surface	29°35'N/94°56'E Namche Bawar WSW-slope 3330 m asl	glacigenic accumulation 620 m below modern glacier tongue	-23,2	4490 +/- 95	Nauri-stadium V
27.9.89/5 L-Hv 17660	vertebra of mammal	exposure of surface of moraine	0,2 m below surface	29°27'30 N/94°28'E junction of Nyang Qu with Tsangpo 3120 m asl	medial moraine	-23,4	410 +/- 100	age of moraine is much older
30.9.89/2 L-Hv 17661	char-coal	exposure of gravels	0,4 m below surface	29°55'N/92°48'E upper Nyang Qu 3800 m asl	outwash terrace no. -1	-23,9	2600 +/- 125	older Dhaulagiri stadium VI

M. Kuhle 1989

besides the main glacier as a subsidiary stream with a now downwards bent direction of flow. Still more *similar* to the shape of the Rakhiot glacier was that of the High Glacial Buldar subsidiary stream, because the topographic points of correspondence of the Buldar Gah with those of the Rakhiot valley are numerous (e.g. Photo 107 ▲ ▲ on the very left, — — fine on the very left). These topographic features need not be described again. In our context a significant aspect of similarity is the corresponding *terminal position* of the present Buldar glacier (3179 m) with that of the recent Rakhiot glacier at about 3200 m asl at an approximately *equal* exposition of the catchment areas to the N. As that of the Rakhiot valley, the gorge of the Buldar valley, brought about by *subglacial* meltwater, which incises the *confluence step* down to the Indus valley by a sharply inserted notch, begins at an altitude of 2300 m and is also lined by still preserved, glacially *round-polished*, 600–700 m higher rising spur cupolas (Photo 107 ▲ ▲ on the very left; 116 ▲ second from the right; 117 ▲ on the left; 118 —— on the very right). Such a rounded spur cupola, which shows the contact of the Buldar subsidiary stream – joining the Indus glacier – with the Rakhiot subsidiary stream and also the *minimum level* of the two tributary glaciers, is the 2930–3014 m high ridge between the adjacent hanging valleys (35°27′N/74°37′E; Figure 28, No. 91; Photo 99 ▲ left-hand quarter, background; 110 ▲ second from the left). Beyond the Rakhiot valley, where its W valley flank comes to an end in the orographic left-hand flank of the Indus valley, flank polishing and abrasion of the Ice Age Indus glacier occurs up to an altitude of c. 3050 m as a *glacially triangular-shaped slope facet*, culminating in this spur of the side valley flank (35°27′27″N/74°34′37″E; Figure 28, No. 92; Photo 118 ◆ right-hand edge).

In the following we turn to the orographic r*ight-hand* Indus valley side, which is running here on the glacial inner bank of the former ice stream, in order to examine the above-mentioned ice level (Photo 118 —— white; 116 —— below No. 8; 111 —— fine; 112 ——) with the help of the indicators preserved there.

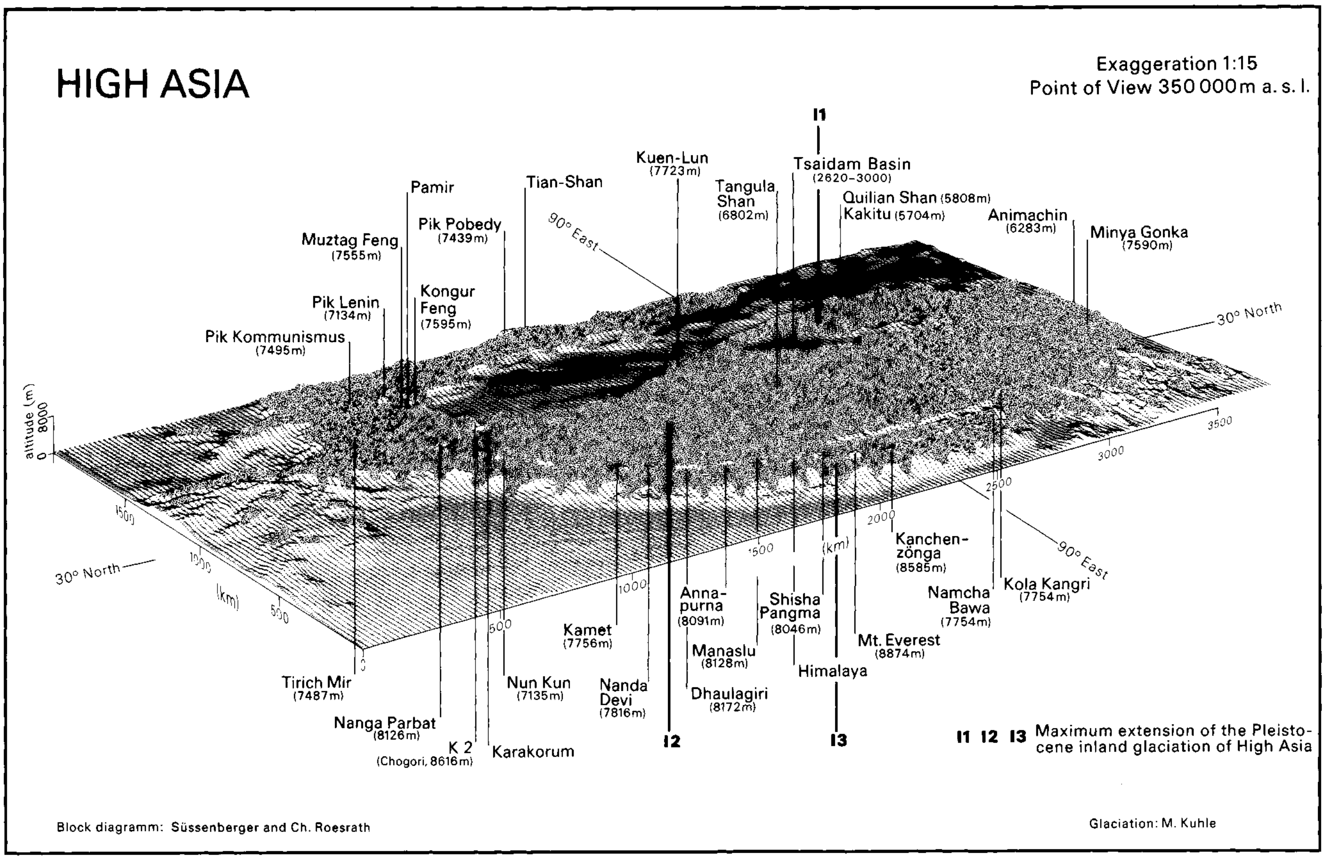


Figure 38. The High Glacial glacier cover of Tibet and the adjacent surrounding mountains of more than 2.4 million km^2. I1, I2, I3 are the more or less dome-shaped glacier centres and marginal ice-stream networks of the Tibetan ice sheet. These centres are partly separated from each other through the ice-free furrow of the Tsangpo valley in the S and through the glacier-free Tsaisam basin in the N. In this paper evidence is provided of the glaciations belonging to this pre-historic glaciation, i.e. Pamir (Muztagh Feng and Kongur Feng), Nanga Parbat-massif with the lower Indus valley, NE Tibet W of the Animachin and between Kangchenzönga and Kamet in the S. By means of the C14-datings, published in this paper, the Tibetan ice sheet has been classified as being of the LGM (Stadium 0 according to Table 1 = Würm or Weichsel or Wisconsin).

Opposite the Astor valley junction, to the true W of it, there is preserved a rock slope, which had been *classically polished backwards* to the shape of a *triangular* slope facet up to a culmination of 3016 m asl (35°34′21″N/74°35′35″E; Figure 28, No. 93; Photo 111 ➘ black, second from the left). Below this rock slope, down to the Indus, a four-stepped *ground moraine* joins, which since the deglaciation had been cut by *glaciofluvial* lateral erosion of the Indus out of an ground moraine cover, which originally was *without any steps*. The culmination of this moraine remnant is at point 1758 m, 620 m above the talweg (35°34′19″N/74°36′55″E; Figure 28, No. 94). From the settlement of Talichi onwards, down the Indus valley, this *ground moraine complex* has an extension of 4 km. Afterwards a valley slope, covered by ground moraine joins, which reaches up via point 2078 m to point 2401 m (35°31′10″N/74°35′58″E; Figure 28, No. 95) on the T. P. Gor Gali massif (3030 m; Photo 116, No. 8; 118 above the seventh ➘ from the left). On the 2505 m hill ridge 1 km further downward, which has been completely *overflowed* and round-polished by the ice of the Indus glacier, a ground moraine remnant has remained, which provides evidence of the *original bed* of the Ice Age Indus glacier (Photo 118 ■ on the right below No. 8, white; 116 ■ small). Attached to the valley flank in S-exposition, it sets in immediately above the Rakhiot bridge on a rock basement, which is undercut by the river, and stretches with a typical *concave surface curve*, corresponding with the cross profile of the glacier bottom, up to at least 1800 m asl, i.e. 650 m above the present river (35°29′50″N/74°35′48″E; Figure 28, No. 96). On the immediately S slope of T.P. Gor Gali, a *ground moraine* (Photo 116 and 118 ■ below No. 8) is preserved in remnants up to 2650 m asl. Above, a *polished* slope surface reaches up to a *horizontal glacially shaped score* at an altitude of 2850 m (Figure 28, No. 97). However, at High Glacial times the 3030 m high cupola of T.P. Gor Gali itself (Photo 116 and 118, No. 8) has been reached and even *overflowed*, too, by the right-hand edge of the Indus valley glacier (35°31′23″N/74°34′37″E). References and proofs are given in the following chapter.

3.7. *Indicators of a maximum ice level on the right-hand Indus valley flank in the environs of the 'Dead Valley'*

T. P. Gor Gali is situated NNW of the mouth of the Rakhiot valley (Figure 28, No. 106; Photo 116, No. 8). Thus it brings to an end the Indus valley section between the Astor-Rakhiot-valley, which has been discussed in the last chapter, on the orographic right-hand side in a downward direction. Finally the glaciogeomorphology of the Indus valley N of Nanga Parbat still 7 km further downwards will be continued, i.e. up to the junction with the next but one orographic right-hand side valley, the Gor Gah at the Drang settlement (Figure 28, No. 102–103). It seems to the author, that on this orographic right-hand section of the Indus valley flank with its talwegs, there are preserved further conclusive indicators of a *considerable High Glacial thickness of the Indus glacier* on the N rim of the Nanga Parbat massif. For instance, the *ground moraine covers* on the rock basements along the right-hand valley slope continue

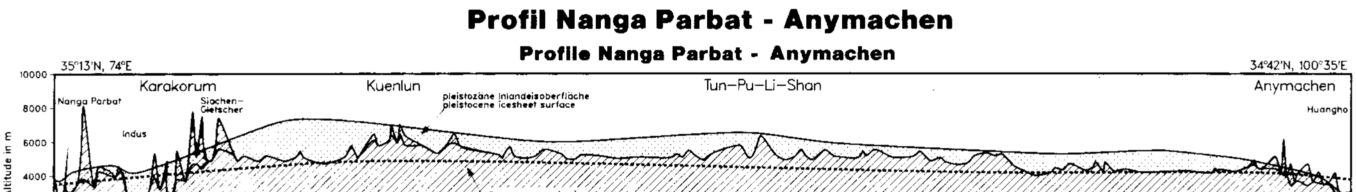


Figure 39. Dome-shaped longitudinal profile of the ice (cf. Figures 38, 13 and 40), derived from the outlines of the reconstructed Tibetan ice sheet (cf. Figures 46–48), the mountain forms of Tibet and the positions of the erratics.

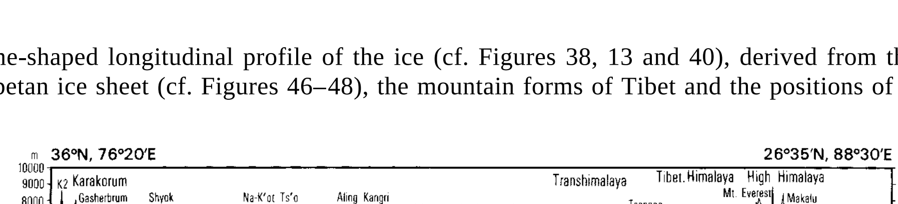


Figure 40. Dome-shaped diagonal profile of the ice (cf. Figures 38, 13, 39) derived from the outlines of the reconstructed Tibetan ice sheet (cf. Figures 46–48), the forms of the Tibetan mountains and the positions of the erratics.

(35°29′44″–16″N/74°34′28″–30′14″E; Figure 28, No. 98; Photo 118 second ■ from the left; 119 ■ on the left). Here they reach up to 1800–1900 m asl. *Corresponding* ground moraines of the same nature, i.e. *surface-forming*, are also immediately opposite on the left-hand Indus valley flank (Figure 28, No. 82–102; Photo 118 ■ on the very bottom up to ■ on the very left) up to an altitude of 1500 m (Figure 28, No. 99; Photo 118 below ↘ on the very left). Halfway between the Rakhiot bridge and the Drang settlement, up the Indus from the junction with the Dirkil Gah, in the environs of point 1660 m (NP-map 1:50,000, 1936) extending over kilometres, ground moraine material of metre to decametre thickness is superposed on a rock basement, which was rounded by the *ground polishing and abrasion* of the Indus ice-stream (Figure 28, No. 98; Photo 118 ■ second from the left and ◓ below; 119 ■ on the very left). This applies, too, to the environs of point 1781 m, down-valley of the Dirkil Gah junction, well over 650 m above the Indus valley talweg (Figure 28, No. 100; Photo 118 ▽).

Haserodt (1989, p. 208) also has observed these moraines. He points out, that, for instance, they might have been produced from beyond, from the Barchaloi Gah (Figure 28, No. 101), as a side valley from the Nanga Parbat group, i.e. as a *local moraine* and *without* the Indus glacier. To this one can reply that the mean altitude of the catchment area of that valley is lying only at 4200 m and with this there must be supposed an ELA depression of at least 2650 m asl, so that such a Barchaloi glacier reached the Indus valley bottom, i.e. could even fill it up to 500 m above its talweg. However, at such a *snow limit*, which then would have been lowered by 2150 m, i.e. about 850 m *more* than the author has reconstructed (see Table 1; 0, Figure 28), the Indus valley, due to the extreme increase of its nourishing area, would already *have been filled anyway* by the glacier ice, which flowed together from *higher and larger* valleys.

In addition, down to the Indus such a *ground moraine substrate* is attached to the 400 m high steep slopes of the rock basements increasing in thickness down-slope, which in the direction of the slope foot more and more concerns *dislocated moraine material*, too, which since the deglaciation has built up debris slopes of moraines in this place (35°28′50″N/74°33′40″E; Figure 28 below No. 98 and 100; Photo 118 second ■ from the left, left below). Point 1588 m even marks a 50–70 m thick *plug of ground moraine* (Photo 118 ■ third from the left), which has been slipped off the glacier bottom in the glacial flow shadow of the rock slope of the right-hand valley flank, 1.3 km down-valley the Rakhiot bridge (Figure 28 below No. 97; Photo 119 ■ second from the left).

The only provable *thicknesses of the Indus glacier*

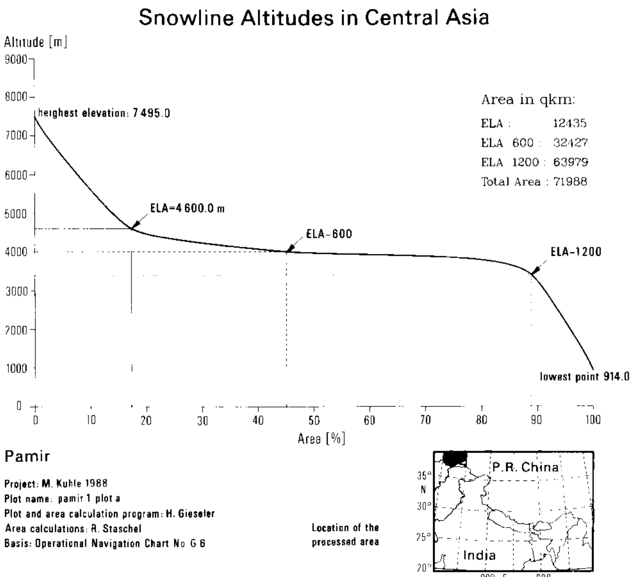


Figure 41. Present extension and increase of the glacier feeding areas (= areas above the ELA) in the Pamir (cf. chapter 2) at an ELA depression in relation to the relief of –600 to –1200 m. Since the adjacent ablation areas below also belong to the feeding areas, the entire area was completely covered with glacier ice at a 1200 m-ELA. The climatically caused depression of the ELA, as well as the tectonically caused uplift of the relief, are included in those –600 and –1200 m, i.e. they add up to –600 and –1200 m. Highest elevation = Muztagh Ata (cf. Figure 45).

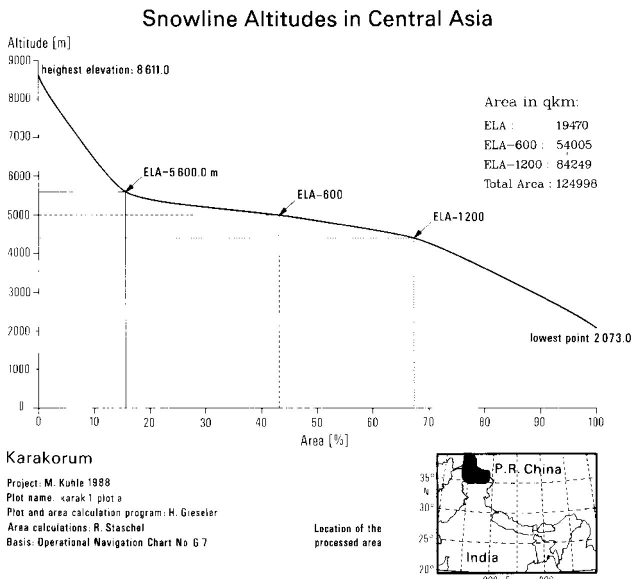


Figure 42. Present extent and increase of the glacier feeding areas (= areas above the ELA) in the Karakorum (cf. Kuhle 1994a) between Pamir (cf. chapter 2) and Nanga Parbat (cf. chapter 3) on the W margin of Tibet at an ELA depression in relation to the relief of –600 and –1200 m. Highest elevation = K2 (cf. Figures 41, 45). At ELA –1200 m the entire area was completely covered with glacier ice up to and including the glacier ablation areas. This applies to AAR = 0.66, i.e. the usual relation of glacier feeding- to ablation area of 2:1.

due to these ground moraines, which in places already reach 1500 m (see chapter 3.5. and 3.6.) are even exceeded – apart from the *rock smoothings* resulting from flank polishing already described – by several hundred metres through preserved *kames* and related *combined glacigenic features* (Photo 118 —— on the left) in the right-hand Indus valley flank: following the parallel valleys of the Dirkil- and Gor Gah upwards into the S flank of the 4669 m-high Chamuri, there can be noted masses of loose material, which Haserodt (1989, p. 208) considers to be moraine material, containing local deposits, and which he declares to be possibly *older* than Late Glacial. The author *agrees* with the definition of the material and considers the stepped accumulation surfaces as being four *kame-terrace* complexes or -remnants of the Late Ice Age (Photo 118 □). On the three western accumulation surfaces there are the dwellings and fields of the settlements of Gor (Figure 28 between No. 100 and No. 103), Gano and Terimal (Figure 28, No. 104). The *lower* margin of the *lowest kame* remnant breaks off in the direction of the Indus valley at 1950–2000 m asl, i.e. 830–880 m above the main valley talweg, so that – representing the *latest*, youngest Late Glacial position of the *kame development* – it indicates an approximately still 830–880 m *thick* Indus glacier. When the kame development, which during a former glacier stage took place simultaneously with the *deglaciation*, coming down *more and more* from above and following the lowering margin of the valley glacier, was still not in progress so far down the valley slope, the glacier bank has been documented by the *kame-terrace* at 2240 m (Figure 28 below No. 104). Here, at point 2243 m, 750 m W of Gano, there is preserved a *lateral moraine cupola*, falling away to the valley slope into a *lateral moraine depression*. Later on this lateral moraine remnant at its base has been partly sedimented up by the younger kame terrace accumulation, which has developed from above (see above). This lateral moraine likewise marks a *Late Glacial* glacier margin of the Indus, since a c. 1 km long, slope-parallel moraine slope culminating at 2850 m asl marks another, still 600 m higher, *ice level* (35°32′30″N/74°33′11″E; Figure 28, No. 105; Photo 118 perspectively covered by these hills ⇓). It proves a thickness of the Indus glacier of about 1700–1750 m. In addition this second hill, pointed out by the author as a lateral moraine remnant, also has an inclination of the slope down into a *lateral valley*, which here is inset up to 2719 m and has the significant depth of 130 m. Thus this is an extensively represented glacio-geomorphological *ice margin* position.

The interpretation of sediments and forms provided here, is partly *in contrast* to that represented by Haserodt (1989, p. 208), who classifies the rampart-like ridges immediately E of Gor (Ghor) (Figure 28, No. 105) as *local moraines*. On the condition that the author has correctly understood his interpretation, these ought to have been pushed upon here, at 2400 m asl, by a S-facing local hanging

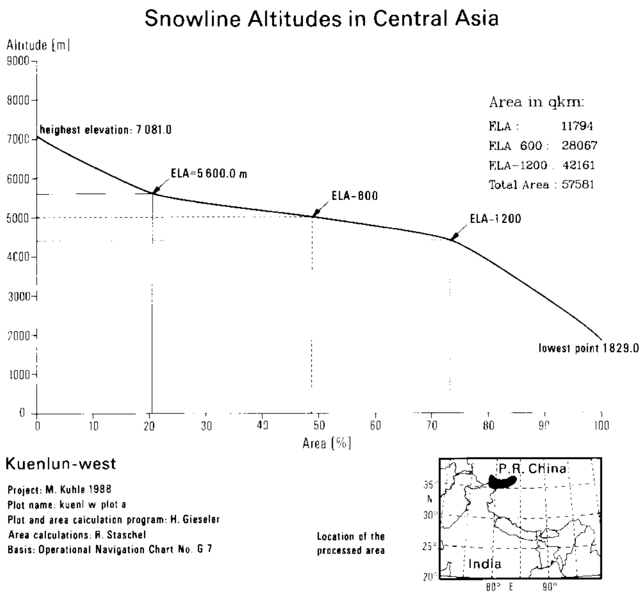


Figure 43. Present extent and increase of the glacier feeding areas (= areas above the ELA) in the W Kuenlun (E of the Pamir, cf. chapter 2, and Karakorum) at an ELA depression in relation to the relief of –600 and –1200 m. Up to and including the glacier ablation areas the entire area has been glaciated at ELA –1200 m (cf. Figures 41 and 45).

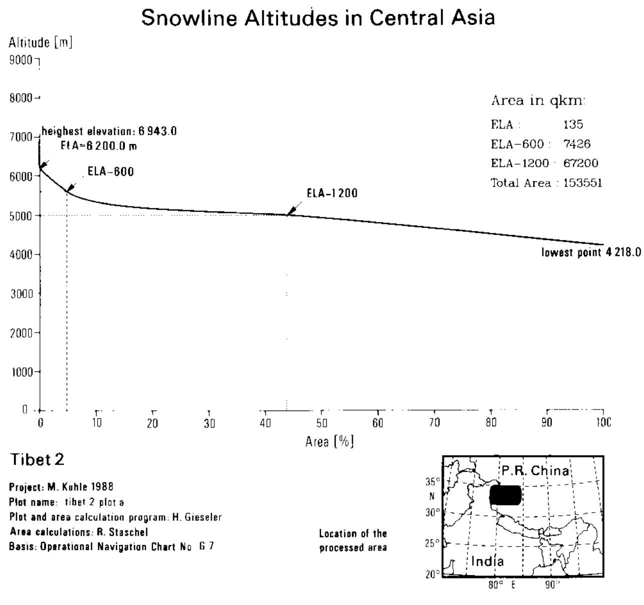


Figure 44. Present extent and increase of the glacier feeding areas (= areas above the ELA) in W Tibet to the S up to the E of the test-areas of Figures 41–43 at an ELA depression in relation to the relief of –600 to –1200 m (cf. Figures 41 and 45).

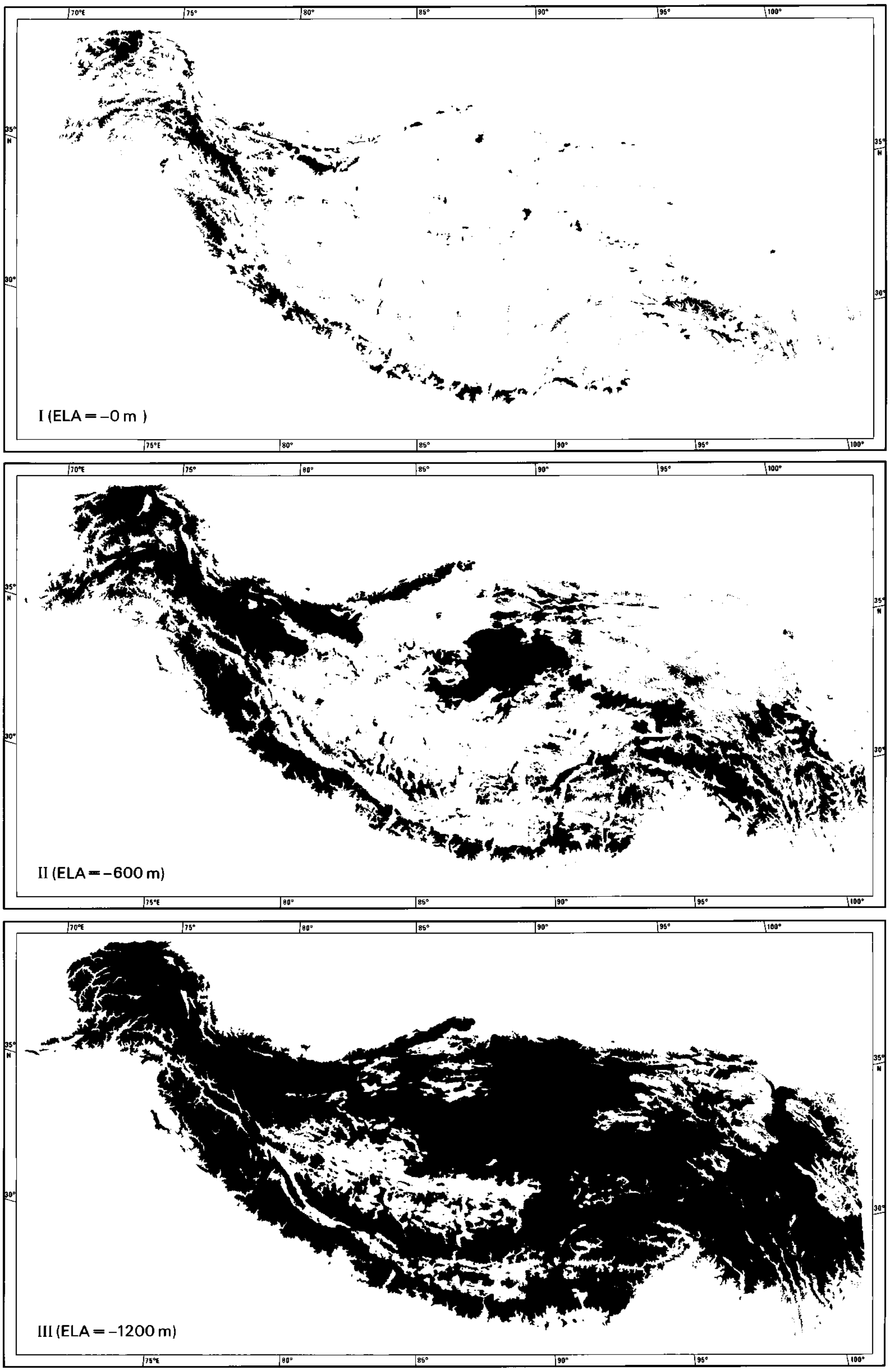


Figure 45. The present extent of the glacier feeding areas in and around central Tibet, S of the Tsaidam basin (without Tian- and Quilian Shan) (I) is shown; the increase of the feeding area, linked with the topography, at an ELA depression of –600 m in relation to the relief (II) and the increase of the feeding area at an ELA depression of –1200 m in relation to the relief (III). These maps have been created from numerous separate test-areas, as exemplarily shown in Figures 41–44, which taken together completely cover Tibet. By adding the glacier ablation areas, at least half of the Tibetan surface was covered with glacier ice during state II (Late Glacial = Stadium I–IV, cf. Table 1); during state III (= High Glacial = LGM = Stadium 0, cf. Table 1) it was completely covered by a unified ice sheet (cf. Figure 38). Project and draft: M.Kuhle; plot and calculation program: H. Gieseler; area calculations: R. Staschel; cartography: E. Höfer and A. Flemnitz.

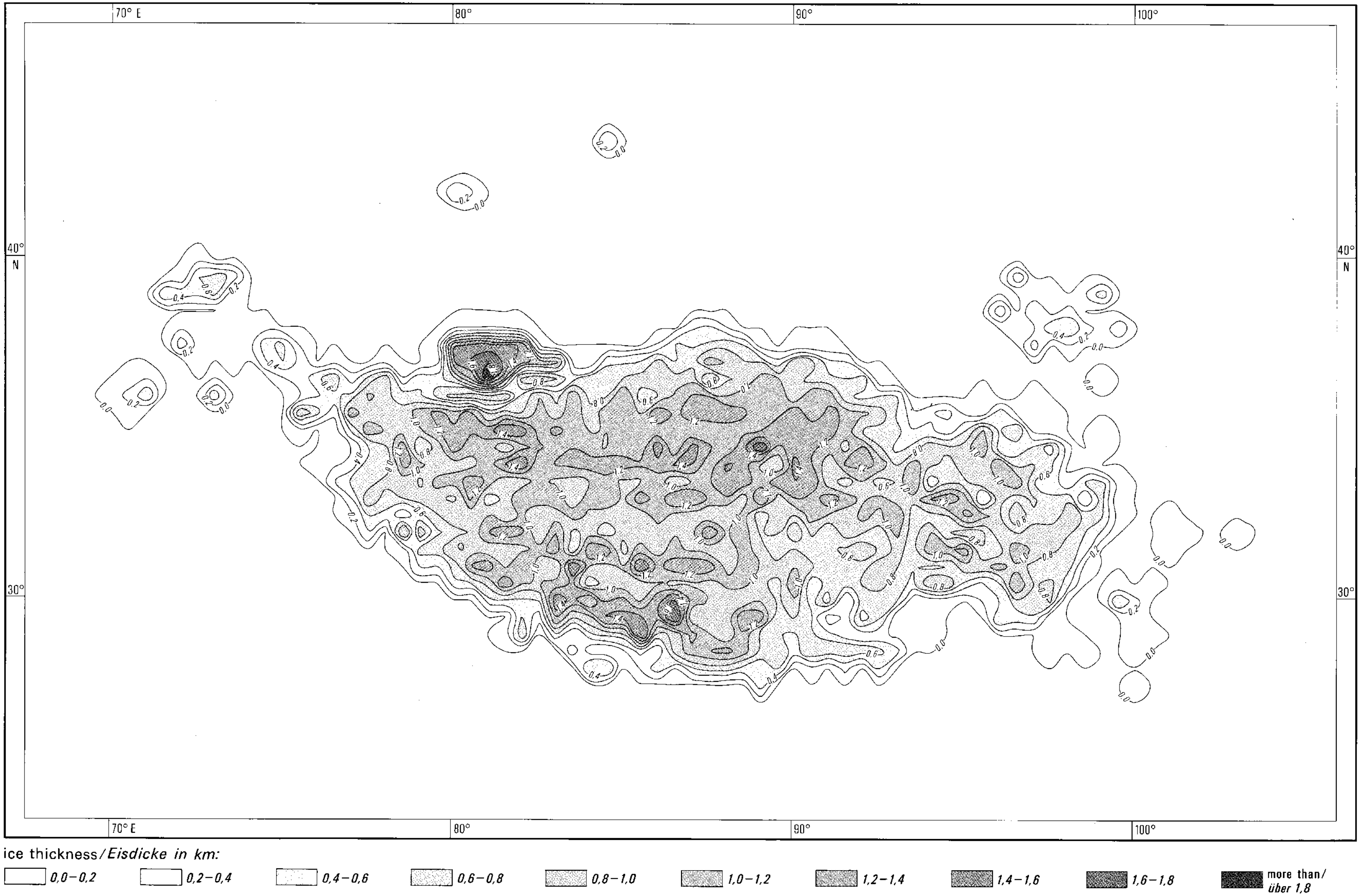


Figure 46. Glacial ice thickness after 10,000 years at a precipitation of 100 mm/yr and an average ELA at 4250 m asl in Tibet. The model, undertaken by Herterich and Calov, is based on the empirical data obtained by the author, i.e. the lowest High Glacial (LGM = Stadium 0) glacier margins, reconstructed with the help of end moraines, and the ascertained ELA depression and estimation of temperature- and precipitation (b max) in Tibet and its surrounding mountains. The model is based in detail 1. on the graph of the annual snow balance b (b max = 100 mm/yr) as a function of the height above the ELA; 2. on the contour lines (m asl) of the glacial snow surface (ELA = 4250 m asl) in Tibet. It fits the observed heights of the glacial equilibrium line (according to Kuhle, Herterich and Calov 1989, pp. 204/205); 3. on $t = 10^3$ yr. Cartography: E. Höfer and A. Flemnitz.

glacier from the Luthi-Gali-Chamuri-flank. However, at an *average altitude of the catchment area* of 4100 m, this would mean an ELA at 3250 m asl, which corresponds to an orographic *snow-line depression* of 1750–1900 m compared with the recent ELA. From the author's experience of the semi-arid areas of High-Asia this *excess* lowering of at least c. 450 m, would have produced such an *important increase* of the nourishing area in the S-adjacent 2000–3000 m higher Nanga Parbat group, that a simultaneous glaciation of the Indus valley up to 2400 m asl and *higher*, could be *immediately derived* from the relation of glacier nourishing- and glacier ablation area. The *discrepancy* addressed here, is recognizable in Haserodt's picture 1 (ibid., p. 197), according to which the Indus glacier, nourished by the Astor glacier, only just reached the Indus valley cross-profile of Gar (Ghor), while the hanging glacier of Gor already discussed, existed *simultaneously* with the necessary snow-line depression. For the author, however, the Indus glacier flowed approximately 100 km *further down-valley* (up to Sazin, cf. Kuhle 1988, p. 606) up to 980 m or even still 20 km further up to below 870 m asl (cf. Photos 120–132 ☗ and ■; Figures 36 and 37) at an ELA- depression of 1200 to at most 1300 m, and consequently without that there must necessarily have existed a Gor hanging glacier, flowing so far down.

To the points mentioned above a further indicator can be added for an *erosion base*, raised by the Indus glacier to 2700–2850 m asl, as there are former *valley glacier surfaces* for all down-slope processes on the now *upwards-shortened* valley flanks: here, 1600 m above the Indus, exists a very *flatly inclined* valley, provided with an intact, 300–400 m wide drift floor, which is set in the *glacigenic* (morainic, glacioflu-vial and/or kame-) material about 150 m in depth already mentioned. This c. 4 km long, extremely *high-hanging* valley, runs in the shape of a bow around that up to 2850 m-high lateral moraine remnant (see above) in a southernly direction down to the Indus valley. It was *adjusted* to an Indus glacier level, having dropped from 2850 to 2700 m, when its further development *suddenly* broke off *completely*. Correspondingly this small valley was named by the cartographers of the Nanga Parbat map 1:50,000 (1936) with a *correct description* as the 'Dead Valley' (Figure 28, No. 105; Photo 118 perspectively covered by these hills ⇓). Such valleys with intact drift floors, which are *heaped up* against a valley glacier and then suddenly have fallen dry or dead, are characteristic for the very *variable hydrology* along the for a longer term *stable* ice edges of large valley glaciers. The development of the 'Dead Valley' took place when the water was flowing along the right-hand Indus glacier edge at the time, when its *surface level* lay about 2850 m asl (cf. Photo 111 —— fine, below; 116 —— below No. 8). This is, to be precise, the level height which was sufficient for the melting water, draining off into the glacier's marginal valley (beyond the lateral moraine) to discharge over the 2840 m-high saddle of the Ghor Gali (Photo 116 ▽) (35°32′39″N/74°34′18″E; Figure 28, No. 106; cf. Photos 118 and 119, No. 8) down-valley towards the Indus. At that time the right-hand edge of the Indus glacier probably *flowed across* the 3037 m-high rock ridge between T.P. Gor Gali (see 3.6) and that Gor Gali saddle (Photo 116 —— below No. 8). This is indicated by the *rounding and smoothing* of the ridge (Photos 116, 118, 119 ☗ ☗ below No. 8), into which since the deglaciation have been set in backward-eroded *funnels*, differing from the *roundings* through a *sharp* working-edge (Photos 116 and 118 ●). Thus the right-hand Indus glacier edge in this upper level had *cut off* the wide bend of the Indus talweg in a *straight line* from the up to 3016 m-high polishing facet W of Talichi across the T. P. Gor Gali (see 3.6) up to the junction with the Gor Gah from S to W (Photo 111 —— fine, below; 116 —— on the left). – To start with, the small *marginal valley* of the glacier with its meltwater beyond the Gor Gali saddle (Photo 116 ▽) followed the upper section of the 'Dead Valley' towards the W across point 2719 m, the present saddle of which was formed only later (Figure 28, No. 104). Thus it followed the contem-porary mule track from Gor Gali to the Terimal settlement. Later on, when the Indus glacier level had *dropped* and the ice abutment W of the Gor Gali saddle was lacking, the 'Dead Valley' has received its *present* SW direction (Figure 28 between No. 105 and 106) from the meltwater stream, which flowed down to the *now lower* placed glacier margin. This process, now forming the lower section of the 'Dead Valley', only lasted for as long as the up-valley glacier level on the E side of Gor Gali made it possible that the meltwater could *spill over* the saddle (Photo 116 ▽ —— below No. 8) (cf. Photo 111 —— fine, below, left-hand end) and reach the level of its lateral moraine and small marginal valley at 2840 m asl. When the ice level, which in this position was lying c. 700 m *below* the synchronous *snow-line*, was dropping further, the lateral water at first flowed *around* the T. P. Gor Gali slope (Figure 28, No. 96, 97; Photos 116 and 118 along the visible mountain flank below No. 8) and with increasing deglaciation formed ever *lower* discharge *levels*. Since *complete* deglaciation a streamlet runs from a retreating source funnel below the Gor Gali saddle in a direction *opposite* of the Ice Age meltwater stream, i.e. counter to the Indus direction, and – *now following the present inclination* of the deglaciated main valley flank – first down to the mouth of the Chamuri gorge (Figure 28, No. 93) and then to the Indus, next to the Talichi settlement (Photo 111 ↘). When the Gor Gali saddle (Figure 28, No. 106; Photo 116 ▽) *fell dry*, the 'Dead Valley' also received *no more water*, so that no backwards dissecting of its drift floor could happen, when the Indus glacier edge dropped below

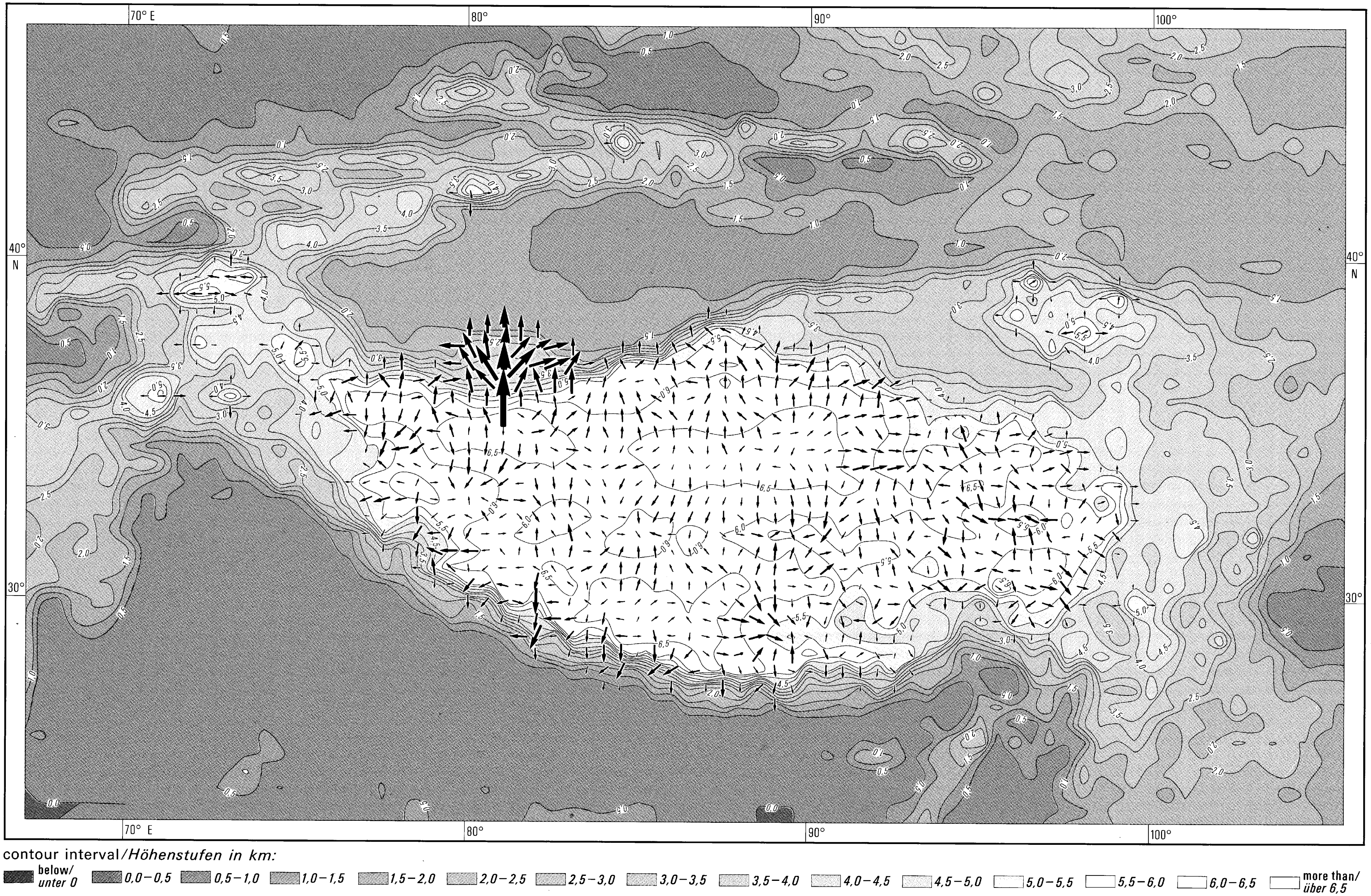


Figure 47. Surface altitudes and ice flow (the arrows and their different thicknesses indicate the flow vectors) of the High Glacial Tibetan ice sheet at an average ELA of 4250 m (Stadium 0, cf. Table 1) (cf. Figure 46), modelled by Herterich and Calov according to ELA reconstructions of the author. Precipitation (b max) = 100 mm/yr; integration time of the ice accumulation 10,000 years. Cartography: E. Höfer and A. Flemnitz.

2600 (2589) m, i.e. below the altitude of the 'Dead Valley' exit (Figure 28 below No. 105). – According to that, the *explanatory model* provided understands the 'Dead Valley' besides the other accumulative and erosive features of this Indus side as an *essential* indication for a High Glacial Indus *glacier level* about 3000 m asl (Photo 91 ——0; 112 ——; 116 —— at No. 8; 111 —— fine; 118 ——; 110 ——0 fine, on the very left; 125 ——) and an *ice thickness* of 1800–1900 m in the main valley on the N rim of the Nanga Parbat massif.

3.8. *Second conclusion, derived from results which have been achieved on the Nanga Parbat massif and in the Indus valley*

During two expeditions (1987 and 1995) glacio-gemorphological and geological observations and indicators have been collected, which permit the reconstruction of a probable highest pre-historic glacier infilling of the valley relief in the Nanga Parbat massif for the *Late Pleistocene Ice Age* (Last Glacial Maximum/LGM).

At the present state of knowledge so far available there are no absolute dating methods which are free of discrepancy, i.e. unambiguously safe and above all direct. Thus, chronologically to classify these indicators for the reconstruction of the glaciation in the *Last Ice Age*, two factors have been taken into account. 1) (*an inductive*): in this semi-arid *steep* relief of highest vertical distance the *destruction* of glacial forms happens *so fast*, that it seems to be unlikely that there could be preserved forms of an age of more than 120 Ka, i.e. such from the Pre-last Ice Age. 2) (*a deductive*): with the applied model of a *continuing recent uplift* of Nanga Parbat and adjacent mountains, there would have existed during *earlier* Ice Ages *not nearly* so much extended high glacier nourishing areas as happened during the Last Ice Age, so that there ought to be implied a *larger drop in the snow-line* for the supposed heavier glaciated earlier Ice Ages. This would mean a regional *supplementary assumption*, because in the Riß Age the ELA was running globally *only about 100 m lower* than in the Würm Age.

On Nanga Parbat there was a total glaciation by the *ice-stream network* (cf. Figures 13, 38, 39) the dendritic branches of which formed *one single connected surface* from the subsidiary glaciers of second and first order up to the main glaciers of the Astor- and Indus valley. Above their levels at 3000–4850 m asl, there towered the higher summits at a maximum of 3200 to 5100 m with their sharp ridges and crests, the flanks of which were covered with *wall ice- and hanging glaciers*. A *secondary feeding* of the subsidiary streams of the valley glaciers was provided by the steep ice in form of snow-, firn- and ice *avalanches*. The *High Glacial glacier snow-line* ran at an altitude of c. 3400–3600 m, i.e. at least 1200 m below the present one, so that the former Rupal-Astor glacier with its components represented the *nourishing type of a firn stream glacier* (Visser 1934; Schneider 1962), of which merely the main glacier surface lay above the ELA in the Rupal-Astor valley, which was already an extension of approximately 60 km up to the position of the Astor settlement. It was thus supplied predominantly by *snow precipitation*, i.e. by *primary* nourishment. From the position of the Astor settlement onwards, the Rupal-Astor glacier, which received inflow from rich subsidiary streams, flowed over a distance of more than 30 km *below* the snow-line up to its confluence with the first order main glacier, the Indus glacier, the surface of which lay here at 3000–3100 m asl. In the author's opinion (Kuhle 1989, pp. 271–273, Figure 11), the Indus glacier flowed together from the *huge catchment area* of the Hindukush, Karakorum and Zansgar Himalaya (cf. the opinion of Haserodt 1989, Photo 1, p. 197) to the *lowest valley glacier* course of the whole drainage system and was supplied, besides the Astor glacier inflow, which connects the S and E face of the massif, by the N slope of the Nanga Parbat with the Rakhiot valley and its parallel valleys. In the 20 km-long Indus valley section between the Astor mouth and the Drang settlement, down-valley of the Rakhiot Gah mouth, there was evidenced a *maximum thickness* of the Indus glacier of 1800–1900 m. By this thickness and such an *increase* in the ice thickness from the valley heads still glaciated today up to the main valleys far below the snow-line, there is confirmed the *regularity* of a, glacially speaking, only small raise of the nourishing-area-surface, something which is already known from the Alps. By means of these *short-connected*, very *productive* nourishing areas of the Nanga Parbat massif, where the Indus valley floor runs here at only 1150 m asl, the Indus glacier, which according to the author's research results so far published (Kuhle 1988l, pp. 606–607) flowed down 100 km further to *at least* the position of the Sazin settlement at 980 m asl, *more probably* to below 870 m, still 20 km further down (Photos 120–132), is reinforced for the last time. The *glacially important glaciation* of the Nanga Parbat group can be seen as a *further confirmation* of the *very extensive glaciation of High-Asia* with its *centre in Tibet* (Figure 38). Due to its *reflection* of the *subtropical* radiation (Figure 50) (Kuhle 1987d, 1988b) it is of *triggering* significance according to the author's hypothesis on the *build-up of Ice Age*s.

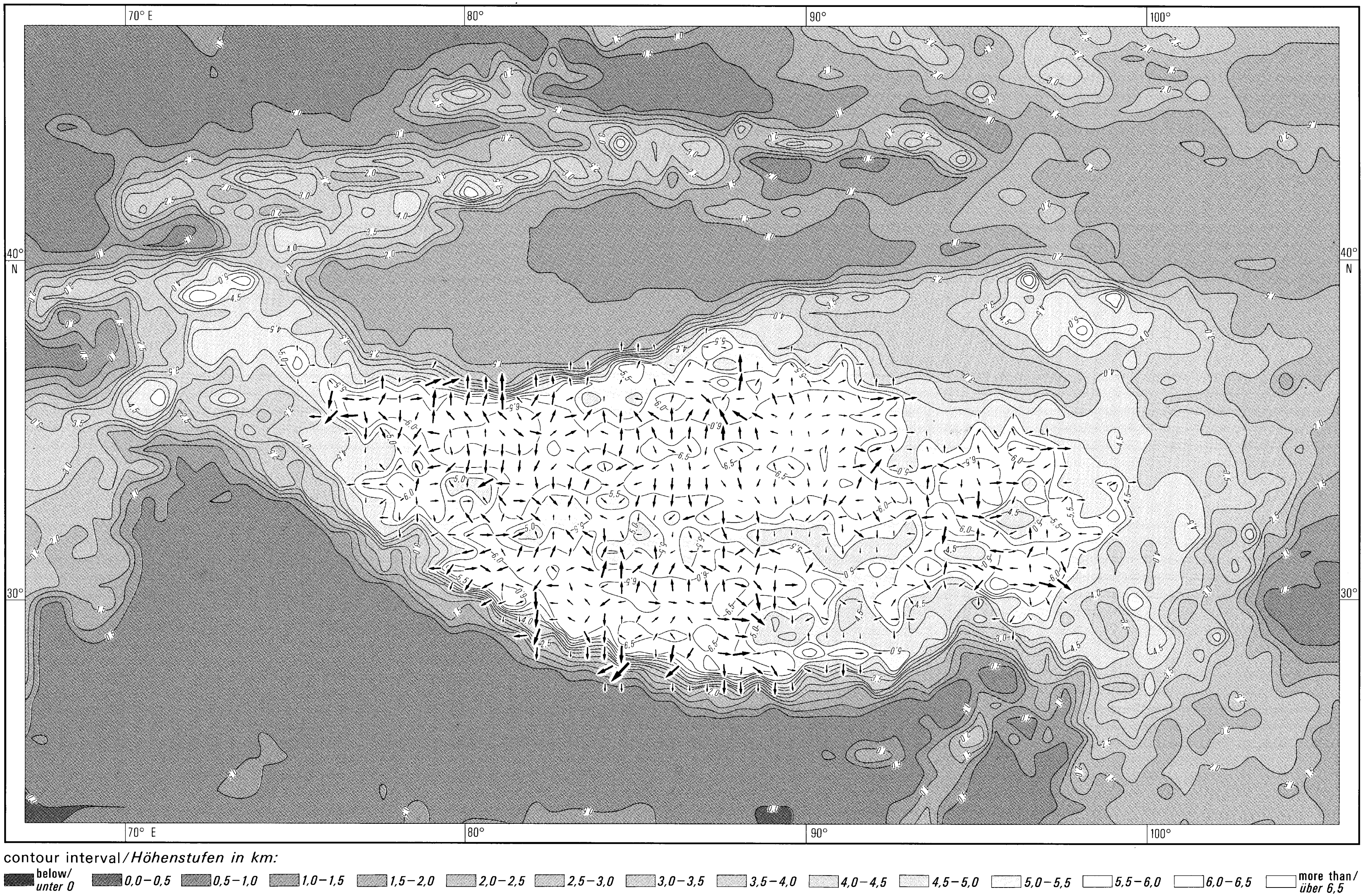


Figure 48. Surface altitudes and ice flow (the arrows and their different thicknesses indicate the flow vectors) of the Tibetan ice sheet during its Early- and Late Glacial extension (Stadium I to II, cf. Table 1) at an average ELA at 4500 m asl, modelled by Herterich and Calov according to ELA reconsructions of the author. Precipitation (b max) = 100 mm/yr; integration time of the ice accumulation 10,000 years. Cartography: E. Höfer and A. Flemnitz.

4. New Investigations and Evidences on the Pre-historic Tibetan Inland Ice

4.1. *In N-Tibet (Figure 1, No. 17)*

During 1994 in N Tibet research works were carried out in addition to those of 1981 (Figure 1, No. 2 and 17). At that time a series of indicators had been recorded, which led to the reconstruction of an ELA (equilibrium line altitude) depression to 4100 m asl, resulting in a *complete ice cover* of NE Tibet (Kuhle 1982e, pp 74–76, Table 1; 1987b, pp. 304–306, 308–311, Table, p. 302, Figure 9 (map after satellite-picture)). The then finding is supported by *scattered erratics*, which could now be mapped from 5 km N of the Bayan Har pass (Photo 134) (34°10′N/97°41′E) to beyond the N edge of the Yen Yougo basin in the large Yeh Matan valley (Photos 135, 136, 137, 139, 140, 142, 143), leading down from W to E, S of Madoi (Mato) (34°41′N/98°03′E), and on the NW edge of the Chaling Hu (Ngoring Lake) (35°04′N/97°42′E). These are *granite erratics* with large sanidine crystals (Photos 137, 140, 143). They have been *transported over a distance* of 70–140 km from the S, from *central* Tibet, where the at present *non-glaciated*, 5160 m-high threshold of the Bayan Har (Photo 134) with partly outcropping granite, determines the ice run-off. The *facetted blocks* (Photo 135, 137, 140, 143), up to the size of a room, belong to typical *ground moraine* with loamy groundmass (Photo 141, 144). They have been deposited over reddish and brown sandstones (Photos 135, 137, 139) and crystalline schists (Photo 141). In the formation of ground moraine they are lying *isolated* from each other (Photo 136, 139, 142) and occur in *polymict company* with fist- to head-sized, locally scoured or *outbroken* components of the relatively most solid metamorphites (Photo 141, 144). Among them are *striated* quartzite boulders (Photo 145). The ground moraine covers *polish depressions* of metre- and *polish thresholds* of decimetre thicknesses as an accumulative element of the *glacially eroded* landscape of an inland ice, marked by *glacial streamlined hills and polished ridges* (Photos 134, 135, 136, 140, 141, 142, 143).

The area concerned is identified by *recent permafrost*, noticeable by thermokarst, but also proved by an excavation at 4500 m (34°09′N/97°42′30″E; Photo 138). The permafrost confirms a mean temperature of colder than –6°C/yr. Thus there have been temperatures of –14 to –16°C during the LGM (Last Glacial Maximum). In the *most arid* and therefore *coldest* glacier areas of High Asia, at the K2-glacier in the precipitation shadow of the Karakorum ridge (Figure 1, No. 5), in 1986 the glacier ice temperatures, measured at a depth of 5 m, amounted to –10°C. This corresponds to the *annual temperature*. In this *indirect* way the *Tibetan inland ice sheet* can be proved, too.

Further evidence will be given by the plateau surfaces of the environs of the Haschi Scha settlement (ONC G-8: Huashih-Hsia). Located at an altitude about 4150 m asl, these plains with their hills and fringing elevations have been formed in rocks, containing up to 70% calcite (Photo 146, 147). On these bedrock calcites *classic ground moraine* over many deca-km^2 has been mapped (Photos 146–148; 35°01′–12′N/98°49′–59′E). The *analysis of the samples* confirmed its genesis, so for instance by a *bimodal* distribution of the fine grains. Besides calcite components, it contains *striated quartzite boulders* (locality: Photo 146). The portions of *granite erratics* included (Photos 147, 148) are essential as indicator boulders. They prove a connection between the inland ice tributary stream with the *western granites* of the Animachin (Figure 1, No. 2; Figure 38), the glaciation history of which has been investigated in 1981 (Kuhle 1982e, 1987a,b). The granites have been *transported over a distance* of c. 80–100 km from the SE, i.e. from the area around the Ischikai station W of the Animachin (cf. Photo 133). Consequently here, at Haschi Sha, *two tributary streams* of the ice joined: the one, which, originally coming from the S from the Payen Khola (with Bayan Har; Photo 134), has been diverted by the Burhan Budai (E-Kuenlun) to the E, and the other, which comes immediately from the S, i.e. from westwards of the Animachin (or Anymachen) (cf. Photo 133, Figures 38 and 39). The northerly and north/easterly connecting *outlet glaciers* and their *lowest ice margin positions* (Photos 149–151) have in part already been reconstructed during 1981 (cf. Figure 39 right-hand edge) (Kuhle 1982e, 1987a,b).

4.2. *In S-Tibet (Figure 1, No. 18)*

To reconstruct the *Ice Age outlet glaciers* of the S Tibetan *ice-stream network* (Figure 38, I3), which flowed through the Himalaya, a 3-1/2-months expedition was carried out during winter 1994/95. The aim was to study the *topographical connection* with the upper glacier courses in Tibet (Figure 1, No. 4, 9 and 20), which had been recorded in 1984, 1989 and 1996. Due to lack of space, the results cannot be proved in detail, but just recorded *cursorily*, proceeding from E to W: in the lower Arun gorge, in the cross-profile of the Num settlement, the Arun valley glacier, which at Kada (Figure 1, No. 9, N of Makalu; Figure 38 between Mt. Everest and Kanchenzönga) was still c. 2000 m thick (Kuhle 1991d, p. 216), even had a *thickness* of 700 m and SSE of Makalu reached down to *at least* 500 m asl (27°24′N/87°08′30″E; Figure 38 on the right below Mt. Everest; Figure 40). – The Buri Gandaki *outlet glacier* flowed down from S Tibet to at least 680 m asl (28°08′N/84°51′E; Figure 38 beween Manaslu and Shisha Pangma). The westerly adjacent Marsyandi outlet glacier, descending between

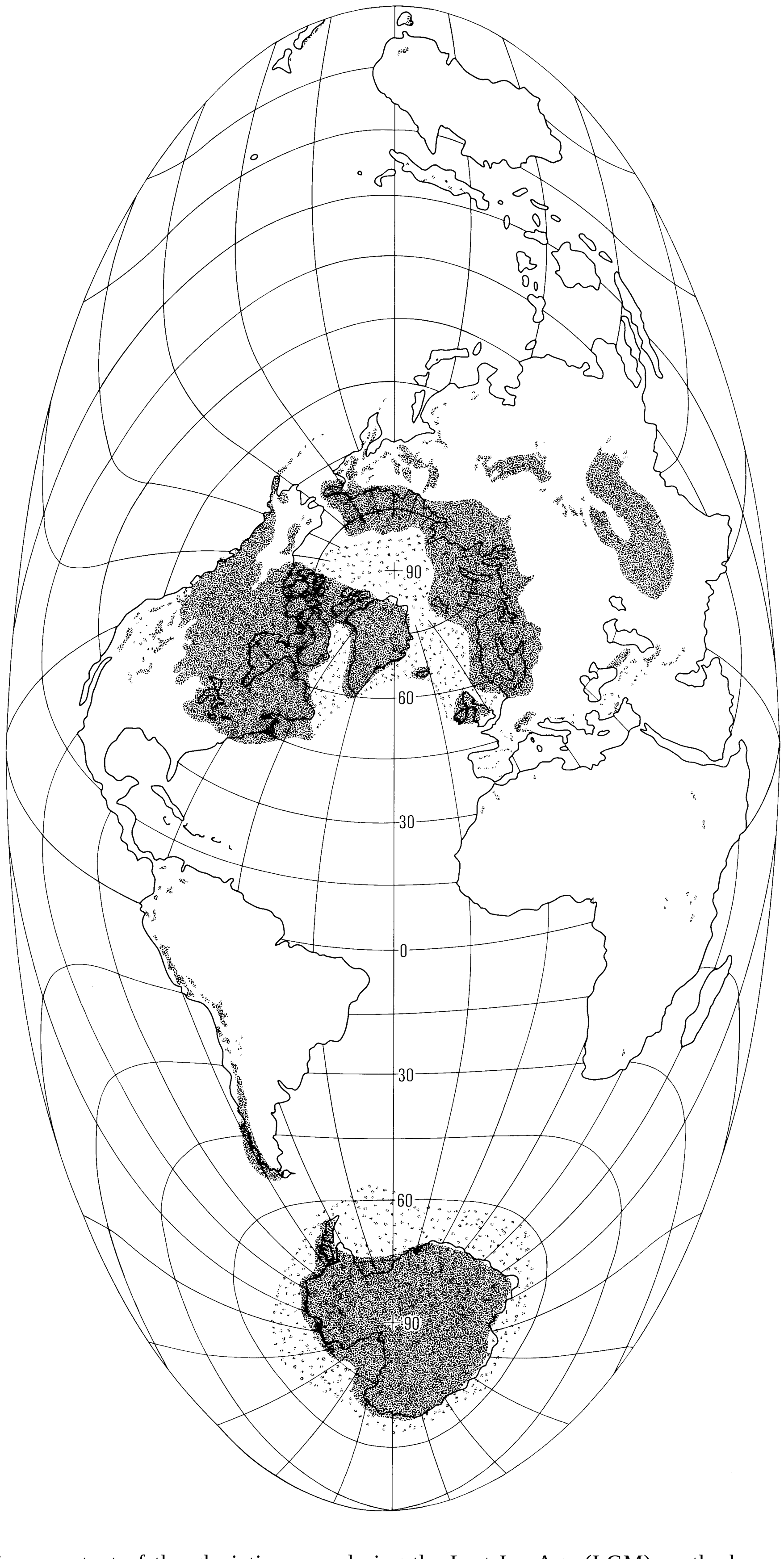


Figure 49. Maximum extent of the glaciation area during the Last Ice Age (LGM) on the base of a an equal area projection. Continental glaciers show a boldface, sea ice a lightface signature. The unique, subtropical position of the over 2.4 million km^2 extension of the Tibetan ice sheet, which is extremely favoured by radiation and moreover attained an average height of 5500–6500 m with its surface, becomes evident in comparison with the ice sheets near the poles. Basic map according to Broecker and Denton 1990, modified according to Kuhle 1982e–1996.

Manaslu- and Annapurna group (Figure 38) from S Tibet (Kyhle 1982), reached the position of the Dumre settlement at 460 m asl (28°07′20″N/ 84°26′E). This High Glacial ice margin position, evidenced by an *extensive ground- and end moraine landscape with erratic augen-gneiss- and granite boulders*, that can be discerned even from the air just by its *colour* from the adjacent *red-weathering* surfaces, which have developed during the *whole Pleistocene*, marks the *lowest glacier terminal* which the author was able to reconstruct in Asia. The area of Dolpo with the Kanjiroba (Figure 1, No. 18 on the left) also had a connection to the S Tibetan research areas of 1976/77 (Figure 1, No. 1), albeit on the W side. Here the ice accumulated in the Barbung Khola and its parallel valleys N of Dhaulagiri, forming the Bheri Khola *outlet glacier* in the continuing main valley. In the cross-profile at Tripurakot about 1900 m asl this glacier had a *thickness of at least 400 m*, as evidenced by *moraines with erratic blocks* (29°02′N/82°46′E; Figure 38 between Dhaulagiri and Nanda Devi). Thus, the *lowest* ice margin is located further down-valley in the Bheri gorge and could not be visited. As the most western, the Alaknanda *outlet glacier*, which was joined by the tributary streams of the Rishi Ganga- and Saraswati glaciers from the Nanda Devi- and Kamet *ice-stream networks* (Figure 38), will be mentioned here. This glacier has been worked on during 1993 (Figure 1, No. 16). Its *lowest* ice margin position about 1100 m asl (30°25′N/ 79°25′E) was reconstructed with the help of *moraines* down-valley of the Pipalkoti settlement (Figure 38 below, between Nanda Devi and Kamet).

5. New Data on the Chronological Classification of the Youngest Tibetan Inland Ice (cf. Figure 38; Table 4)

After having reported on *unpublished* observations from the NW-, SW- and NE edge of I2 and the S edge of I3 (see above chapters 1, 2, 3; Figure 38: Pamir; Nanga Parbat; left of Animachin; Kanchenzönga up to Kamet), *new data* from the S fringe of the *central inland ice complex* (I2) (Figure 38, left of Namcha Bawa) are to be introduced. Photos 53–55 in Kuhle 1991d (p. 185) show an 80 m-high exposure, which has been investigated (Figure 1, No. 9 left of Namche Bawar) and described in detail in 1989 (Kuhle 1991d, pp. 171/172). In the meantime there do exist age *determinations of conifer trunks* (Table 4), which were recovered from 2 m upwards of its base (see Kuhle 1991d, Photo 53). In all 8 samples, over a vertical distance of 30 m within the lower 32 m, i.e. from the lower half of the exposure, have been dated.

The sequence of data in Table 4 is listed from top to bottom of the exposure.

Varve-clays of 8 m thicknesses (see Kuhle 1991d, Photos 54, 55 p. 185) overlay the dated basal sands and evidence that in the here *ice-free* Tsangpo valley there existed an *ice-dammed lake* of *High* Glacial or *Late* Glacial Age on the orographic right side, 1 km down-valley from the Ganga bridge. This is the locality, which in Figure 38, W of Namcha Bawa between I2 and I3, is left free of ice. According to the *varve* counting this lake existed c. 1000 years. It might belong to a final phase of damming-up by the Nyang Qu *outlet glacier*, which bent into the Tsangpo valley 17.5 km down-valley from the N (see Kuhle 1991d, p. 230, Figure 43 No. 38, 39). As *lateral moraines* prove, the glacier flowed down the main valley, thus *damming up* the Tsangpo (Figure 38, ice-free area to the W, i.e. left of Namcha Bawa). The Nyang Qu glacier developed from the *ice-stream network* of the Nyainquêntanglha (Figure 1, No. 9, NW of Namcha Bawa), which belonged to the *central inland ice complex* I2 (Figure 38, E of Tangula Shan; see Kuhle 1991d: Figure 43, No. 30–39). Within the limitations of this paper it is not possible to go into details concerning the sequence of the strata and the dating. To sum up one may say that during the *Last Ice Age* that ice-stream flowed down out of an at present glacier-free valley, which was one of the *deepest* that was cut into the central Tibetan plateau. – Xu Daoming and Shen Yongping (1995) represent corresponding findings from other areas of Tibet. They *agree* with the author's interpretation of a *Tibetan inland ice sheet* (Figure 38). They date the ice to 130,000–30,000 and in reduced extension to 20,000–11,000 YBP. The *lake reconstructions*, represented by Wünnemann and Pachur (1997) and their age of c. 30,000–23,000 YBP evidence a phase of *humidity* from the northern edge of High Asia to Central Asia, which – as can be concluded from the *synchronism* – could be connected *genetically* with the Tibet ice. – The Pleistocene *loess production* as a condition for that enormous sedimentation ENE of Tibet can be explained *methodologically* in the most informal way by the inland ice concerned, because the uniformity of the *glacial genesis of loess* is to be preserved only in that way.

5.1. *Third conclusion, derived from the results of chapters 4 and 5*

The investigations on the glaciation history of High Asia during the last 20 years have led to the result of an *ice sheet*, which was *much more extended* than has been assumed for this area, and even to the reconstruction of a *subtropical inland ice on the Tibetan plateau*. In this context new observations of the fieldwork are to be introduced with concern to the N-Tibetan ice cover and the *lowest outlet glacier ends* on the southern margin of the plateau, which flowed down to 460 m asl. In addition to these findings during the years 1994/95 age determinations of the 1989-sampling are represented, according to which the *last total glaciation of the plateau* can be classi-

Table 4. Samples (tree trunks) for radiocarbon dating (C14) (29°18′N/94°21′E; Figure 38) W (left-hand) of Namcha Bawa and thus detailed description in the area under investigation by the 1989 expedition to Central Tibet (Figure 1, No. 9; cf. Table 1). Locality: lower Tsangpo valley, up-valley of the Nyang Qu confluence, at a distance of 1 km from the Gangga Bridge on the orographic right-hand side of the Tsangpo river (Kuhle 1991d: 229/330, Figure 43, No. 38, p. 185 Photo 53). Laboratory analysis: M.A. Geyh, Lower Saxony State Office for Soil Research, Hanover, Germany; samples taken by M. Kuhle

sample nr.	sample material	taking of the sample	sample depth	sample location	sample environment	$\sigma^{13}C$ [‰]	conv. ^{14}C-age (YB 1950)	stadium (stage)
26.9.89/13 L-Hv 17657	tree trunk	exposure in limnic sands	48 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3090 m asl	in ice-dammed lake-sediments 42 m below root-horizont, highest level with wood	-25,6	24040+/-450	last High Glacial Maximum; LGM; Würm:0
26.9.89/14 L-Hv 17659	tree trunk	exposure in limnic sands	50 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3088 m asl	in ice-dammed lake-sediments 44 m below root-horizont, second highest level with wood	-24,3	495+/-85	?
26.9.89/9 L-Hv 17658	tree trunk	exposure in limnic sands	56 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3082 m asl	in ice-dammed lake-sediments 50 m below root-horizont, third highest level with wood	-23,8	1575 +/-75	?
26.9.89/8 L-Hv 17656	tree trunk	exposure in limnic silt	63 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3075 m asl	in ice-dammed lake-sediments 57 m below root-horizont, 4th highest wood-level	-25,9	16350 +/- 580	Late Glacial Ghasa-stage: I
26.9.89/7 L-Hv 17655 cf./6/4	tree trunk	exposure in limnic sands	76 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3062 m asl	in ice-dammed lake-sediments 70 m below root-horizont, 5th highest wood-level	-26,1	48580 +/- 4660-2930	Last High Glacial Maximum; Würm: 0
26.9.89/6 L-Hv 17652 cf./7/4	tree trunk	exposure in limnic sands	76 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3062 m asl	in ice-dammed lake-sediments 70 m below root-horizont, 5th highest wood-level	-26,2	45700 +/- 3050-2200	Last High Glacial; Würm: 0
26.9.89/4 L-Hv 17653 cf./7/6	tree trunk	exposure in limnic sands	76 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3062 m asl	in ice-dammed lake-sediments 70 m below root-horizont, 5th highest wood-level	-27,2	43130 +/- 2500-1750	Last High Glacial Maximum; Würm: 0
26.9.89/1 L-Hv 17654	tree trunk	exposure in limnic sands	78 m below surface	29°18'N/94°21'E lower Tsangpo Valley; 3060 m asl	in ice-dammed lake-sediments 72 m below root-horizont, 6th highest wood-level	-24,3	9820 +/-350	Late Glacial Sirkung-stage: IV=older than 9820

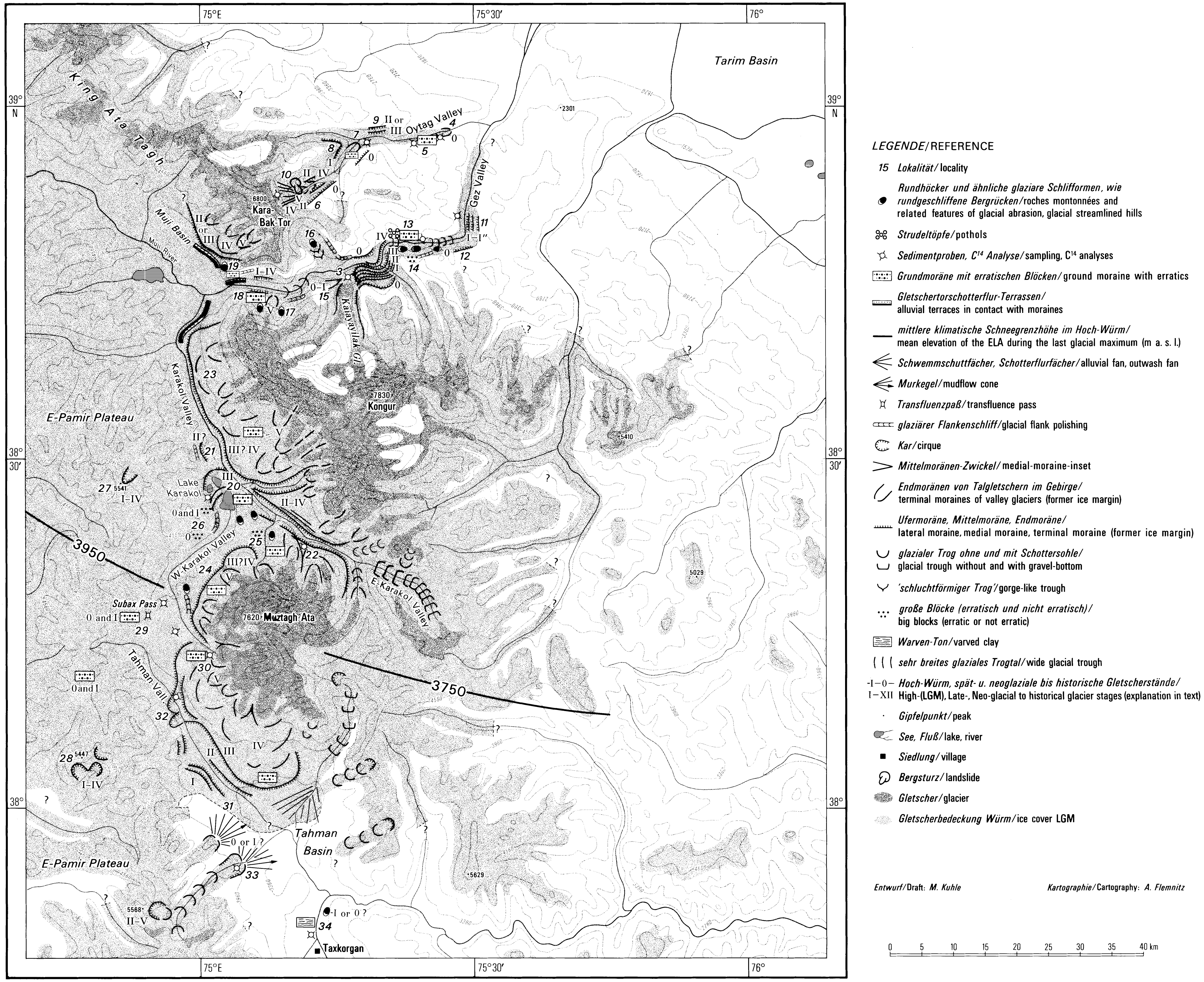


Figure 14. Map: Glacial-geomorphic Indicators of the Ice Age Glaciation of E-Pamir.

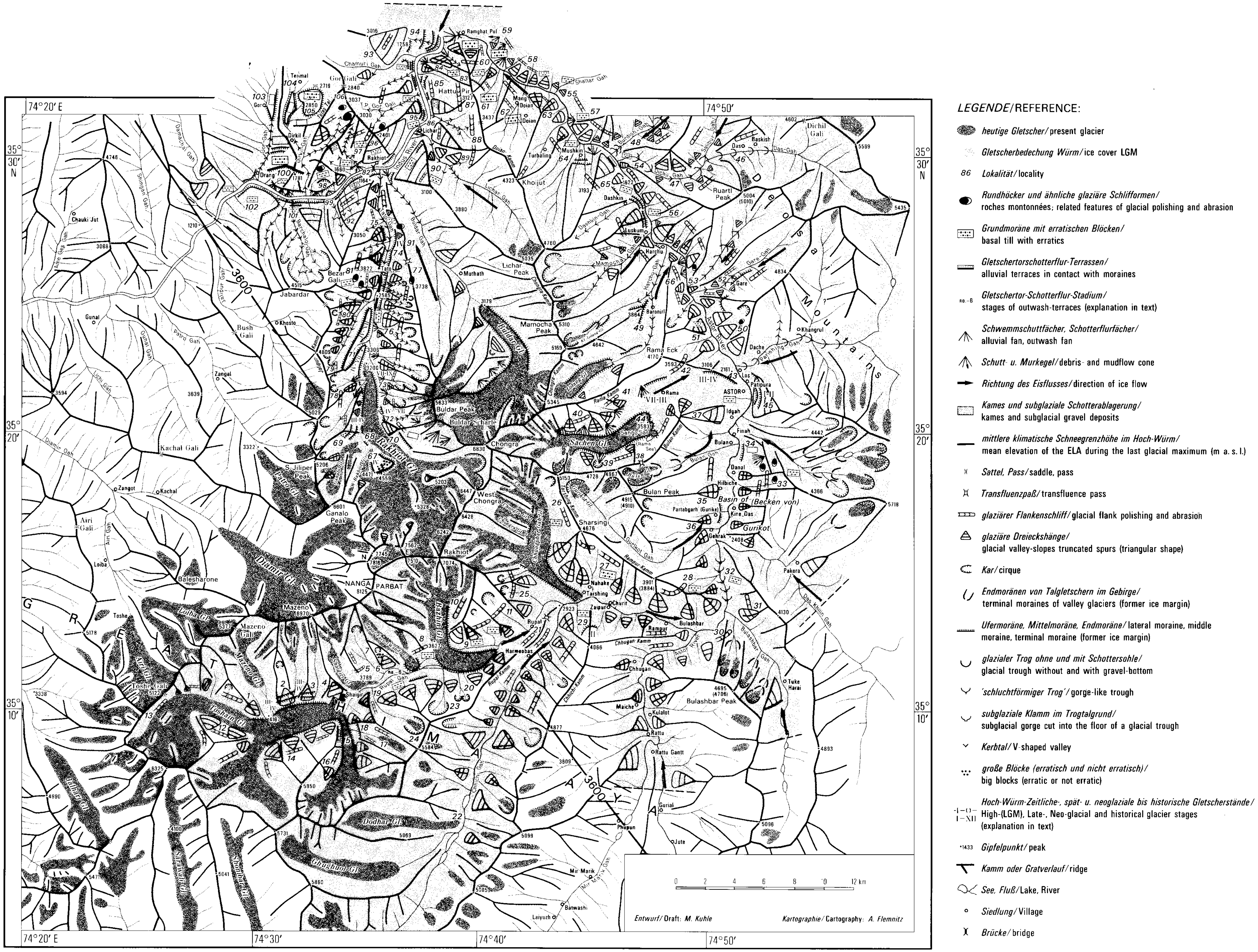
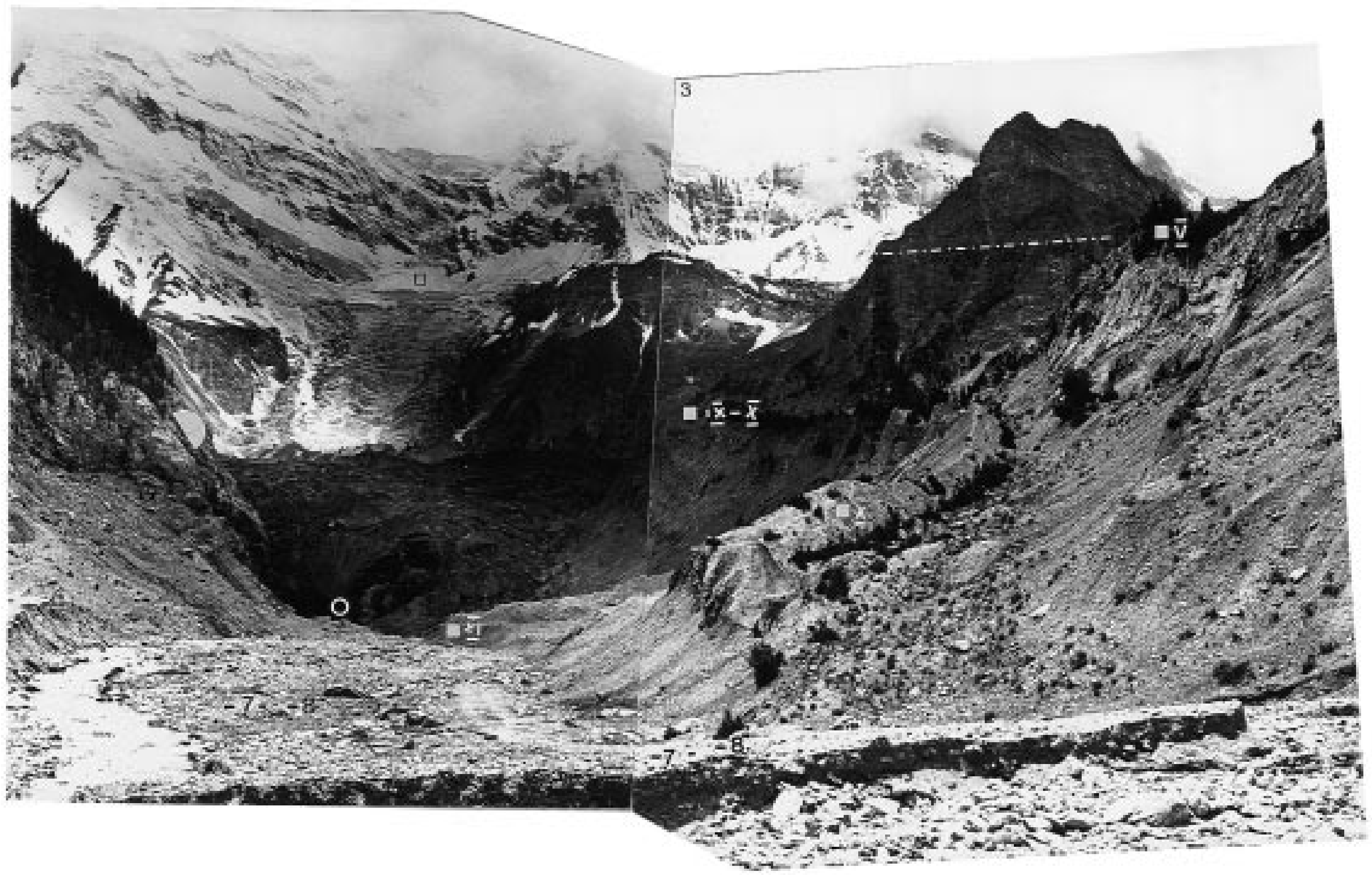


Figure 28. Map: Glaciogeomorphological indicators of the Maximum Ice Age glacier cover of the Nanga Parbat massif and the reconstructed ice-stream network.

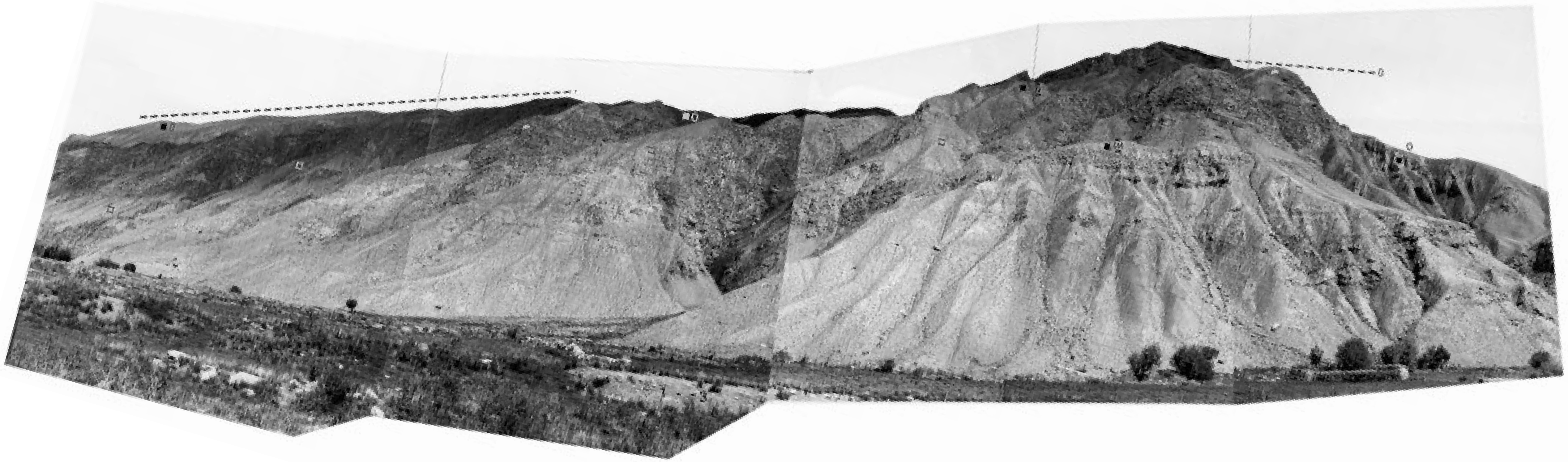


▲ **Photo 1.** From c. 2950 m asl looking towards the W into the two uppermost valley heads of the right-hand source branch of the Oytag valley (38°52′08″N/75°07′09″E; Figure 14 left-hand of No. 6). (3) is the c. 6800 (or 6634) m-high Kara-Bak-Tor, the highest peak at the southern end of the King Ata Tagh (Kungai Kalajili). Both branches of the 'Oytag glacier', joining downwards, are covered by surface moraine (□). ■ X–XII mark the lateral moraines, built up c. 180–0 years before 1950 (cf. Table 1) (cf.: On the younger glacier history of the Tienshan and NW-Karakorum, Meiners 1996). The central rock summit (middle of the panorama, right-hand of No. 3) is a classic glacially shaped horn ('Torsäule') which was formed through polishing to the very top. (——) marks a still visible High- to Late Glacial ice scour limit, i.e. a pertinent glacier level. The mountain flanks, which have been glacially polished and abraded at prehistoric times ◤ ◠ ◥, have already crumbled away and eroded extensively. Photo: M. Kuhle, 10.06.92.

◀ **Photo 2.** From 2680 m asl facing SW seen towards the tongue end of the 'Oytag glacier' at 2750 m asl (○) (38°52′N/75°08′30″E; Figure 14 left-hand of No. 6). Flank- and wall-glaciation of the c. 6800 (or 6634) m-high Kara-Bak-Tor is visible in the catchment area. Below the séracs and ice balconies, the glacier, regenerated beneath a firn- and avalanche-cauldron (□), begins with an ice fall. The orographic snow-line (ELA) runs at c. 4775 m asl at the level of the firn- and avalanche cauldron. (■) marks the Historical (IX–XI) to Neoglacial (V) lateral and end moraines; (–7 – –8) a recent gravel field (sander) cf. Table 1); (◥) indicates historical glacigenic flank polishing (cf.: On the younger history of glaciation of the Tienshan and NW Karakorum, Meiners 1996). On the right-hand side of the middleground there is the glacially-shaped horn ('Torsäule'), also visible in Photo 1 (left-hand above ■ V), with a High- to Late Glacial glacier level, confirmed by a polishing line (——). Photo: M. Kuhle, 10.06.1992.

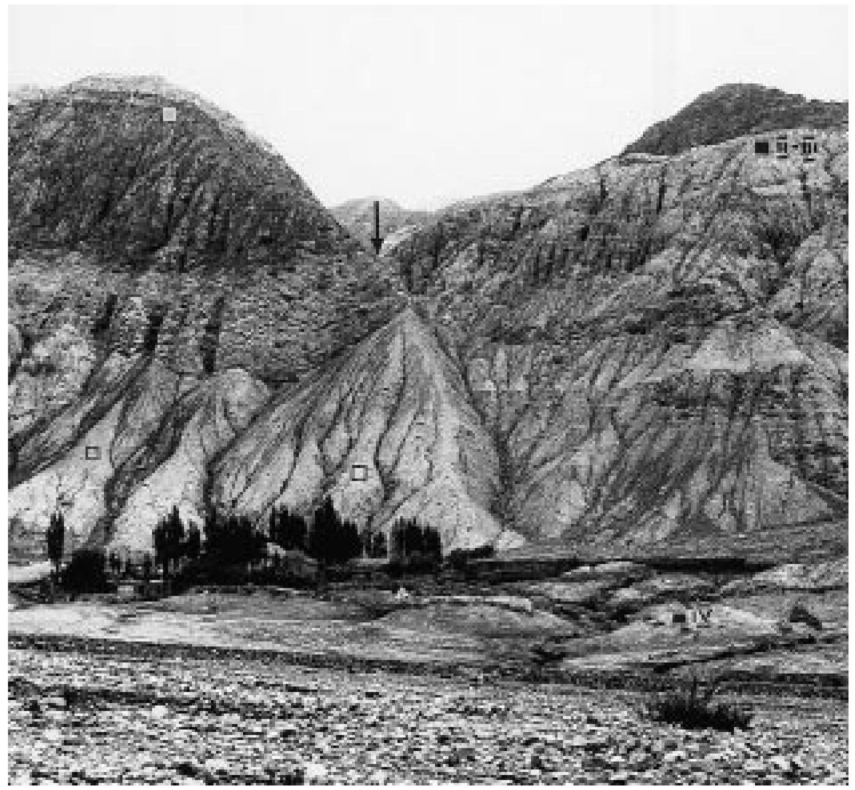
▲ **Photo 3.** Taken from 2400 m asl in the direction of the Oytag glacier to the c. 6800 (or 6634) m-high Kara-Bak-Tor (No. 3) (Figure 14 above No. 6; 38°53′30″N/75°12′30″E). The glaciated valley head (see Photos 1, 2 and 4, 5) lies in a SW direction. (■) marks the Late Glacial lateral moraine levels of Stadia II, III and IV; (——) the High Glacial ice level. (□) signifies remnants of ground moraine on the orographic left-hand valley flank. Both the ground moraines and lateral moraine- and kame terraces, running along the slopes, have been incised by ravines (▼) since the deglaciation. Their material has been deposited in the form of outwash debris slopes (▽) at the slope foot. The valley floor is formed by Holocene alluvial fans (☖); The lower limit of the forest is xerophylous and runs at 2500 m asl on glacio-fluvial gravel floors. Photo: M. Kuhle.

▼ **Photo 4.** View from c. 2860 m asl from one of the youngest historical lateral moraines (■ Stadium X–XII, on the true left of the photo) of the Oytag glacier, i.e. seen from the valley head downwards in a NE direction (Figure 14 on the left below of No. 10; 38°52′09″N/75°07′09″E) through the trough profile of the valley, which has been polished-out by the High Glacial (LGM) glacier. (■ 0) marks the High Glacial (LGM) moraines on the valley flank, 500–700 m above the valley floor; (——0) the pertinent glacier level; (II, ■ III and ■ IV) mark the lateral moraines of the Late Glacial glacier positions (cf. Table 1), partly fitted into each other; (□) indicates the positions of ground moraines, which are preserved on the trough flanks. They can be partly classified as belonging to Late Glacial glacier positions (□ I–II). At a smaller distance from the point where the photo was taken and the present glacier terminal, there are lateral- and end moraines of the Neoglacial to Historic glacier positions (■ V–X) (cf.: On the younger glacier history of the Tienshan and NW-Karakorum, Meiners 1996). (◗◓◖) marks only badly preserved glacial rock polishings on bedrock metamorphites (phyllites), which are of low resistance and splinter easily; (▷) indicates the deposition of a Post Glacial rock fall (Figure 14, No. 10), which is explained as the crumbling away of the glacigenically over-steepened trough valley flank since the deglaciation. The upper forest limit runs at 3500 m asl; it is thermal. The lower xerophylous forest limit runs at 2500 m asl. Photo: M. Kuhle, 10.06.1992.



▲ **Photo 5.** From 2400 m asl looking into the orographic right-hand flank of the Oytag valley cross-profile below the present Oytag glacier end (that is the orographic right-hand source branch of the larger down-valley Oytag main valley, which joins the left-hand source branch, called the Wuyitag valley) (Figure 14 between No. 6 and 8; 38°53′30″N/75°12′31″E). On the rocks of the valley flanks, which are only in some places preserved glacially smoothed, ( ) are to be observed remnants of ground moraines (□). On this valley slope, the bank formations, i.e. the remnants of kame- and lateral moraine terraces (■) are preserved from the middle Late Glacial (Stadium III and II, cf. Table 1) to the High Glacial (LGM) (■ 0) (cf. from other points of view Photo 4 ■ 0 down-valley and Photo 6 ■ III, II, 0 in the left quarter of the picture seen up-valley). The LGM moraines (■ 0 left-hand) lie on the valley shoulder up to high altitudes, i.e. nearly up to the culmination of the intermediate valley ridge (Figure 14 between No. 6 and 5). They reach heights of 500–700 m above the valley floor. This proves at the same time the minimum thickness of the Ice Age glacier (500–700 m plus the thickness of the Post Glacial valley floor infilling); (——) marks the LGM ice level. The present valley floor, which is settled today, has been filled with young-Late Glacial to Historic glacio-fluvial gravels (◇ 1–3), which overlie the High- to Late Glacial ground moraine. Photo: M. Kuhle.

► **Photo 7.** View from 2400 m asl downwards the orographic right-hand source branch of the Oytag valley from the glacier tongue basin of Stadium IV in a NE direction (Figure 14 below No. 8; 38°53′30″N/75°12′31″E). (■ IV) marks the end moraines at 2130 m asl (cf. Photo 6); (□) the ground moraines on the valley flanks up to the High Glacial (LGM) moraines (■ 0). In the intermediate elevations occur Late Glacial glacigenic bank formations (remnants of lateral moraines and kame-terraces) (I, II–III) in which gravels and sands are deposited (●). They are from a sander which has been sedimented in the lateral valley of the glacier (lateral sander). (——) indicates the maximum prehistoric glacier level (LGM). Photo: M. Kuhle.



▲ **Photo 8.** From 2050 m asl seen from the floor of the Oytag main valley (Figure 14 below No. 9; 38°57 ′30″N/75°19′30″E) towards the N into the orographic left-hand valley flank. Moraine material (□), partly moved, is exposed there below ground- and lateral moraine terraces (■) of Stadia II–III. In the area of the isolated settlement a hilly end moraine (■) of Stadium IV is situated (cf. Photo 6). Photo: M. Kuhle.

▲ **Photo 9.** Seen from 2050 m asl (Figure 14 below No. 9; 38°57 ′30″N/75°19′30″E) down the main Oytag valley towards the E. The valley shows a classical glacigenic trough valley cross-profile – very close to a U-shaped valley. (□) marks ground moraines, which reach up to the High Glacial (LGM) glacier level (0——). This point of view is 14 km away from the lowest Ice Age glacier terminal (Photos 11 and 12). Photo: M. Kuhle.

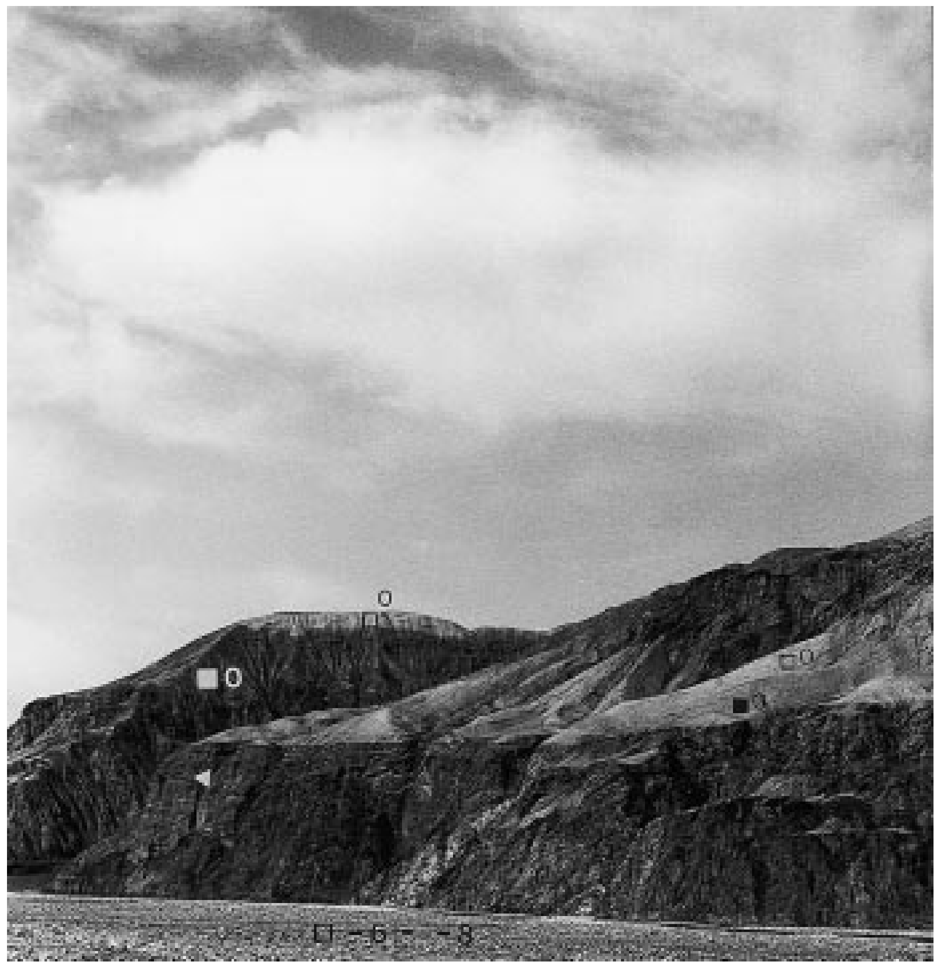
◀ **Photo 10.** The ground moraine, deposited at 1920 m asl (□) on the floor of the Oytag valley (Figure 14, No. 5; 38°57′N/75°23′E), is incised 10–12 m deep and exposed by the river in the talweg. The ground mass (fine material ground mass, see Figure 7) contains large erratic blocks of quartzite and gneiss (↖). The portions of quartzite grains of the ground mass were too insignificant for a morphometric analyse. The picture was taken up-valley towards the NW in the direction of the orographic left-hand valley flank showing lateral moraine remnants (■) of the Late Glacial Stadia I–II. 5–6 km away from its lower terminal, the High Glacial (LGM) glacier in the background had still a thickness of at least 250 m; (——) indicates its ice level. The hazy air contains particles of loess. Photo: M. Kuhle.

◄ **Photo 6.** Looking from 2150 m asl (Figure 14, No. 7; 38°56′30″N/75°17′E) across the confluence of the upper Oytag- and Wuyitak valley to the Oytag main valley, and this valley down in an ENE direction. The two source branches show trough-valley-cross- profiles, which are more or less well formed. Their partly preserved glacial flank smoothings (◤◓) are extensively covered by attached ground moraines (□). Such ground moraine (□ on the valley floor) is also exposed on the valley floor in metre-thicknesses. Starting from the valley flanks of the source branches, the Late Glacial lateral moraine ledges of the Stadia II and III can be followed far down the main valley (■). They contain glacio-fluvial gravels and glacio-limnic sands, which have been deposited along the glacier margins in the glacigenic lateral valleys (small lateral valleys, lateral depressions) in the form of sanders (outwash) sediments (●). Moraines of the orographic right-hand source valley (upper Oytak valley) of Stadium I and the LGM (0) have been observed in the highest positions of the spur, separating the two source valleys (■ I and 0 left half of the panorama above the houses). Stadium IV had its glacier tongue end immediately in the position of the photograph, as proved by the end moraine ramps and -hills (■ IV left half of the panorama). The end moraines of the Wuyitak glacier (orographic left-hand source branch of the Oytag valley), being of the same age, lie 2 km further down the main valley up to the isolated settlement and c. 100 m lower (2000 m asl) (IV right-hand third of the panorama) (cf. Photo 8). (——) marks the estimated glacier level during the LGM. Photo: M. Kuhle.

◄ **Photo 11.** Looking up-valley from the end moraine (of the dumped end moraine type) of the High Glacial (LGM) Oytag glacier at 1860 m asl towards the W (Figure 14, No. 4; 38°58′N/75°26′30″E). In this lower section the valley to all appearances has been cut into Tertiary conglomerates, partly lying flat, but also partly slightly folded, which fall away to the Tarim basin in an ENE direction (○). The end moraine, which is very rich in fine material (see Figure 2; this sample could not be morphometrically analysed because of its lack of quartzite grains) contains large to very large polymict and partly erratic blocks of quartzite and gneiss (◄) (see also Photo 12). The dumped end moraine shows a characteristic hummocky surface (■) and is exposed in a thickness of at least 20–25 m down to the river (■ 0). Photo: M. Kuhle.

◀ **Photo 12.** View from the same locality as Photo 11, but looking the lower Oytag valley downwards to the E. The viewpoint is situated on the High Glacial (LGM) dumped end moraine (■ 0). (▼▼) indicate large polymict boulders of quartzite and gneiss; (■) shows a moraine block the size of a hut. The moraine has been cut to a depth of decametres by the Oytag river and exposed. The valley flanks consist of Tertiary conglomerates (○), which, bound to the clefts, are crumbling away. Down-valley of this lowest ice margin position (end moraine), large alluvial debris- and mudflow fans (□) are adjusted to the Oytag valley talweg, which in parts are slightly dissected. They stem from tributary valleys on both sides. In the background (●) towards the confluence with the Gez valley (where the settlement of Oytag is situated) are preserved more than 100 m-high glaciofluvial gravel terraces (sander) probably coming from the penultimate Ice Age (Riß-Glacial -I). On their surfaces are metre- to decametre thick layers of outwash loess (↓). In the left quarter of the panorama there is an irrigation channel. Photo: M. Kuhle.

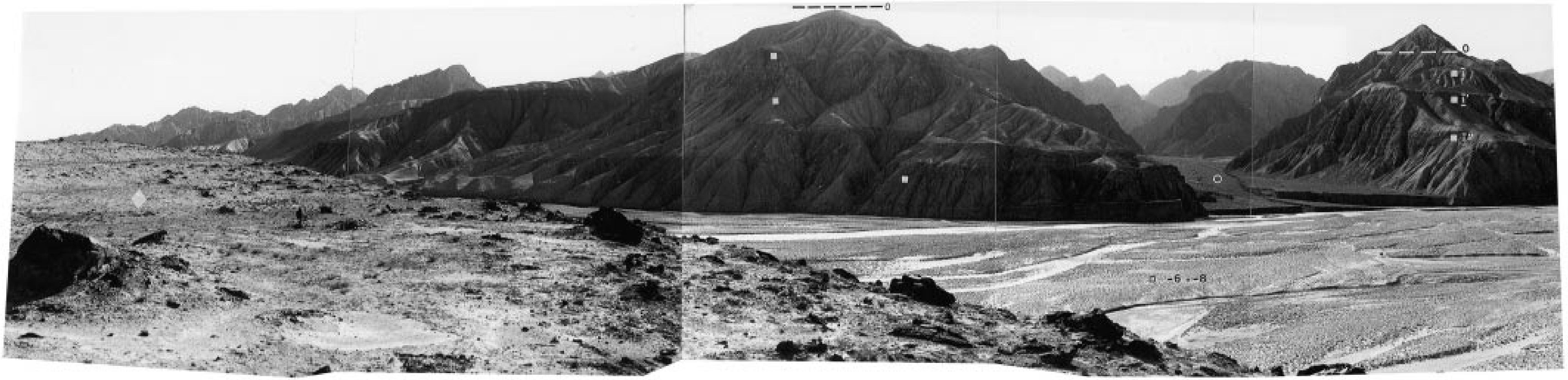
◀ **Photo 13.** View from 1750 m asl into the orographic left-hand flank of the Gez valley towards the E. The location is situated in the confluence area of the Oytag valley opposite (east of) the settlement of Oytag (Figure 14 right-hand of No. 4; 38°58′N/ 75°32′E). In the middle ground there is the gravel floor (▽) and the bed of the Gez river; behind them (■ 0) a glaciofluvial gravel body, which is coarsely bedded (sorted) and only roughly washed. Thus, it shows the features of high energy flow, characteristic of outwashed moraines and glacier mouth gravel-fields which are immediately adjacent to Ice Age glacier terminals. The characteristics of loose sediments near the glacier are completed by the large erratic blocks from the Muztagh Ata or Kongur (massive crystalline rocks such as granite), which are incorporated (e.g. ↓). Therefore the LGM ice margin in the Gez valley is assumed to have been 1–3 km up-valley at about 1800 m asl (cf. Figure 14). (□ 0) marks metre-thick post High Glacial to Holocene layers of outwash loess, which must be considered to be typical interglacial depositions of arid High Asia. Photo: M. Kuhle.



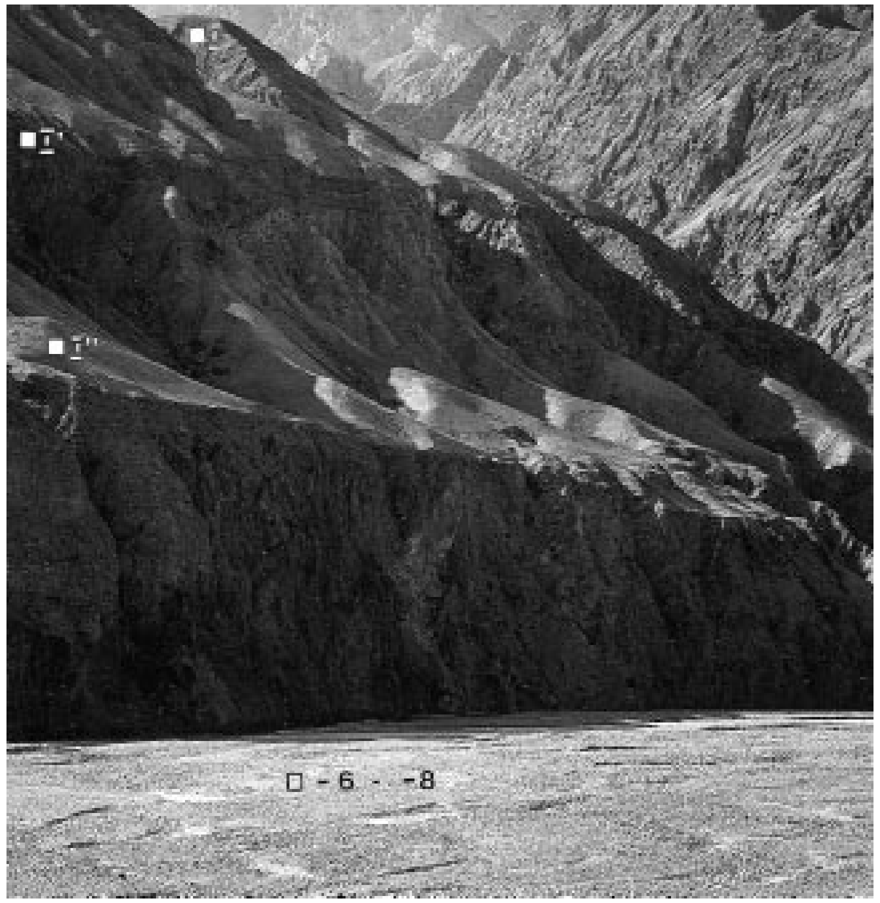
◀ **Photo 14.** Seen from 1800 m asl towards the NE into the orographic right-hand flank of the Gez valley (Figure 14, above No. 11; 38°55′N/ 75°30′E). Immediately adjacent to the High Glacial (LGM) terminal of the Gez outlet glacier there lie ground moraine-like glacigenic diamictites (■ 0) on the stepped valley slope. In parts these are superimposed by outwash loess and alluvial sand (□ 0), which has been developed glacilimnically in the bank area of the glacier. Partly the diamictically, i.e. chaotically sedimented material, which is interspersed with large erratic blocks (◀) passes into – or is dovetailed with – stratified to bedded sander material, which has been roughly washed by fast flowing meltwater. Thus, judging from the relation of the position of form and sediment, we are here in an area of the lowest ice margin position of the 'sander root' type (transition from ground- and end moraine to sander). (□ –6 – –8) indicate the present high water bed of the Gez river and thus the sander of the recent Kongur glaciers. Photo: M. Kuhle.

◀ **Photo 15.** View from 1820 m asl towards the ENE into the orographic right-hand flank of the lower Gez valley, c. 20 km above its exit into the mountain foreland of the Tarim basin (Figure 14 above No. 11; 38°54′N/75°29′50″E). The preserved moraine remnants (■ 0), which might have been superficially flushed down the slope and thus fused with alluvial loess in their upper decimetres, provide evidence of an ice thickness of the Gez outlet glacier of still more than 100 m in this valley cross- profile. Photo: M. Kuhle.

▼ **Photo 17.** Seen from c. 2000 m asl towards the NE up to the SSE from an orographic left-hand mudflow fan (◆), which has been heaped up kame-like against the valley glacier or which is of a Post Glacial age (38°51′N/75°29′E). With regard to its grain size composition the debris flow- or mudflow fan contains typical moraine material; at the same time erratic blocks of granite and gneiss (cf. Figure 8) can be observed and in addition local schist material. The moraine material (■) of the orographic right-hand flank of the Gez valley permits three Late Glacial moraine terraces (I, I′, I″; cf. Table 1; Figure 14, No. 11) to be distinguished. (——0) indicates the highest, i.e. High Glacial (LGM) level of the Gez outlet glacier, which was reconstructed by means of moraine material (cf. in detail Photos 18, 19). Tributary valleys which are very rich in loose material (○) are adjusted to the glaciofluvial gravel floor of the Gez main valley (□ –6 – –8). This alluvial debris has been removed and washed away from the Ice Age moraine- and sander bodies. Photo: M. Kuhle.



▲ **Photo 16.** Looking from 1850 m asl in S direction upward the Gez valley (Figure 14 left-hand above No. 11; 38°53′N/75°29′E). No. 1 marks the 7830 m high Kongur massif; No. 4 up to 5600 m high satellites and marginal chains of the massif, situated in front of it to the NE, which at present are still slightly glaciated. Their Ice Age valley glaciers, however, did not reach any more the Gez outlet glacier. (——0) marks the High-Glacial (LGM) ice level of the Gez outlet glacier (compare the background with Photos 17–21), which has been reconstructed with the help of preserved remnants of ground- and lateral moraines. In places remnants of glaciolimnic sands (□) were observed (cf. Photo 14). They can be considered as being typical of the bank areas of very long outlet glaciers, which flow down far below the ELA. (–6 – –8) are the gravel fields (sander) of the recent glacier meltwaters of the Kongur- and Muztagh Ata massifs, deposited by the present Gez river which has the form of a braided river. Photo: M. Kuhle.

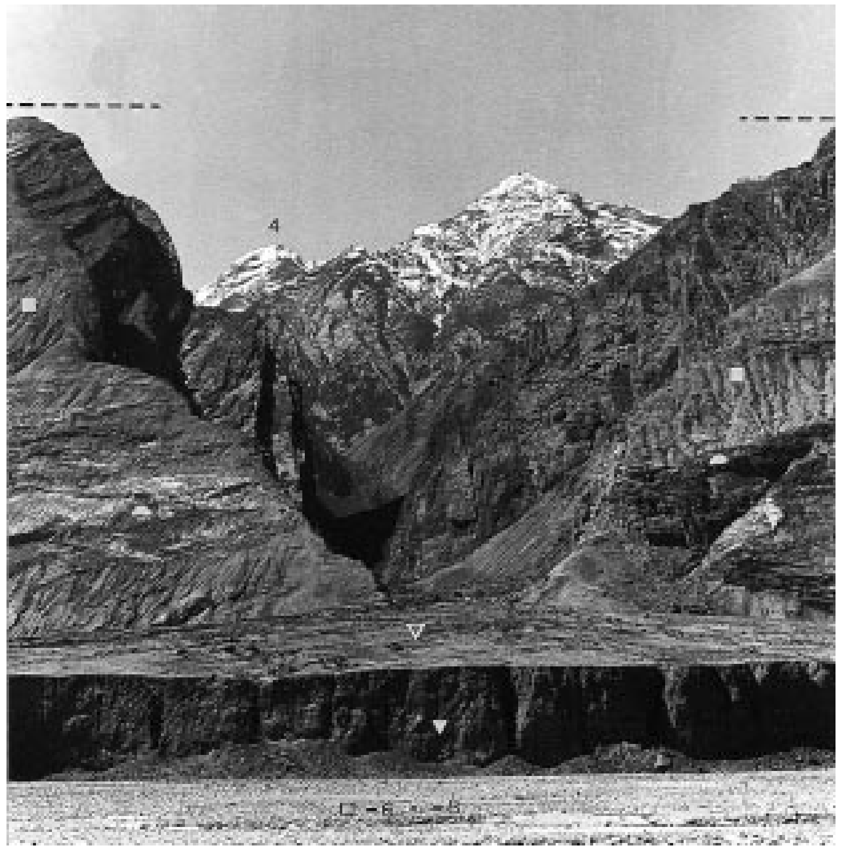


◄ **Photo 18.** Orographic right-hand flank of the Gez valley (Figure 14, No. 11; 38°50′N/ 75°29′E; 2000 m asl). The three Late Glacial lateral moraine terraces (I, I′, I″) are visible in the exposure. The large blocks, which can be seen clearly in this place, are polymict and 'swim' in isolation from each other in a fine (clayey-silty) ground mass, which is also interspersed with sand lenses and gravel nests. The material has the high density of ground- and lateral moraines. As a result of its concrete-like resistance steep-standing exposure-walls have been formed. The particular floors of the exposure have been glaciofluvially undercut since deglaciation and consequently present a steep profile. Today the moraine (■ I″) is undercut by the glaciofluvial gravel-field of the recent glacier (□ –6 – –8). Photo: M. Kuhle.

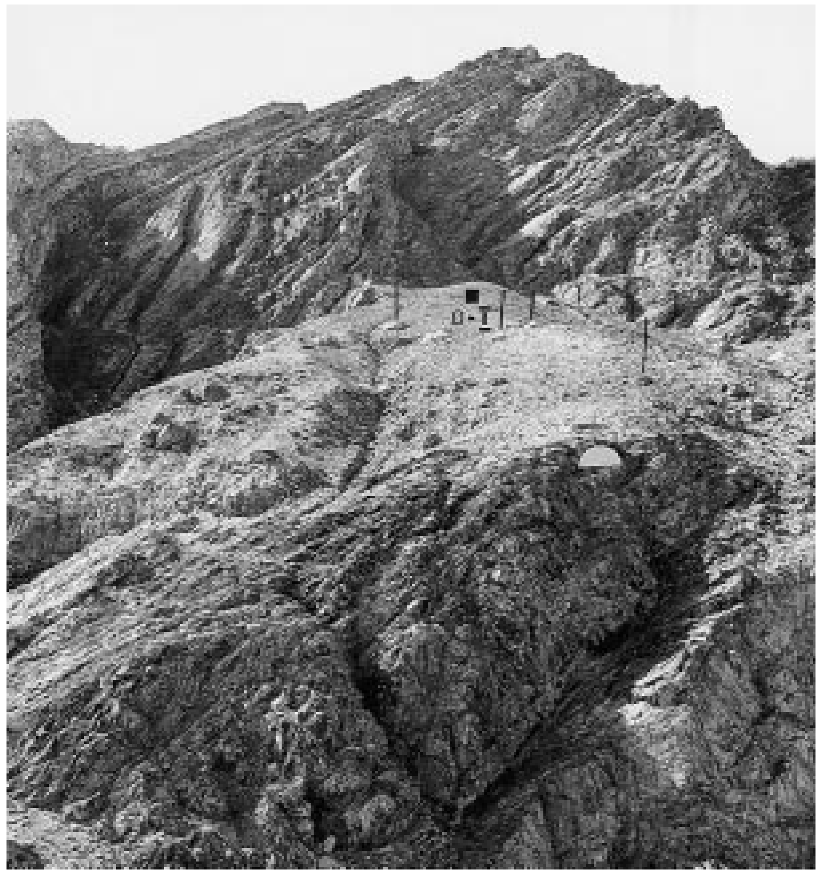
► **Photo 19.** Approximately the same locality as Photo 18 (somewhat more down-valley) seen towards the ESE. The 40 m (I″), 80 m (I′) and 140 m (I) high lateral moraine terraces jut like steps into the recent valley floor (□ –6 – –8). They provide evidence of a reduction of the valley-glacier-tongue along with the deglaciation during the Late-Glacial, which made the tongue more and more narrow and poor in thickness. (—— 0) marks the High Glacial (LGM) level of the Gez outlet glacier which is proved by moraine remnants (■) almost 500 m higher than the valley floor. Photo: M. Kuhle.

▼ **Photo 20.** View from c. 2000 m asl looking up the Gez valley towards the S in the direction of the N-bend of the Gez valley (Figure 14, No. 12; 38°49′N/ 75°28′30″E). On the orographic right- hand side (■ on the left) the Late Glacial moraine terraces (I, I′, II″) are visible (cf. Photos 17–19). (■ 0) indicates the highest orographic right-hand moraines of the Gez outlet glacier (see Photo 21). They confirm the Ice Age thickness of c. 500 m, measured from the gravel floor (□ –6 – –8) up to the pertinent glacier level. The rest of the (■) indicates ground- and lateral moraine remnants on the valley flanks further down. (△) marks the cones and fans of alluvial debris and mudflow from moraine material which has been moved downwards. Photo: M. Kuhle.

▲ **Photo 21.** Moraine material (■ 0) lies up to a height of somewhat above 2500 m asl in the orographic right-hand flank of the Gez valley (Figure 14, No. 12; 38°48′N/75°28′E). It has been superficially cut and dissected by Post Glacial rill-rinsing. Its position (cf. Photos 16 and 20 ■ i.e. ■ 0, the most highly situated in the background) proves an Ice Age minimum thickness of the ice of 500 m. (——) marks the surface level of the outlet glacier. Photo: M. Kuhle.

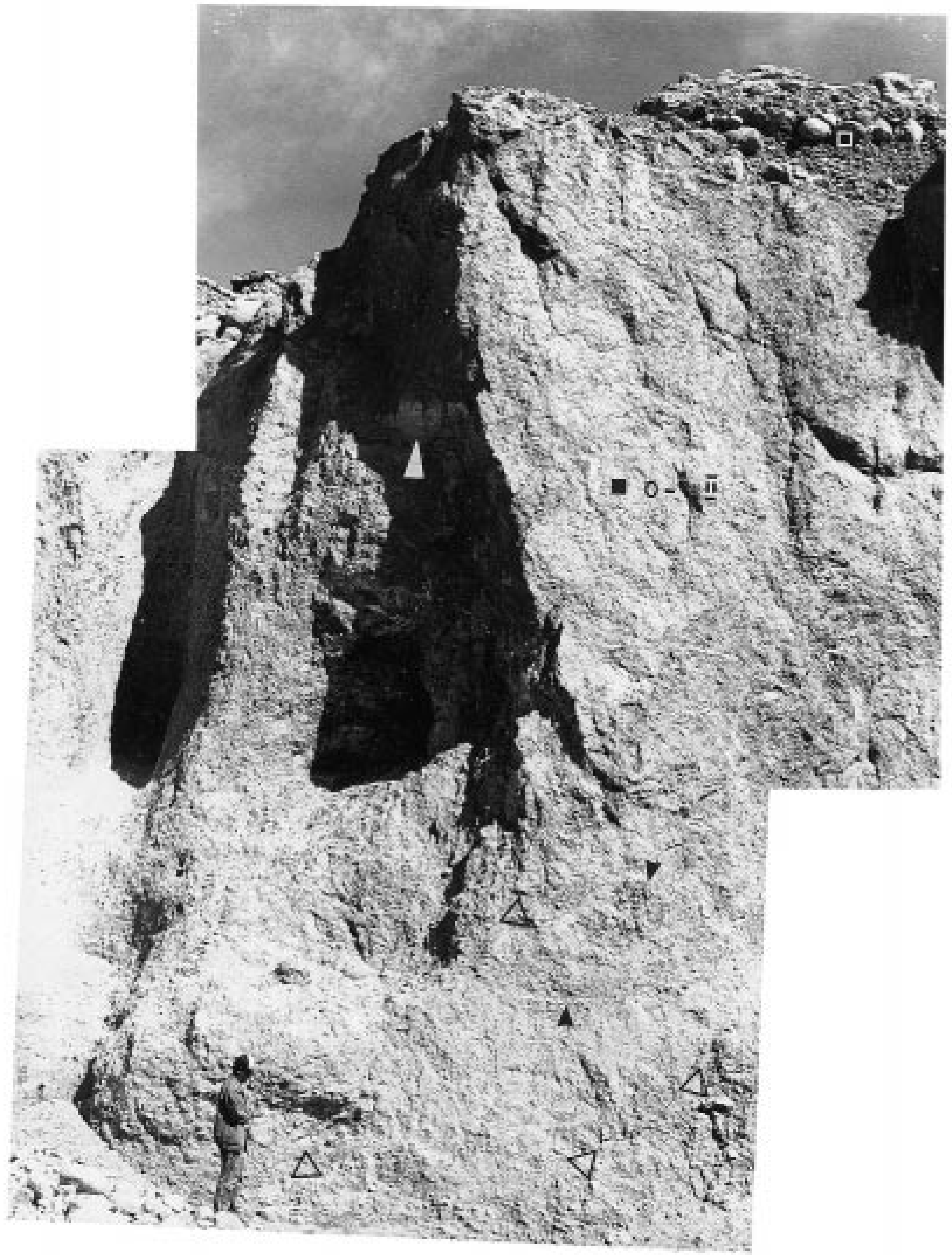


◄ **Photo 22.** From c. 2060 m asl from the valley floor of the Gez valley (with the recent glaciofluvial gravel field (sander) □ –6 – –8) looking into an orographic right-hand tributary valley facing S (Figure 14 left-hand of No. 12; 38°47′30″N/ 75°27′20″E). It is a gorge, the Ice Age glacier of which did not reach the Gez valley and its outlet glacier. The reason for this is the medium height of the glacier's catchment area of the connected max. 5600 m high massif (No. 4; cf. Photo 16), which was not sufficient. The Gez outlet glacier, the level of which is marked by (——) has polished back this gorge-exit. This can be recognized by the smoothed rock slopes (⏶). (■) signifies remnants of glacial ground moraine; (▽) a debris- and mudflow fan, which has been heaped up on the floor of the Gez valley after deglaciation. It is a few thousand years old and undercut by the present Gez river (▼). Photo: M. Kuhle.



▲ **Photo 23.** Looking from 2190 m asl into the orographic right-hand valley flank of the Gez valley towards the S (Figure 14, No. 14; 38°48′N/75°22′E). Moraine depositions (■) of the High Glacial (0) to Late Glacial (I) and erratic blocks (||) lie on a glacially round-polished rock (⏶) 100–250 m above the talweg. The blocks are rounded or rounded at the edges (glacigenically facetted) and therefore not to be mistaken for the authochtonous blocks of the weathered detritus, crumbled away in situ. Photo: M. Kuhle.

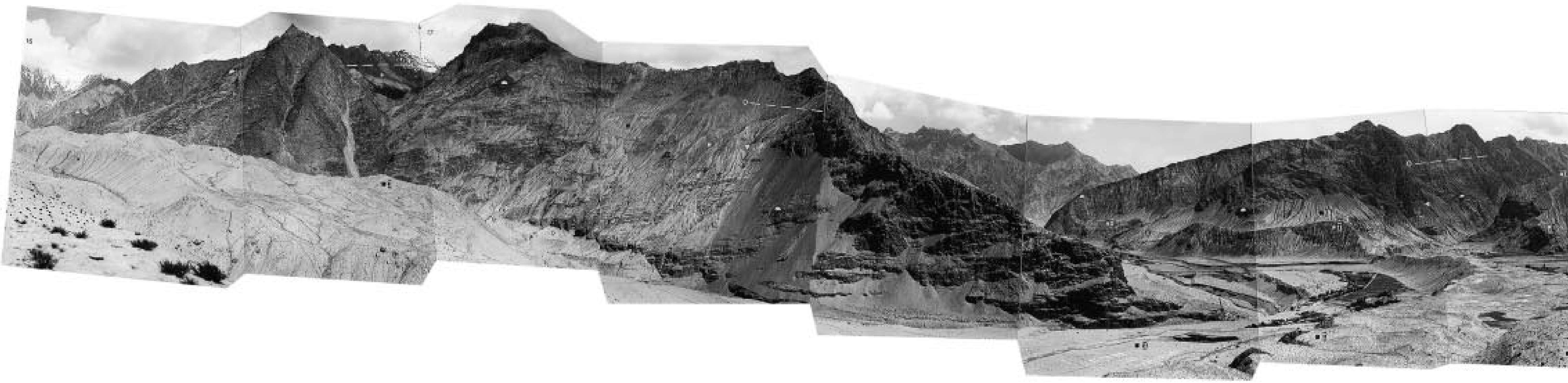
◄ **Photo 24.** From approximately the same location as Photo 23 seen down-valley towards the E. In the background three roches moutonnées (⏶) are visible, upon which Late Glacial moraine remnants are preserved. Ground moraine (■ 0–II) of a High- to Late Glacial (II) age is exposed in the foreground. In front of it glacially transported erratic blocks (■) are visible. They have the morphometrical characteristics of boulders, transported by the glacier, i.e. they are rounded at the edges and facetted. Photo: M. Kuhle.

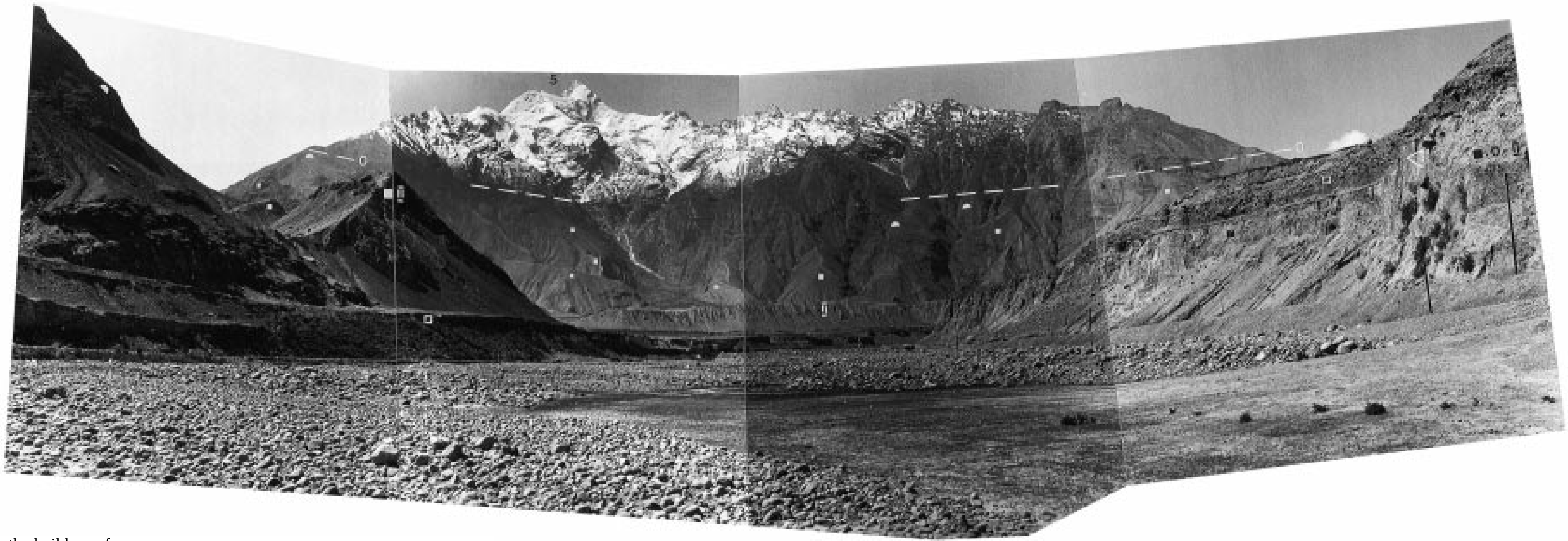


▲ **Photo 25.** At 2180 m asl a ground moraine exposure on the orographic left-hand side of the Gez valley talweg (Figure 14, No. 13; 38°49′N/75°21′E; see Photo 26 ■ 0–II; Photo 27 ■ 0–II). The ground moraine (■ 0–II) is covered by glaciofluvial gravels (□); 'nests' and lenses of sand and gravel intervene (▼▲). The moraine is strikingly densely-packed and relatively rich in fine material, which is to be explained by the high pressure caused by the superimposed load and heavy trituration. They are both characteristic of ground moraines. However, owing to the crystalline bedrock in the catchment area the ground mass is altogether very coarse-grained. (◁) marks large polymict blocks, 'swimming' in isolation from each other in the ground mass. Photo: M. Kuhle.

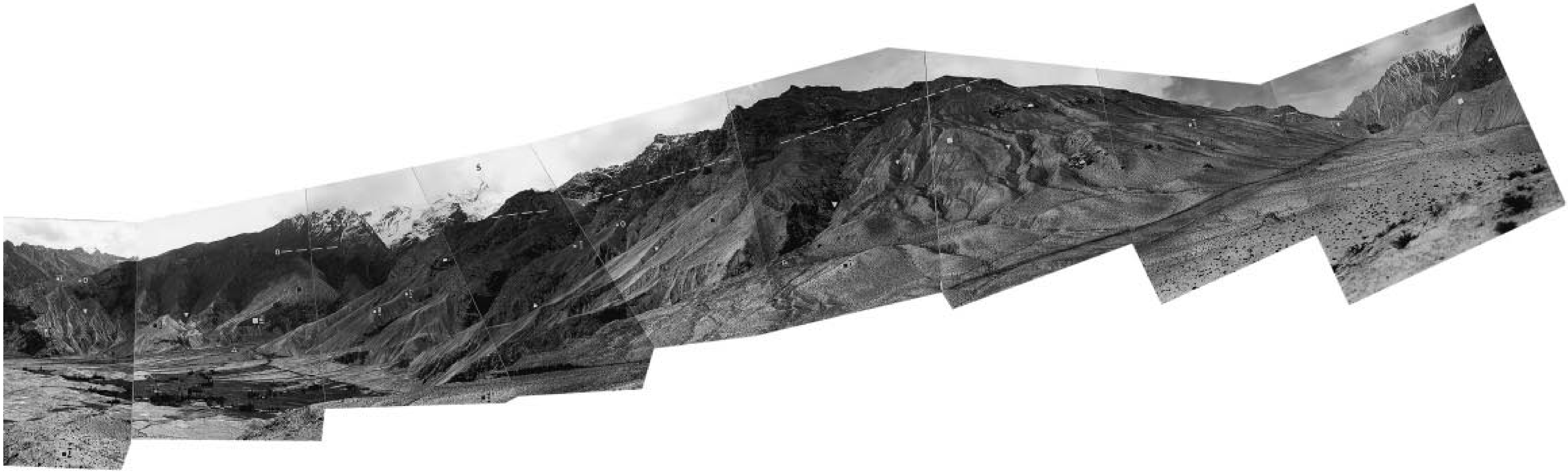
► **Photo 26.** Taken from 2200 m asl from the gravel floor (□) of the Gez valley towards the NE seen down-valley (Figure 14 left- hand below No. 13; 38°49′N/75°20′E). (□ 0–II) indicates the ground moraine described (Photo 25), to which debris fans (▽) are adjusted, built up by dislocated moraine material since the complete deglaciation of this valley cross-profile. Remnants of such moraine material (ground moraine) which primarily has been deposited high above on the orographic left-hand valley flank, are marked by (■ 0–I). (◥ ◤) shows preserved smoothings of the glacial flank abrasions. Photo: M. Kuhle.

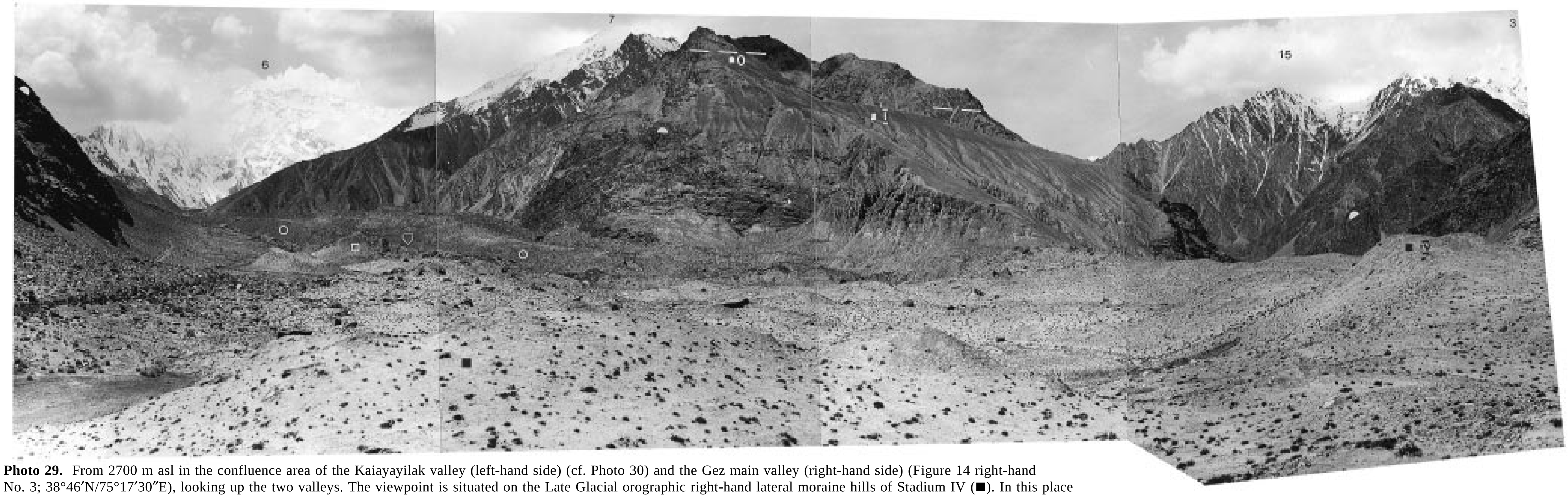
▼ **Photo 28.** From 2620 m asl, 300 m above the talweg, a 360°-panorama from the orographic right-hand lateral moraine terrace of the Late Glacial glacier sub-Stadium (■ I″) was taken (Figure 14 between No. 3 and 14; 38°46′N/75°18′E). In the middle of the panorama the downward-course of the Gez valley and the Late Glacial end moraine (■ II background) in the valley chamber, shown up-valley in Photo 27, is visible (in a NE direction). On the orographic right-hand side of the end moraine (■ II background) a tributary valley joins, which leads down to the N from behind the 5600–6000 m high summit No. 5 (still glaciated today) of the Kongur massif. It is cloaked by High-(LGM) to Late Glacial moraines (■ I ■ 0) and has supplied the former Gez glacier with a correspondingly thick valley glacier (——0). The ground moraine bed of this tributary-glacier (◇), lying higher than the bottom of the main valley, has been preserved with its original trough-cross-profile. (——0) indicate the High Glacial (LGM) level of the Gez main glacier at an altitude of at least 3000–3100 m. Below there are provable glacial polishings and abrasions (⌓); (■) marks ground moraine, superimposed on the valley flanks and (■ 0, I, I′, I″, II, III, IV) are attached lateral- to end moraines of the corresponding High- to Late Glacial glacier positions (cf. Figure 14 between No. 3 and 14). Especially the Late Glacial lateral moraine- and kame-forms show on the surfaces of their terraces up to decimetre-thick loess covers (■ I– ■ IV) (cf. also Photo 29). (↘) marks the position of potholes, having been developed by subglacial meltwater. Since the deglaciation, i.e. during the Holocene, the dissection of the Ice Age moraine-accumulations by rill-rinsing (▼) and the renewed sedimentation of the transfered moraine material in the shape of mudflow fans occurred (△). The characteristics of the boulder clay of the moraines, which build up the water, favours the two settlements of the irrigation-oasis type. (15) marks a southern spur-peak of the Kara-Bak-Tor (King Ata Tagh), today still glaciated; (17) means an eastern satellite-peak or more distant spur-peak of the same massif. Photo: M. Kuhle.





► **Photo 27.** From the same viewpoint as Photo 26 seen upwards from the Gez valley in a SSW direction (Figure 14, No. 13). (5) marks a c. 5600–6000 m high N-spur and satellite-peak of the Kongur, which above c. 5000 m manifests contemporary glaciation. (■■) indicate High- to Late Glacial ground- and lateral moraines i.e. end moraines. Above these moraines glacial polishings and abrasions (◥ ◓) on the valley- i.e. mountain flanks prove the glacier infilling of this valley, which during the LGM has reached up even higher (——0) (cf. another perspective in Photo 28). On the right-hand side the ground moraine, described in detail (■ 0–II) (see Photo 25), with the included large erratic blocks (▽) is visible. The ground moraine is covered by gravels (□ on the right), deposited after the deglaciation. On the orographic right-hand side (□ left) the corresponding glacio-fluvial gravel-field-terrace occurs. (■ II) marks the end moraine of the last Glacial glacier, which was involved in the build-up of the ground moraine (■ 0–II). The younger Gez glacier Stadia III and IV just reached the lower Gez valley (from ■ 0–II down-valley) with their deepest tongue ends. Photo: M. Kuhle.

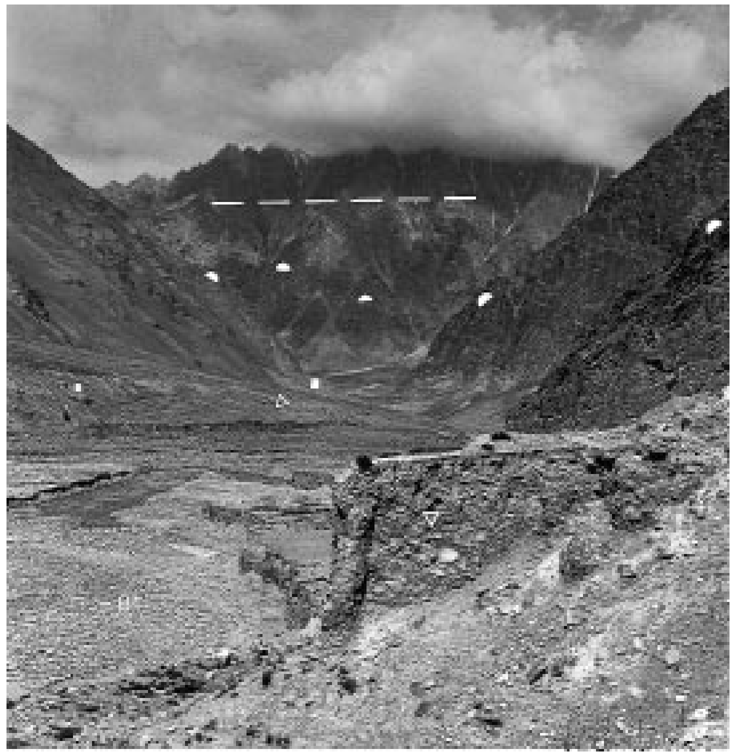




▲ **Photo 29.** From 2700 m asl in the confluence area of the Kaiayayilak valley (left-hand side) (cf. Photo 30) and the Gez main valley (right-hand side) (Figure 14 right-hand of No. 3; 38°46′N/75°17′30″E), looking up the two valleys. The viewpoint is situated on the Late Glacial orographic right-hand lateral moraine hills of Stadium IV (■). In this place the sample of Figures 15 and 27 has been taken from an excavation. The centimetre- to more than decimetre-thick loess overlay gives proof of the many thousands of years greater age of these moraines compared with the Neoglacial (□) to Historical moraines (○), which flank the terminal of the modern (1992) Kaiayayilak glacier (⇓) at a shorter distance (cf. for Tienshan and NW-Karakorum Meiners 1996). At present its end lies at c. 2820 m asl (⇓). The Kongur-N-flank, visible in the background, belongs to its nourishing area (below of No. 6). (7) indicates a N-spur of the Kongur massif, which is still glaciated today. (——0) below, marks the High Glacial (LGM) level of the valley glacier in this confluence area of side- and main glaciers, signified by the preserved glacially scoured slope. (■ I) indicates the lateral i.e. medial moraine, classified as belonging to the Early-Late Glacial (see Table 1), which has been accumulated between main- and side glacier (Figure 14, No. 3). It is situated 700–800 m above the talweg of the Gez valley. (◥ ◓ ◤) show glacigenic abrasions on the valley flanks. (3) is the position of the Kara-Bak-Tor main peak; (15) marks a still glaciated southern spur-peak, flanking the Gez valley. Photo: M. Kuhle.

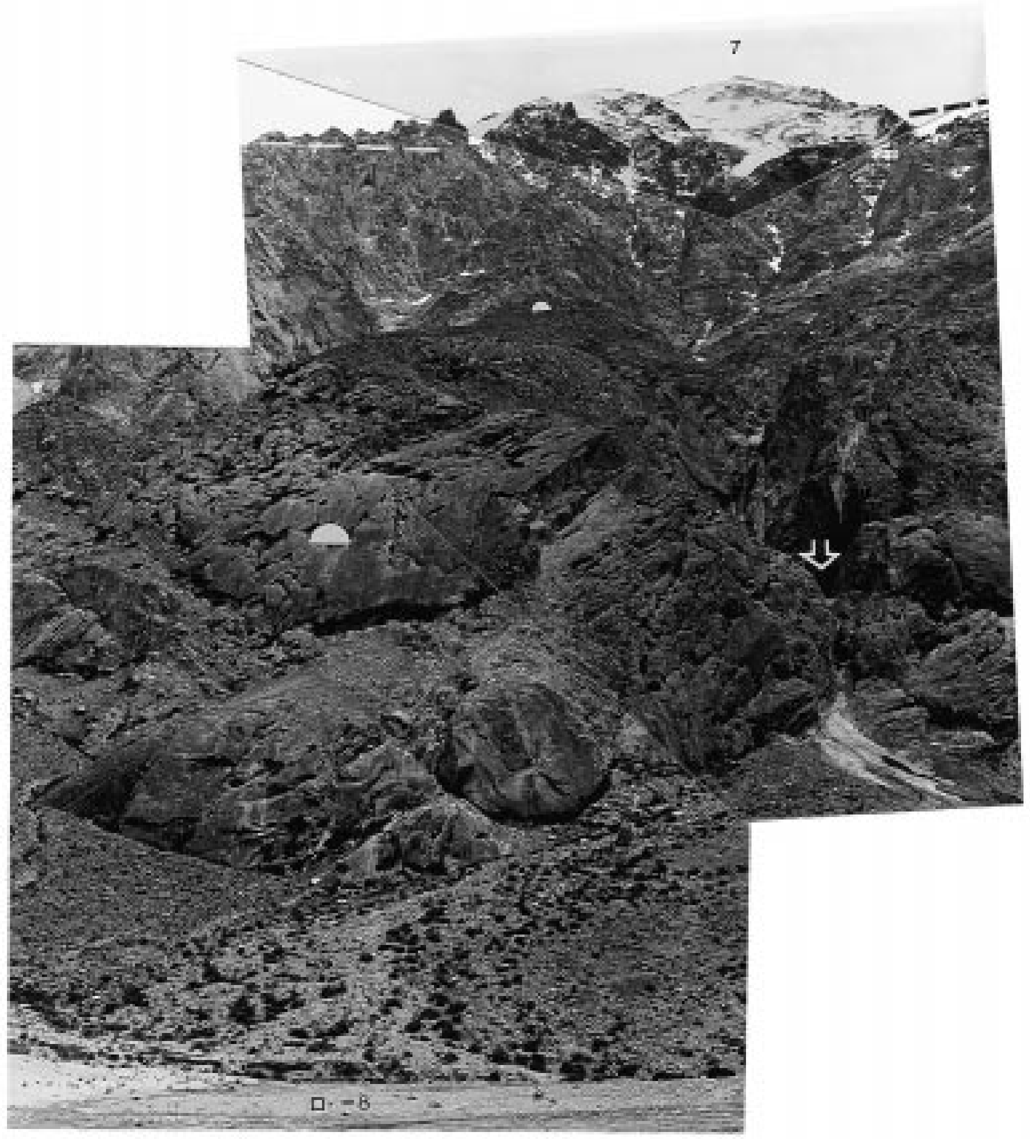
◄ **Photo 30.** View from 2500 m asl from the valley bottom of the Gez valley (Figure 14, No. 3; 38°47′N/75°16′E) in a S direction looking into the Kaiayayilak valley. (1) is the main peak of the Kongur (7830 m asl) with the N-wall, which falls away beneath. It feeds two tributary streams of the Kaiayayilak glacier. (⇓) marks the glacier's tongue end at c. 2820 m asl (cf. Photo 29). (■) indicates moraine material, deposited neoglacially to historically (c. Stadium V to X, cf. Table 1). It provides evidence of an historical ice margin down to c. 2500 m asl, which belonged to an ELA-depression (snow-line depression) of c. 150 m compared to the present snowline altitude (cf.: On the younger glacier history of Tienshan and NW-Karakorum, Meiners 1996). (◥ ◓) shows rock abrasions of the High Glacial (LGM) ice filling of the valley (cf. Photo 29). (□ –8) indicate the glacier-mouth-gravel-field (outwash i.e. sander) of today, which has been heaped up by the recent (1992) glacier stream. Photo: M. Kuhle, 05.06.1992.

◄ **Photo 31.** Seen at 2540 m asl from the Gez valley (Figure 14 left-hand of No. 3; 38°46′20″N/75°13′E) towards the NNW into the Erkuran valley (Figure 14, No. 16). (15) marks the position of the southern spur-peak of the Kara-Bak-Tor, which today is still glaciated (cf. Photos 28 and 36). The valley has a typical trough- or U-shaped valley cross-profile. (◥ ◓ ◤) indicates rock surfaces, which are polished by the Ice Age glacier and therefore rounded. (■) shows Late Glacial moraine material; (□) moraine material, which has been rinsed and washed out by glaciofluvial melt-water. Thus it was slightly dislocated and heaped up into a terrace. Photo: M. Kuhle.

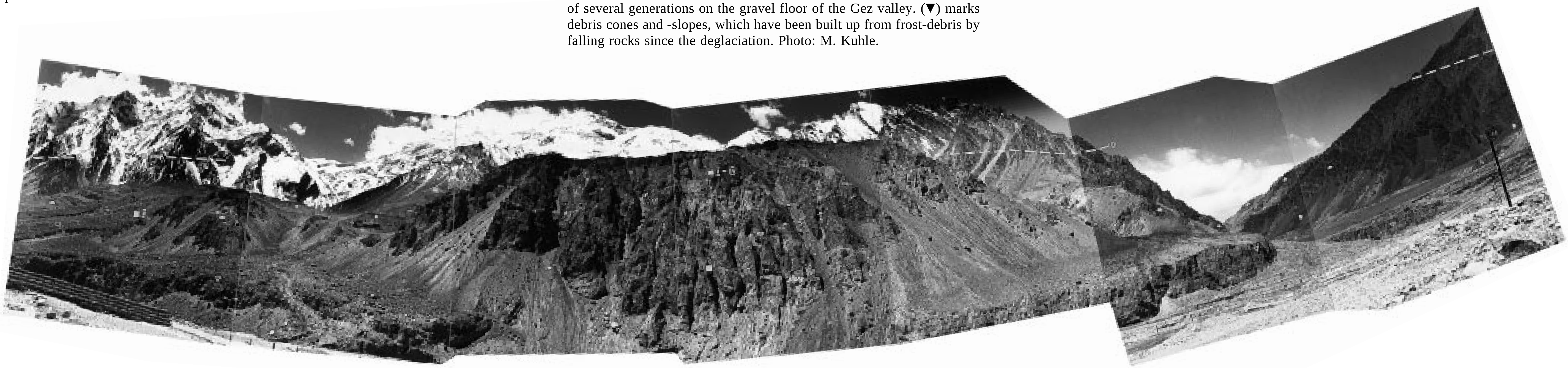


▲ **Photo 32.** Taken from 2530 m asl from the confluence area of the Erkuran valley (Figure 14 left-hand of No. 3; 38°46′20″N/ 75°13′15″E) the Gez valley up towards the W. (■) marks ground moraine remnants; (▷) alluvial debris- and mudflow fans i.e. their exposure (in the foreground). Besides local weathered detritus of bedrock phyllites (crystalline schists) these fans also contain dislocated moraine material. The erratic blocks included confirm the long-distance transportation down the Gez valley. (□ –8) is the present glaciofluvial gravel field (sander), which has been heaped up and annually mixed thoroughly by the meltwater of the recent glaciers. Since glaciofluvial gravel depositions are concerned lying at a distance of kilometres to decakilometres from the present glacier end as the source of the meltwater, which are restricted in their extension at the sides of the valley bottom by the valley flanks, they are to be described as 'channelized-gravel-fields (-sander)' or 'valley-gravel-fields (-sander)' in contrast to the 'free gravel fields' (Kuhle 1983, p. 337 and following pages). (◣◓◢) marks glacigenic rocks, smoothed by valley flank abrasion, which in many places are roughened by subaerial weathering; (——) indicates a Late Glacial Gez outlet glacier level, indicated by a polish line. Photo: M. Kuhle.

► **Photo 33.** Seen from the bottom of the Gez valley from 2850 m asl into the N-flank of a c. 5800–6000 m-high mountain (7) of the Kongur massif towards the SSE (Figure 14 above No. 17; 38°44′30″N/75°12′E). The mountain (below of 7), glaciated in the upper section of its flank, which from this place is c. 3000 m high, forms the orographic right-hand flank of the Gez valley. The flank shows perfectly preserved glacier polishings (◓), i.e. flank polishings of the Gez outlet glacier. In order to reach these polished rock surfaces at a 1800 m lower altitude, the hanging glacier (below 7), which today comes down to c. 4700 m asl, would need an ELA-depression of c. 900 m. This is the ELA-depression during the LGM (cf. chapter 2.7). At that time the Gez outlet glacier has filled this main valley cross-profile up to the level (——). This is provable by the glacigenic flank polishings, which end up there. In addition these very well preserved glacier polishings, formed in bedrock granites (◓), cannot have been produced by the steep tongue of a hanging glacier, which towards its end was less thick and thus weak in load-pressure and which, because of reasons of the feeding balance, hardly ever moved. At the time of the Ice Age this hanging glacier was adjusted to the surface of the Gez outlet glacier. The water of the hanging glacier has linear- erosively dissected the flank polishing of the Gez glacier since its melting (⇓). Photo: M. Kuhle.

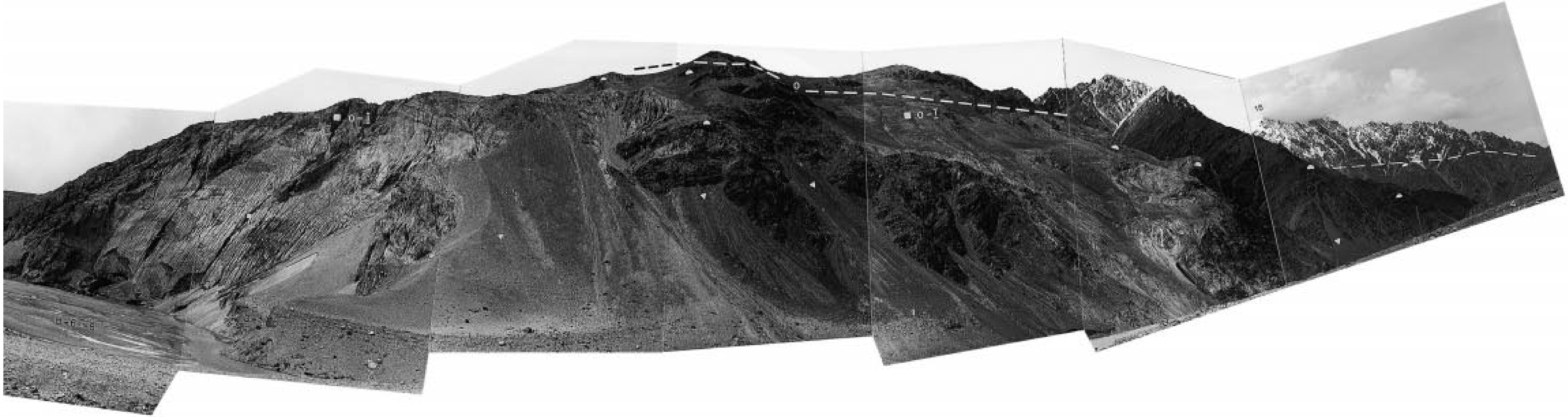


▼ **Photo 35.** From c. 3000 m asl from a mudflow fan in the orographic left-hand side of the Gez valley (Figure 14 above and between Nos. 17 and 18; 38°45′N/75°07′E) from down-valley towards the E (7) via the S (1–16) into the N-flank of the W-section of the Kongur massif as far as W, seen up the Gez valley. (1) indicates the Kongur peaks, which cannot be immediately seen from this place, representing an extension of the heavily glaciated main ridge of the massif. The visible mountain ridge is c. 6400–7100 m high. For (7 and 16) see Photo 34. (——0) marks the Ice Age (LGM) glacier level, provable with the help of the highest flank abrasions (◣◓◢). Rock smoothings and roches moutonnées, situated far below this polish line, have been more and more covered by older (■ I–IV) Late Glacial and younger (■ V) Neoglacial moraines (ground- and end moraines) (cf. Table 1). In the course of this the High- to Late Glacial moraine landscape (■ I–IV) has been destroyed by the Neoglacial (Holocene) (■ V) to recent ice streams (⇓ = recent (1992) surface of the W Kongur-N-glacier) i.e. it has been remoulded and worn down by overthrusting at a right angle (from the S).The ground moraine ramparts (■ I–IV) suggest an overthrusting of the short, steep tributary glaciers over the main glacier (Gez outlet glacier) (cf. 'Überschiebungs-Grundmoränen-Rampen' Kuhle 1982, text, p. 45f; 1983 p. 238f). In connection with the end moraines (■ V) outwash (sander) depositions (□) are noticeable, which have been built up simultaneously. Dislocated glaciofluvially as well as purely fluvially and by means of mudflows, the moraine material has been deposited in large young fan-forms (▽) of several generations on the gravel floor of the Gez valley. (▼) marks debris cones and -slopes, which have been built up from frost-debris by falling rocks since the deglaciation. Photo: M. Kuhle.



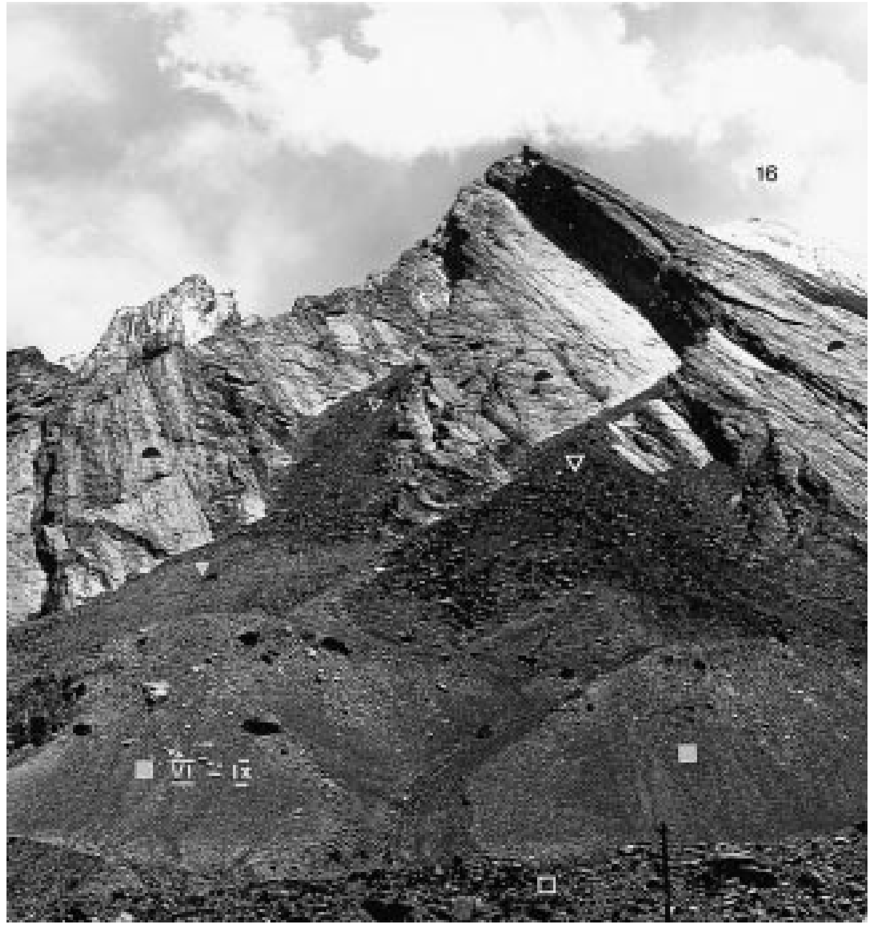
◀ **Photo 34.** Taken from approximately the same position as Photo 33, looking up the Gez valley. The main valley, being very narrow in this place, runs in granite and shows minor extended Ice Age flank abrasions (◥ ◤) preserved here. In between there predominate the post-glacial crumblings of the bedrock granite and the resulting debris slopes. Here, at 2850 m asl, the glacigenic gorge-form with its V-shaped valley profile can be explained by the subglacial meltwater erosion which occurred in the High Glacial, too (cf. in detail Kuhle 1983, pp. 120, 155; Visser 1938, vol. II, pp. 135–139). This took place c. 950 m below the ELA (LGM) by means of water, confined under the ice, in the shape of cavitation-corrasion. Above (◥ ◤ close to the upper edge of the photo) the valley cross-profile, as a result of pure ice-work, becomes trough-shaped wider. (■) marks Late Glacial moraine material (Stadia I–IV) of the most westerly Kongur-N-glacier (Figure 13 between No. 17 and 18; Photo 35 (■ I–IV)). (16) is a c. 5300 m high spur-peak of the most north-westerly foothills of the Kongur massif. Photo: M. Kuhle.

▼ **Photo 36.** Viewed from the same locality as Photo 35 into the left-hand flank of the Gez valley towards the N. (15) is a presently still glaciated southern satellite peak of the Kara-Bak-Tor, rising up somewhat higher than 5800 m. From up there (15) a High (LGM)- to Late Glacial hanging-glacier (tributary glacier) flowed down to the main glacier (Gez outlet-glacier), thus over-thrusting it. (——0) indicates the level of the High Glacial Gez glacier, which has been reconstructed with the help of preserved flank abrasions (⏶), ending upwards towards a clear polish limit. The tributary glacier was adjusted to this glacier surface level in the extension between (——0 left) and (——0 right). With the dropping of the ice surface towards the Late Glacial (I-IV) there developed an 'overthrusting-ground-moraine-rampart (■ I–IV) ('Überschiebungs-Grundmoränen-Rampen' Kuhle 1982, text, p. 45f; 1983, p. 238f). During the last stadium of this valley glaciation this moraine complex (■ I–IV) became an orographic left-hand lateral-moraine-fragment of the main valley glacier and an end moraine of the hanging glacier, and thus a medial moraine between the two glaciers. This was the case during Stadium IV (last Late Glacial Stadium, cf. Table 1), when the hanging glacier at the same time has built up the small ground-moraine complex (■ IV). The glacially smoothed valley flanks, built up from phyllites, splinter and break off because of the Holocene (Post-Glacial) frost weathering, thus forming debris cones and -slopes (▼). They cover more and more of the ground moraine remnants (■). Holocene to Historic and still active mudflow- and alluvial debris-fans (▽) fringe the overthrusting-ground-moraine-rampart and bury its base. The fans contain dislocated moraine material with erratic granite and granite blocks (○). Photo: M. Kuhle.



▲ **Photo 37.** From c. 3150 m asl from the upper commencement of the Gez valley (Figure 14, No. 18; from the confluence of the Karakol valley and the Muji basin, 38°45′10″N/75°04′50″E) looking into its orographic left-hand flank from towards the WNW (left-hand) via N to E (right-hand). (◠ ◠ on the true left) are preserved rock ridges of phyllites, polished round by the Ice Age glacier ice in the exit of the Muji basin. (■) and (■ 0–I) indicate the High (LGM)- to early Late Glacial ground moraines, preserved on the orographic left-hand slope of the Gez valley, almost up to the highest provable pertinent glacier level (——0). Since the up to (——0) at least 550-m thick Gez outlet glacier set in on the NE edge of the plateau, discharging the plateau ice, this is a key-locality for the evidence of the Ice Age (LGM) glacier cover of the E Pamir plateau. In order to glaciogeomorphologically understand the relation of these positions of High Glacial ground moraine and Late Glacial lateral moraine (■ 0–I) up to a height of at least 3600 m and thus at least 400 m above the gravel floor of the adjoining E-Pamir plateau section (along with the Muji basin), the ice cover of the north-eastern plateau (see Figure 14 left-hand of No. 18, 19; Photos 38 and 41) must be referred to here. (◠ ◥ in the centre and at the right-hand side) marks – as a more High Glacial indicator, which might be preserved still more extended beneath the ground moraine – the glacial flank abrasions on truncated spurs of the stratified bedrock metamorphites. C. 5 km down-valley there stands the peak (15), shown in the valley cross-profile of Photo 36, which illustrates the geomorphologic-topographical connection (cf. also Photo 38). (□ 3–1) marks the complex of glacio-fluvial gravel-terraces (gravel field- or sander-terraces), which have been deposited in the Late Glacial and incised by the meltwater in the Holocene (Post Glacial). (□ –6 – –8) indicate the gravel field (i.e. the deposited sander and the meltwater run-off) of the recent glaciers (see Photo 41,43 and others; Figure 14). (▼) is the production of debris cones, which has taken place since deglaciation. The surfaces of the cones are adjusted to the terraces (□ 3–1) and therefore must have been built up since the Late Glacial trough the Holocene up to the present. (▷) signifies young mudflow- and debris fans after heavy rains and at times of snow-melting, as being still active. Photo: M. Kuhle.

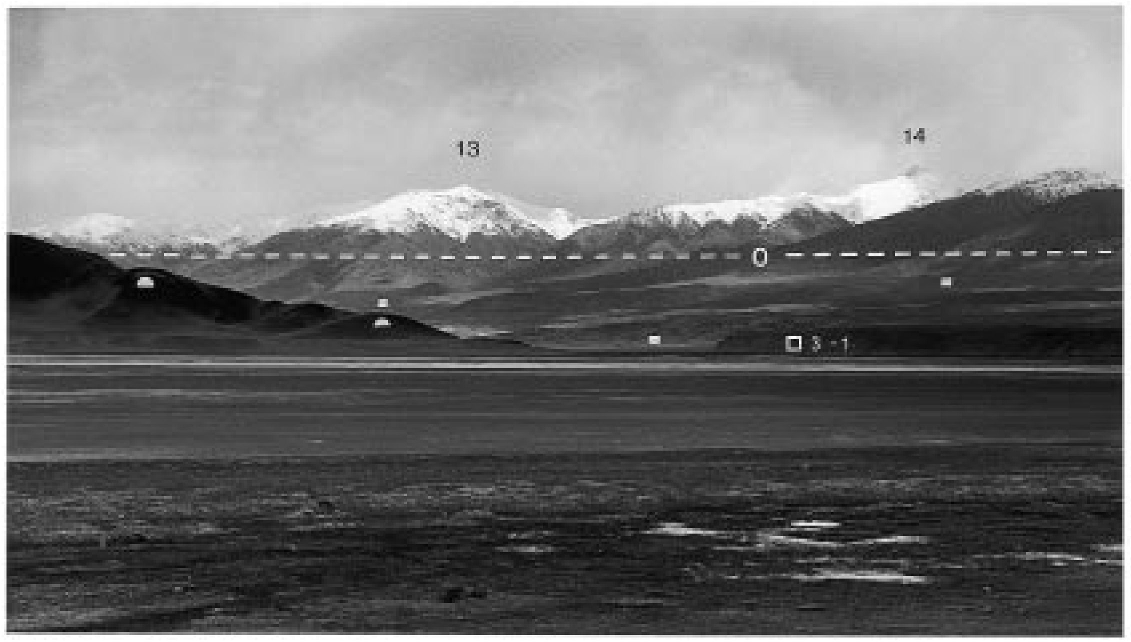
► **Photo 38.** From c. 3250 m asl from the orographic right-hand southern edge of the Muji basin or Muji valley in the area where the Karakol valley debouches into the upper Gez valley (background at the right-hand side) (Figure 14 left-hand of No 18; 38°44′N/75°02′E) seen towards the ENE. (3) is the Kara-Bak-Tor (6800 or 6634 m asl), the highest peak of the southern King Ata Tagh (cf. the peak in Photos 1–3 , seen from the NE) with its present glaciation. (◠ ◥) marks rock ridges and valley flank slopes in bedrock metamorphites, which have been polished round by the High (LGM)- to early-Late Glacial glacier cover and relief-filling. The upper ice scour limit proves a permanent former glacier level (——), falling away from c. 3700-3900 m (—— in the centre of the photo) to an altitude of c. 3600 m. (■ 0–I) indicates the orographic left-hand ground- and lateral moraine complex of the Gez outlet glacier, shown in Photo 37 in detail. It flowed down at a minimum thickness of c. 550 m from the NE edge of the E-Pamir plateau to the Tarim basin. (15) is the satellite peak, seen from a shorter distance in Photos 36 and 37. (◁) is a young mudflow- and debris fan with glaciofluvial gravels of the small glacier in Photo 40. (□ 3–1) indicates the Late Glacial gravel-field- terrace, also shown in Photo 37; (□ –6 – –8) is a glaciofluvial gravel (sander)-deposition of the recent glacier meltwaters, today in the process of forming. Since the run-off of the water through the Gez valley after Stadium I or II must have been blocked by the local mountain-glacier-ice of the Stadia III–IV, the underlying bed of these gravels can be supposed to be Late Glacial sediments of an ice-dammed lake. That was the time immediately after the melting of the High Glacial E-Pamir plateau ice. Photo: M. Kuhle.



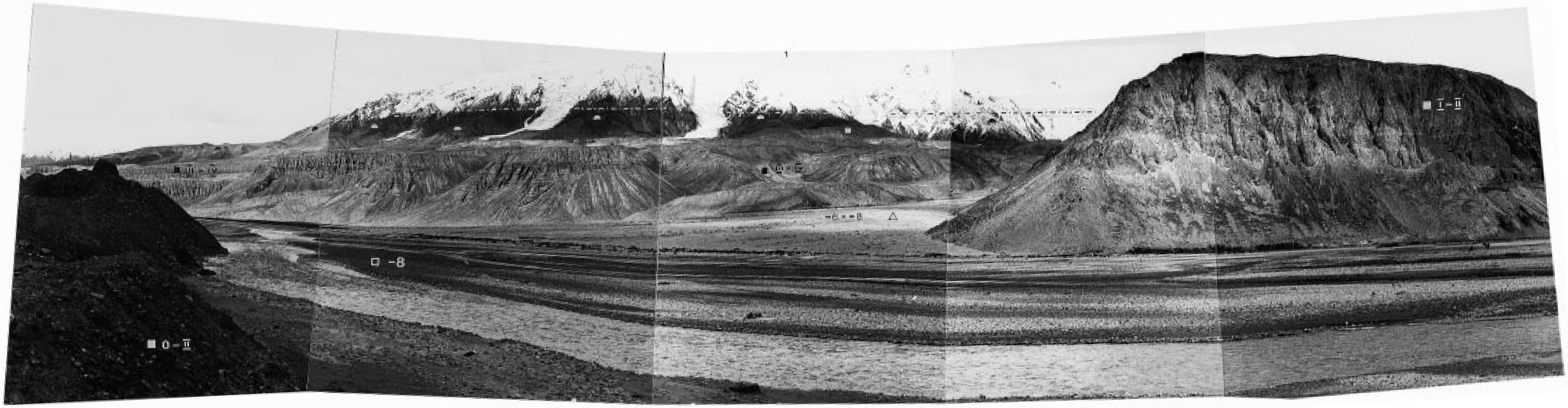
▲ **Photo 39.** From c. 3150 m asl in the upper start of the Gez valley (Figure 14, No. 18; in the confluence area of the Karakol valley and Muji basin; 38°44′N/75°03′E) into the orographic right-hand flank of the valley, facing SE. (16) is a north-western c. 5300-m high glaciated spur-peak of the Kongur massif (cf. Photos 34, 35). The crystalline schists (phyllites), standing nearly vertically, dip towards the W. It is obvious that the Ice Age glacier polishing (◓) has smoothed the very resistant surface of the strata. However, the structure of the steeply adjusted strata sequence dictates and completely steers the heavily dissected large-scale form of this valley flank. This valley flank therefore remains climato-geomorphologically absolutely indifferent. Thus it demonstrates that the glacial forms must not have been shaped i.e. preserved wherever a heavy glaciation has taken place. Photo 37 shows a corresponding opposite valley flank, which is completely covered with ground moraine. (■ VI–IX) mark Neoglacial to Historic orographic right-hand lateral moraines of the glacier tongue, visible in Photo 40. In order to build up these moraines, the terminus of the glacier had to flow c. 150–250 m further down than today. This was probably the case between the Stadia VI and IX (see Table 1); (cf.: On the younger glacier history of Tienshan and NW-Karakorum, Meiners 1996). (□) marks material of end moraines, moved by mudflows and glacioflu-vial activities of the Neoglacial to recent meltwater in the glacier forefield; (▽) rockfall-cones, which are adjusted to older Neoglacial lateral moraines and kames (▼). Photo: M. Kuhle.

▲ **Photo 40.** Seen from c. 3150 m asl from a somewhat more westerly viewpoint than in Photo 39 (Figure 14, No. 18), facing SSE to the NW spur of the Kongur massif. (16) is a 5300 m-high spur-peak (cf. Photos 34, 35, 39). (◢) marks glacigenic flank polishing, which is concordant with the stratification. The recent glacier tongue flows down the subsequent valley (No. 1, gully in Figure B-10 in Pan Yusheng (ed.), 1992, p. 81) between the slope of the stratification (left-hand) and that of the outcropping edges of the stratum (right-hand) up to c. 3300 m asl (■). The end of the glacier tongue is covered metre-thick by surface moraine debris. Thus it is likely that it has been in the same more or less stable position since c. 1950 (Stadium XI, see Table 1). Possibly this is even a remaining dead-ice-glacier-tongue. The bare ice of the glacier is situated c. 50–80 m above point (■) (cf: On the younger glacier history of Tienshan and NW-Karakorum, Meiners 1996). The prolific debris of the surface- and also end moraines of this small glacier can be explained by the typical very productive frost-weathering on the flank of the outcropping edges of the stratum of this small valley with its systematic-structural asymmetry. (▽) is a debris cone, channelized by the rock, which confirms that considerable debris-production. (□□) indicate dislocations of historical end moraine material, glaciofluvially (by the recent meltwater of the glacier) induced by mudflows. Photo: M. Kuhle, 12.06.1992.

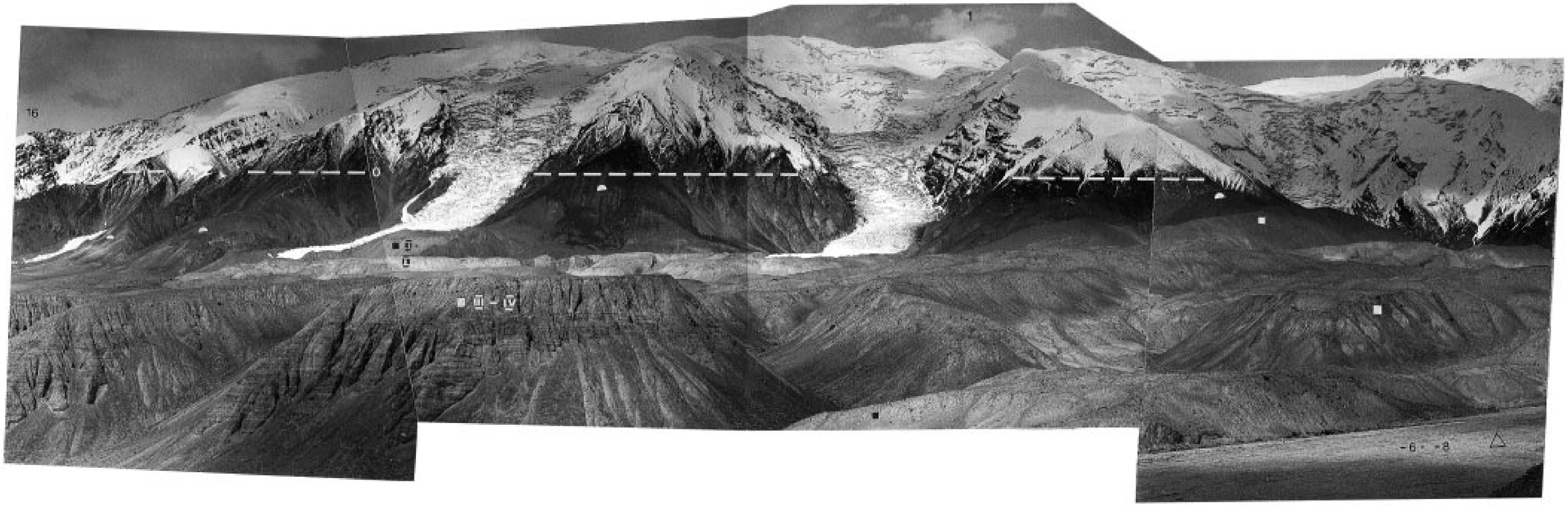
► **Photo 41.** Approximately the same position as in Photo 38 (a little further to the W). Seen from 3250 m asl, from the area of the inflow of the Karakol valley into the Gez valley, facing N. (13 and 14) are the massifs of King Ata Tagh, today still rather heavily glaciated, which reach approximately or tower somewhat above an altitude of 6000 m. They belong to the upper catchment area of the Oytag valley, which runs down north-eastwards behind them, and continue the Kara-Bak-Tor massif towards the NW (cf. Figure 14). (■■) mark the Late Glacial moraines of the Stadia II or III, which provide evidence of a south-western connection of the piedmont-glaciation of the King Ata Tagh into the Muji basin. They reach down to 3500–3250 m and suggest ELA-depressions of c. 400–600 m. During the oldest (earliest) Late Glacial (Stadium I) and during the High Glacial (LGM) the Muji basin was completely covered with glacier ice. Among others this is proved by round-polished rock ridges (roches moutonnées) (◓), and confirmed by the run-off of the pertinent Gez outlet glacier (see Photos 37 and 38 ——). The level of the ice surface (——0) ran between c. 4000 m (left-hand) and 3700–3900 m (right-hand). (□ 3–1) marks the gravel field- (sander-) terraces, adjacent to the Late Glacial piedmont-moraines. Photo: M. Kuhle.

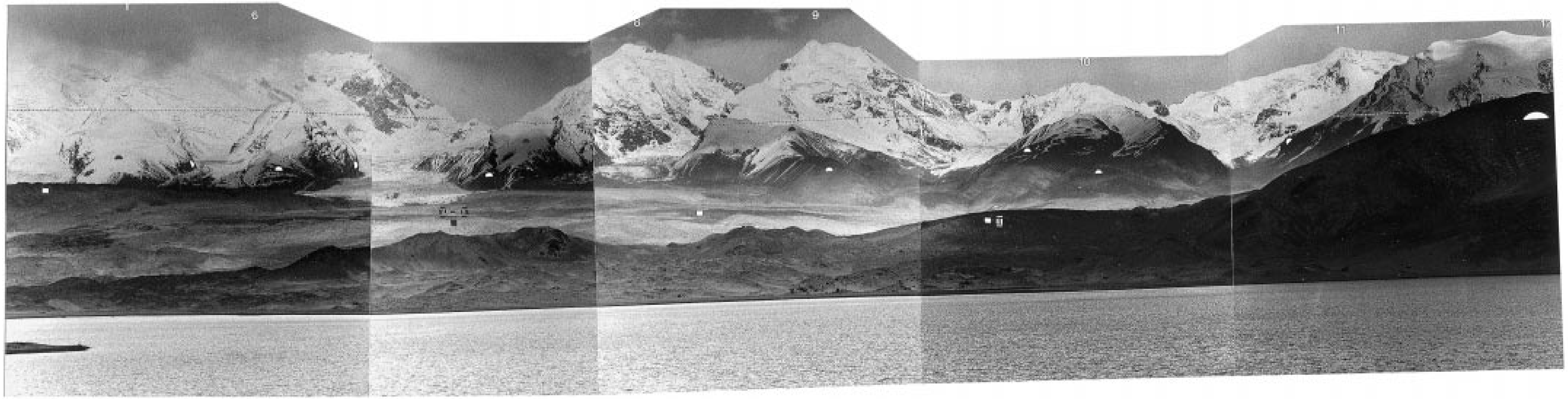


► **Photo 42.** From c. 3320 m asl from the W-foot of the Kongur massif (Karakol valley) (Figure 14 below No. 23; 38°33′N/75°00′10″E) towards the ENE, looking into the Kongur-W-slope. (1) indicates the position of the c. 7830 m high main peak, the highest peak of the entire Pamir. The present glaciers still reach the piedmont- area of the massif, which – like the Muji basin – is situated in the lower level of the E-Pamir plateau. Here, the recent glacier tongues are set into a ground-, pedestal- and end moraine landscape, which at a maximum reaches a Late Glacial age (■ III–IV). The moraines (■ III–IV), lying with increasing age in the form of more and more widely extended lobe-arcs on the E-Pamir plateau surface, are up to several hundred metres thick, thus proving a uniform piedmont-glacier-cover, into which have flowed the separate tributary streams from the Kongur. The still older foreland moraines (■ 0–II) (■ I–II) of the oldest (earliest) Late Glacial Stadia I and II have been deeply, though not completely, cut by the meltwater-outflow of the Karakol Lake (□ –8). The recent sander-deposits of the connected meltwater-side-valleys (–6 – –8 ▷) are adjusted to the level of the Karakol river with its glaciofluvial gravel field (□ –8). The moraine-packs (■ I–II), being exposed by this cut, show the characteristics of very tightly packed ground moraines with substantial portions of ground mass between the large granite- and gneiss blocks, 'swimming' in it. This ground-moraine-character and the already considerable distance of their position from the Kongur massif point to the fact of their glaciogemorphological association with the High- to early-Late Glacial E-Pamir plateau ice sheet. Their structure suggests a completely overlying glacier cover with only sparse movements and nearly no flow-direction.The stratification of the younger moraines of the piedmont-ice (cf. Photo 43 ■ III–IV) indicates heavy glacier movements from the Kongur massif. (◓) marks truncated spurs with round-polished and facetted edges, (——) the level of the E-Pamir plateau ice between c. 4500 and 4800 m asl. Photo: M. Kuhle.



▼ **Photo 43.** From c. 3300 m asl from the E-Pamir plateau across the western foot of the Kongur massif, seen from the Karakol valley (Figure 14 below No. 23; 38°34′N/75°02′E) towards the ENE to the 7830 m high main peak of the Kongur (1). (16) marks the c. 5300 m high NW-spur-peak of the Kongur massif (for the topographic context cf. Photos 34, 35, 39, 49). The glacier tongues, flowing down from the massif, which still today towers extensively above the ELA (running at c. 4900–5200 m), show the characteristics of outlet glaciers from a central-connected glaciation, covering the upper massif. They flow down to an altitude below 4000 m. (■ XI–IX) mark particularly perfect examples of end moraines of historical glacier positions on the edge of the recent glacier tongues. Their age amounts to c. 340 to 40 years before 1992. The pertinent ELA-depressions come to c. 40 to 20 m in comparison with the present snow-line (cf. Table 1) (cf. for Tienshan and NW-Karakorum Meiners 1996). The glacier tongues formed a connected piedmont-ice during the Late- Glacial (as is suggested by the ground- and end moraines ■ III–IV). Interrupted by minor Holocene advances, they have melted back to their contemporary position. During the advances, the glacier tongues were blocked in many places by older ablation moraines and dumped end moraines, so that they alternatively sought another way and thus created again and again new tongue basins. This is a regular feature in the mountain forelands, which are always rich in moraines (cf. Kuhle 1982, p. 92; 1983, p. 276f). This Holocene to recent glaciers advanced upon up to more than 100 m thick moraine podests (pedestal moraines) and thus have the characteristics of dam-glaciers (Heim 1933, Photo 11; v. Wissmann 1959, p. 31, Photo 2, p. 198). The ground-moraine- pedestals of those dam-glaciers especially block the newly advancing glacier tongues or narrow their bed (cf. Photo 44). (☁) mark High- to Late Glacial glacier abrasion-surfaces; (——0) the High Glacial glacier level. Photo: M. Kuhle, 12.06.1992.



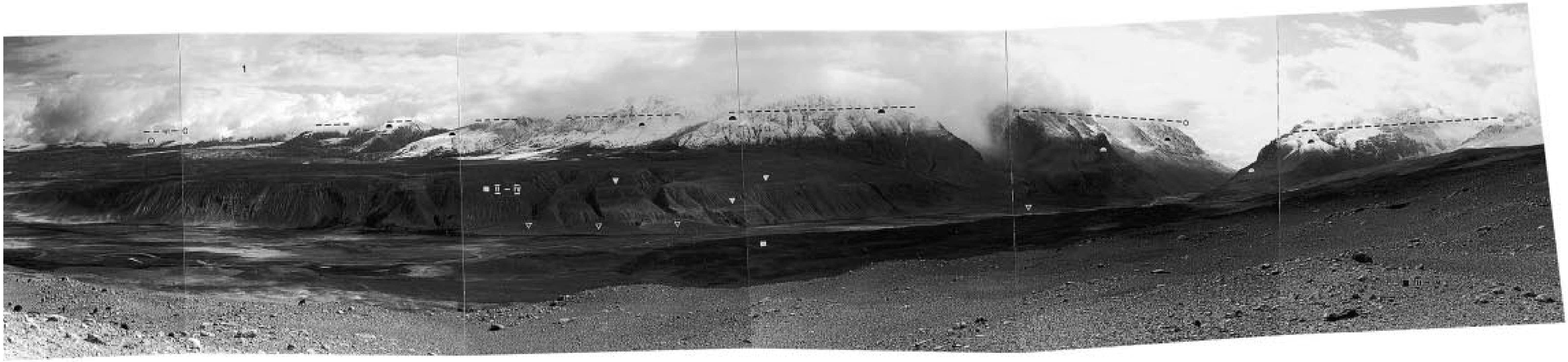


▲ **Photo 44.** From 3660 m asl from the W-bank of the large Lake Karakol (Figure 14, No. 20; 38°36′20″N/75°02′30″E), seen across this lake (foreground) towards ENE (centre of the panorama) to the Kongur (1) and the satellite-peaks (6,8-12), forming the S-spur of the Kongur massif. The peaks have altitudes of c. 5900 m (10) to c. 6350 m (according to ONC G 7). (——) marks the maximum (LGM) ice level, reconstructed with the aid of the rounding glacier abrasions on truncated spurs (◥ ◓ ◤), which indicate the limit of ice scouring in an upward direction. (■ III) mark the Late Glacial moraines of the glacier tongue basin in which the Lake Karakol is dammed. (■) and (■ XI–IX) indicate the late-Late Glacial (Stadium IV), Neoglacial to Historic ground- and end moraines in the piedmont-area of these mountains (see Table 1). The recent glacier tongues about 4000 m asl are adjusted to these accumulations (cf. for Tienshan and NW-Karakorum Meiners 1996). The very important up to several metre thickness of the completely covering foreland (piedmont) moraines (■) (proved by the exposures; cf. Photos 42, 43, 45) indicates that these glaciers, according to a set regularity, have been adjusted to the level of the E-Pamir plateau as the mountain foreland of these high massifs, and have accumulated moraine debris during the Pleistocene Early- and Late Glacials and even during the interglacial periods (i.e. as today). Photo: M. Kuhle, 05.06.1992.

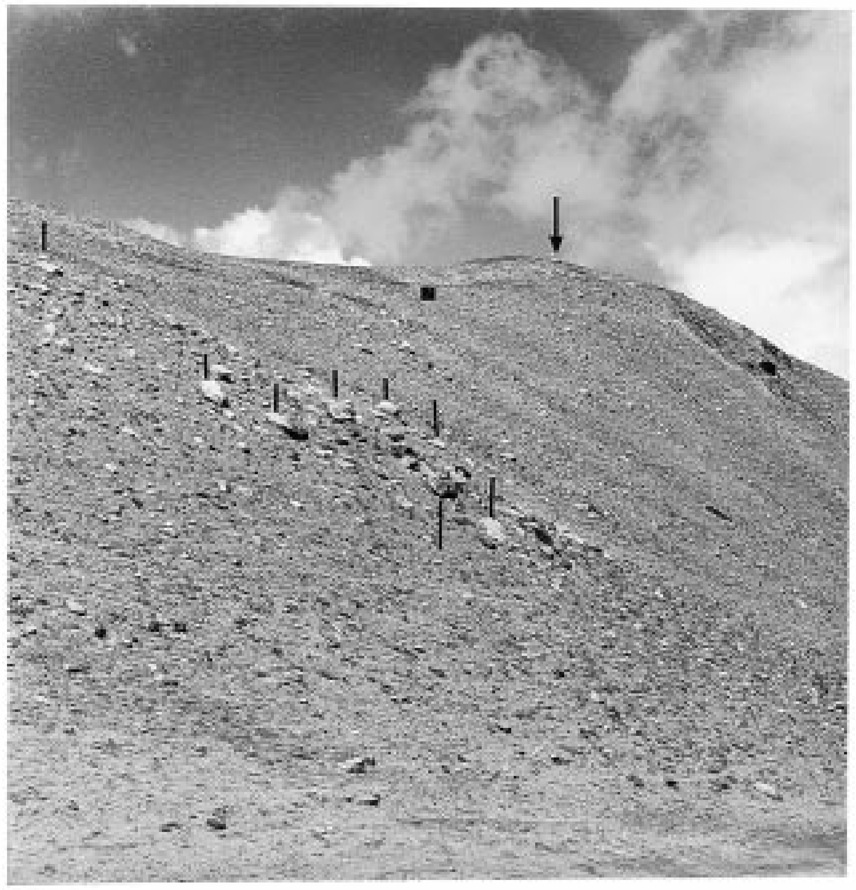
► **Photo 45.** From 4250 m asl from the N-slope of the Muztagh-Ata massif (Figure 14, No. 22; E-Karakol valley; 38°22′N/75°10′E), facing N towards the Kongur massif. (1) is the position of the c. 7830 m-high main peak, the firnificated glacier-surfaces of which can be recognized among the clouds. In the foreground hummocky moraines of the Late Glacial (■ III–IV; Figures 18, 19) stretch down as far as the Karakol valley at 3750 m asl (■). To the left-hand side this valley leads down to the Lake Karakol. These moraines with granite-blocks have been built up by the glacier catchment area of the Muztagh Ata (sheep to compare the proportions). The upper E-Karakol valley and its side valleys show classic U- and trough-shaped forms (right-hand third of the panorama) (Figure 14 right-hand of No. 22). Beyond (N) of the E-Karakol valley the at least 150–200 m thick moraine plate of the foreland of the Kongur massif joins (■ II–IV) (cf. Photos 42–44). Recent glacier tongues flow down to it (○). Between the separate valley exits of the pertinent glacier-valleys there are truncated spurs, smoothed by glacigenic flank abrasions (◓). The polished flanks of the upper E-Karakol valley show these signatures (◓ right-hand third of the panorama). Their polish line marks the maximum, i.e. High Glacial (LGM) level of the E-Pamir ice sheet (——0). It ran between c. 4900–5000 m in the right-hand half of he panorama, and in its left-hand half down to c. 4500 m asl (——0). The middle section of the E-Karakol valley is completely set into Late Glacial moraine material (■ II–IV) (in the two left-hand thirds of the panorama). The considerable extension of the valley here is due to the ice-infilling of the Late Glacial parent-glacier, the moraine-bed of which fringes this valley section. During Stadium III its tongue end and end moraine have created the basin of the Karakol Lake (↘), i.e. they were a barrier to the normal equidirectional N-incline (cf. Figure 14, No. 20; Photos 44 ■ III; 46). During Stadium II its tongue probably reached c. 10 km further down towards the NNW (Figure 14, No. 21). (▼) marks the marginal polish- and exaration-rills and the associated horizontal patterns and steps of moraine-edges of this parent glacier's gradually decreased level positions in the moraine material of its bed. During the middle- to late- Late Glacial the moraine material has been pushed against the glacier's ice body and deposited like a kame (■ II–IV). During the early Late Glacial (Stadium I), when the ELA still ran lower, the E-Karakol parent-glacier was much more extended and received a stream of tributary-glaciers from all the slopes and valleys of the Kongur- and Muztagh Ata-massifs. (▽) indicate the Holocene alluvial-debris-fans. They derive from erosion-rills, which since the deglaciation of the parent-glacier have been cut into the moraines in a reverse direction. (—— on the true left) shows the level of the Ice Age E-Pamir ice sheet (see Photos 50–52) at a time, where the Karakol valley was completely filled with ice and the Kongur- and Muztagh Ata ices were united with the E-Pamir ice sheet to form an uninterrupted glacier surface. Photo: M. Kuhle.

▲ **Photo 46.** From 3650 m asl across the Karakol Lake (Figure 14, No. 20) seen towards the Muztagh Ata (2). The lake is located in a Late Glacial tongue basin, the tongue of which flowed down in a NNW direction from the Muztagh Ata massif (2). During Stadium III the glacier tongue joined the Karakol glacier, i.e. the Late Glacial parent-glacier between Kongur and Muztagh Ata (cf. Photos 45, 44 III). The tongue basin contains ground moraine (see Figures 25, 26) with large facetted granite-boulders (■). Erratic granite- and gneiss-blocks on metamorphic schists and phyllites are deposited on the round-abraded foothills of the mountain (☗) (see Photos 47–49). The High Glacial level of the E-Pamir ice (——0) ran at c. 5000 m asl. Photo: M. Kuhle.

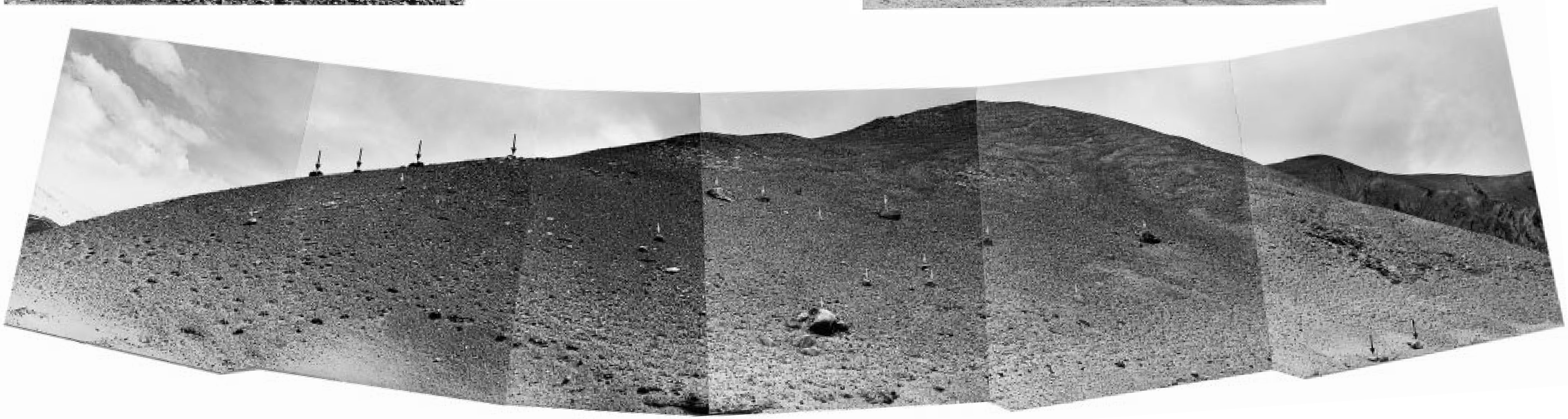
▲ **Photo 47.** View from c. 3730 m asl towards the northern foothills of the Muztagh Ata massif (see Photo 46 below ☗; 53, second ■ from the left), looking up one of the small valleys there, facing E (Figure 14, No. 25, between the E- and W-Karakol valley; 38°23′N/ 75°06′30″E). (■) marks ground moraine, which overlies the round-polished rock ridge, (| |) isolated erratic granite- and gneiss-blocks, overlying the bedrock sedimentary rock of the glaciated knob (schists, phyllites, sedimentary metamorphic rocks) (see Photo 48). The northern continuation of these rock- hills and -ridges, which were overflowed during glacial times by the glacier which, in the form of small intermediate valley ridges, are the boundary of the small valleys lying in between, is visible on the left side of Photo 45 (☗). (■ 0–IV) mark the partial filling of this valley with High- to Late Glacial moraine material by the tributary stream of a glacier, flowing down from the Muztagh Ata. The gravel floor, consisting mainly of out-rinsed and moved moraine (□), is flowed through solely after precipitation, because the valley is *not connected* to recent glaciers. Photo: M. Kuhle.



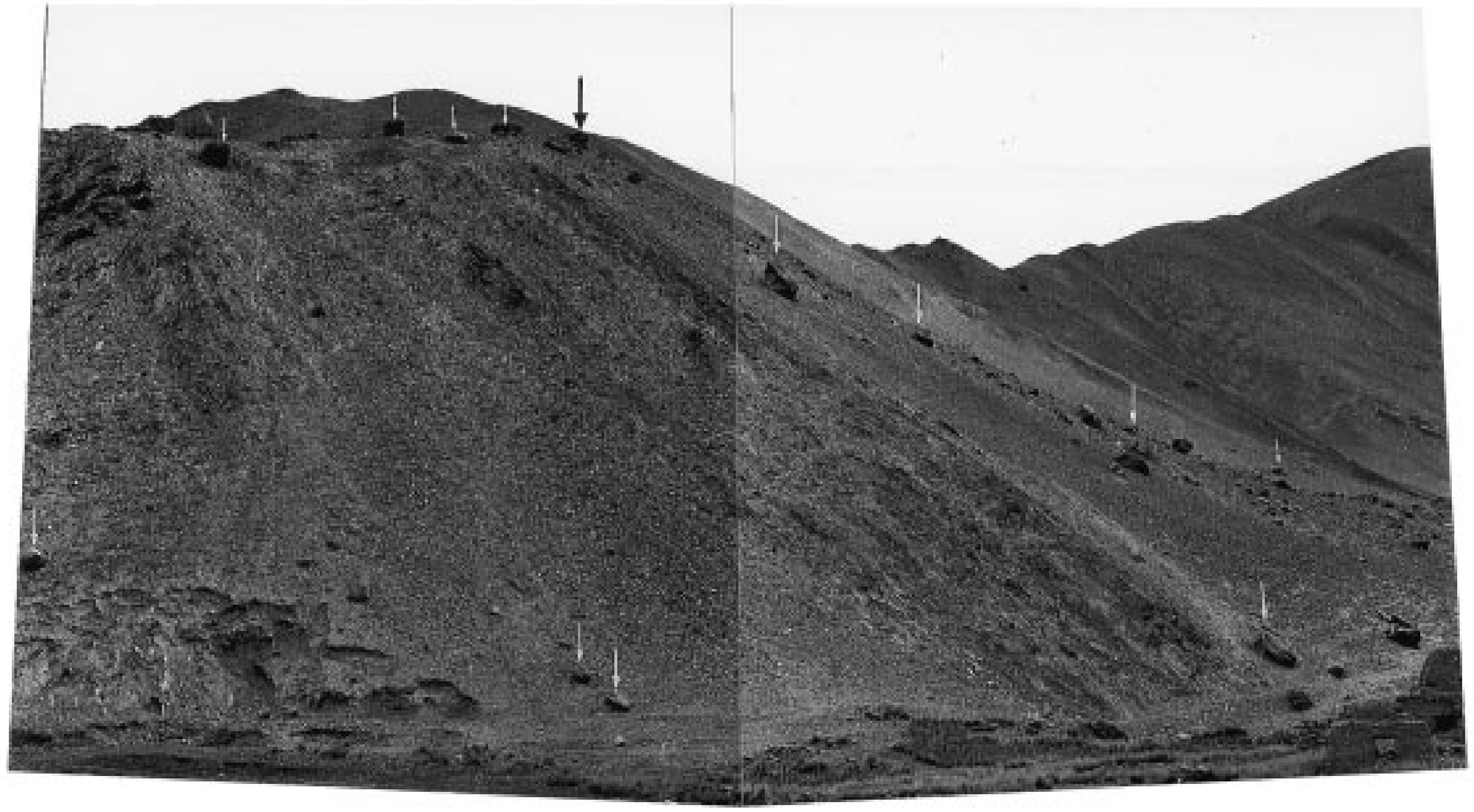
◀ **Photo 48.** Here the same rock ridge is shown as in Photo 47 (in the area of the second ■ from the left in Photo 53), but more in detail and approximately in its cross-profile. Thus the rock-hill-form (☗), which in a typical way has been created by overflowing glacier ice, becomes still clearer. At the same time a one-sided fluvial undercutting, shown by the steep escarpment, is evident. It is proved by the morphological discordance of the round profile-line to the steep escarpment, which sets in with an edge (△). The undercutting came into being by subglacial meltwater erosion. This began after a High Glacial (LGM) rounding glacier-ground-scouring in the Late Glacial at a raised ELA. Today there is a shaded frost-cliff in this place, which continues the forming of the steep escarpment. (↓) are erratic boulders; (■) is a High-(LGM)- to Late Glacial ground moraine cover, which cloakes the glacigenic 'landscape of ground-scouring'. Photo: M. Kuhle.



◀ **Photo 49.** Ground moraine (■) with erratic granite- and gneiss boulders (| ↓), covering ridges of phyllites (schist, metamorphic sedimentary rocks) (➘), which have been rounded by an older glacier-ground-scouring. Seen from c. 3750 m asl (Figure 14, No. 25; between the E- and W-Karakol valley; somewhat to the E of Photos 47, 48; Photo 53 in the area of the second ■ from the left), facing SW. Photo: M. Kuhle.



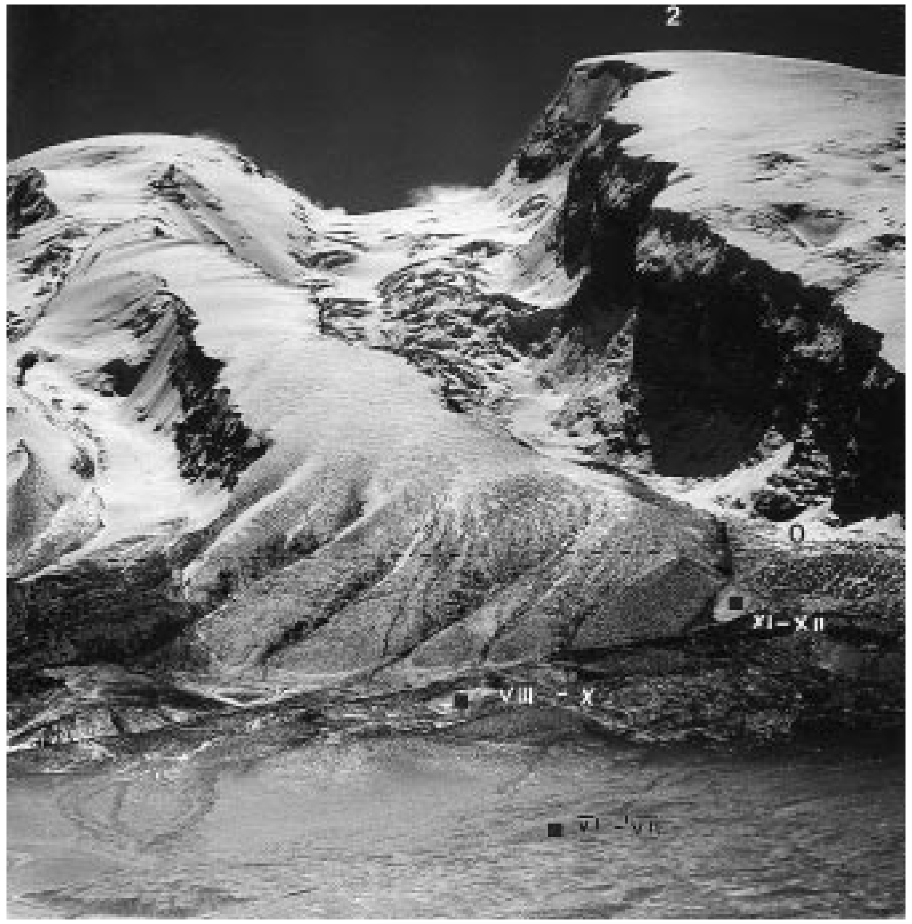
▲ **Photo 50.** From 3620 m asl, W of the valley-depths of the W-Karakol valley (Figure 14, No. 26; 38°23′N/75°00′E; Photo 53 ■ on the very left) facing W, looking at a round-polished mountain ridge. It consists of crystalline schists (schists, phyllites), of thin-stratified clay- and silt rocks, and shows a merely very thin and in places even interrupted debris-veil. Numerous erratic granite- and gneiss boulders (↓) are scattered on the mountain ridges. They must have been transported by the glacier ice from the E, beyond the valley bottom line, from the Kongur and Muztagh Ata, because this massive-crystalline bedrock only occurs there (cf. Photos 51, 52). Due to the main direction of the inclination, the ice-run-off took place from the SSE, from the Muztagh Ata, where at a horizontal distance of c. 12 km the nearest-situated bedrock of granite and gneiss occurs. In comparison with the very thick piedmont-moraines of the Kongur and Muztagh Ata, which are rich in material (cf. Photos 42–45, 53, 63, 69, 79), this very sparse High Glacial (LGM) glacigenic accumulation is striking. Two factors are the reason for this seeming discrepancy: 1. the entire E-Pamir plateau was glacier-covered, so that the most important ice masses, pushing towards the local valley bottom line, did not come from the Muztagh Ata, but from the W-adjacent plateau surfaces (see Figure 14). Thus only a small material-impulse with granites of the Muztagh Ata was possible; 2. during the LGM the ELA ran between a mere 3750 to 3950 m asl, with which these plateau surfaces must have been dominant glacigenic denudation areas down to 3600 or 3500 m asl. At the time, when the ELA had been lifted up to its Late Glacial altitude, the ice margin had retreated into the piedmont-'wreaths' of the massifs of Kongur and Muztagh Ata, so that in this locality there never existed a permanent and thus accumulation-productive belt of end moraines. The ice margin, remaining here only for a short time (Stadium I?), has just laid down these thinly scattered erratics (↓). Photo: M. Kuhle.



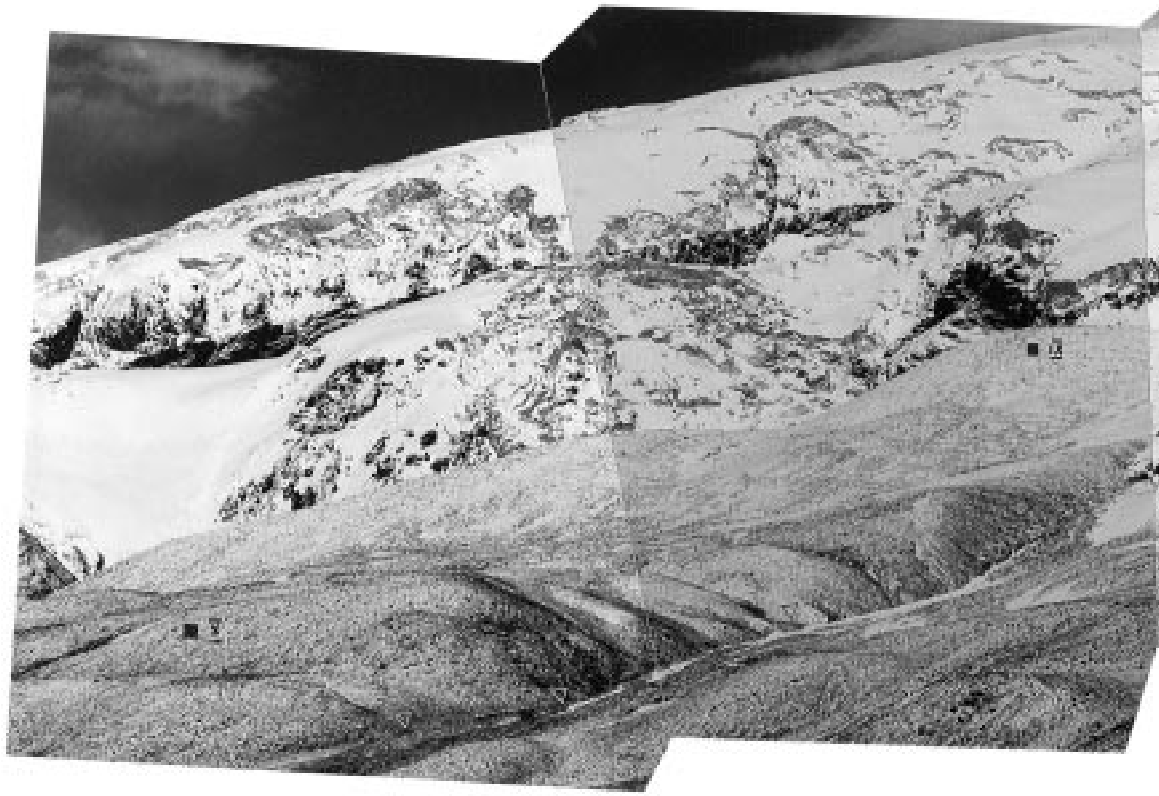
▲ **Photo 51.** View from 3620 m asl facing W. A locality somewhat N of Photo 50 (Figure 14 above No. 26) with round-polished mountain ridges from schist and a thin autochthonous debris-veil, which in many places has been broken through by the bedrock. On these ridges are lying erratic granite- and gneiss-boulders (↓) of medium to large dimensions (to compare the size see the ruin below to the right). In the pertinent catchment area of the slopes there is no granite- and gneiss-bedrock. The nearest bedrocks of this kind are to be found at the Muztagh Ata at a distance of more than 12 km. The position of the erratic boulders, but also the poverty in weathered debris on this very easily frost-weathering bedrock, provide evidence of a complete glacier ice cover of these ridges (Stadia 0 and I). Photo: M. Kuhle.

► **Photo 52.** A ground moraine remnant in the Karakol valley with erratic granite- and gneiss boulders (↓), seen from 3620 m asl facing W (locality near to that in Photo 50; Figure 14, No. 26). It lies in the northern extension of a moraine remnant WNW of the basin, which joins W of the Muztagh Ata massif (see Photo 53 ■ on the very left). In the foreground the fine-stratified structure of the bedrock schist is visible. The far-travelled erratic boulders (see Photos 50, 51) confirm a High-(LGM; 0) Glacial to early-Late Glacial (Stadium I, see Table 1) ice cover, which has led to this landscape, marked mainly by glacial erosion and thus supplied with an only insignificant moraine overlay. This landscape belongs to the High Glacial phase of development, which due to its proximity to the decreased ELA made a great part of the entire E-Pamir-plateau-surface a glacier nourishing area. Thus, this locality is far away from the area of the simultaneous end moraine accumulations. This is situated in the marginal 'outlet-valleys', as for instance the Gez valley, between c. 3000 and 1800 m asl (cf. Figure 14). Photo: M. Kuhle.

▲ **Photo 53.** From the W-margin of the bottom of the 15 km-wide basin W of the Muztagh Ata massif, 3700 m asl, in the W-Karakol valley (Figure 14 left of No. 24; Photo 58, in the middleground on the very right, behind the people), looking towards the ESE to the Muztagh Ata (2) (c. 7620 m). Close to the left-hand edge of the panorama the Kongur massif (1) is visible, situated at a distance of more than 40 km, facing NE. Below there runs the reconstructed High Glacial (LGM) E-Pamir ice level (——) at c. 4800 to 4500 m asl (Photos 42–45). The Kongur massif and its piedmont area are divided from this basin W of the Muztagh Ata (□ 3–1) by a hummocky rock threshold (◓ left-hand half of the panorama). This has been completely covered by the Ice Age glacier, as proved by hill-forms (◓), moraines and erratics (■ left-hand half of the panorama) (see Photo 47–52). Accordingly, the High Glacial glacier level (——0) ran at c. 5000 m asl. (■) and (■ I–0) in the right-hand quarter of the panorama mark plateau surfaces, covered by High- to early-Late Glacial ground moraine (see Photos 58–61 ■ I–0). During the late-Late Glacial Stadium IV there existed nothing but a piedmont glaciation in the immediate foreland of the Muztagh Ata massif (cf. synchronous circumstances on the Kongur massif: Photo 43–45). This is confirmed by relatively freshly-preserved ground- and end moraines (■ IV). Between them and the recent glacier terminals there have been documented Neoglacial (Holocene) to Historic glacier end positions (■ X–V; cf. Table 1). The exact Holocene to Historic moraine-classification has been differentiated in the forefield of the recent tongue of the WNW glacier in Photo 54 (■ VI–XIII); (cf. for Tienshan and NW-Karakorum Meiners 1996). (○) mark three of the large recent glacier tongues. The at a time older moraines are partly covered by younger glaciofluvial gravel fields (sander) of the back-melted younger glacier margins (i.e. glacier mouths). Accordingly, the entire bottom of the basin, having been covered at High- to early-Late Glacial times by the E Pamir ice (foreground), has been covered after the deglaciation by glaciofluvial gravel of the Late Glacial Stadia II-IV (□ 31; cf. Table 1). Photo: M. Kuhle, 13.06.1992.



◀ **Photo 54.** Summit of the Muztagh Ata (2) (c. 7620 m; Figure 14; 38°16′30″N/75°07′E; cf. Photo 53) seen from the basin, the Karakol valley, which is situated to the NW, facing ESE. The classic U-shaped trough valley, formed by its throughout, ie glacial and interglacial glaciation, divides the summit in two parts. Because no V-shaped-valley-phase had occurred when this valley came into being, it is the very rare example of a *primary* glacigenic valley, i.e. of a valley, which has been primarily formed as a trough valley. The summit is completely covered with glacier ice (cf. Photo 55–57). However, only the glacier, channelized by the valley, reaches the foreland of the massif with its tongue. The tongue end flows down to c. 4250 m asl (Photo 53, ○ on the left). (——0) marks the High Glacial (LGM) glacier level of the E-Pamir ice about 5000 m asl; (■ VI–′VII; cf. Table 1) indicates Neoglacial moraines of the valley glacier, which here in the foreland widened to the shape of a ‘hammer-head’; (□ VIII–X) marks its Historic end moraines, belonging to a much more narrow glacier bed, which indicates a change of the flow direction of the tongue compared with the one at present and that during the last 60 years (■ XI–XII). It was the abutment of the older end moraines which let the newly advancing (during Stadia VIII–X) glacier tongue swerve to the N (to the left) from its push-direction (cf. Photo 43 and text). Today, however, it almost follows its true push-direction in continuation of the valley-axis (see Photo 53 below the left-hand ○); (cf. for Tienshan and NW-Karakorum Meiners 1996). Photo: M. Kuhle, 13.06.1992.

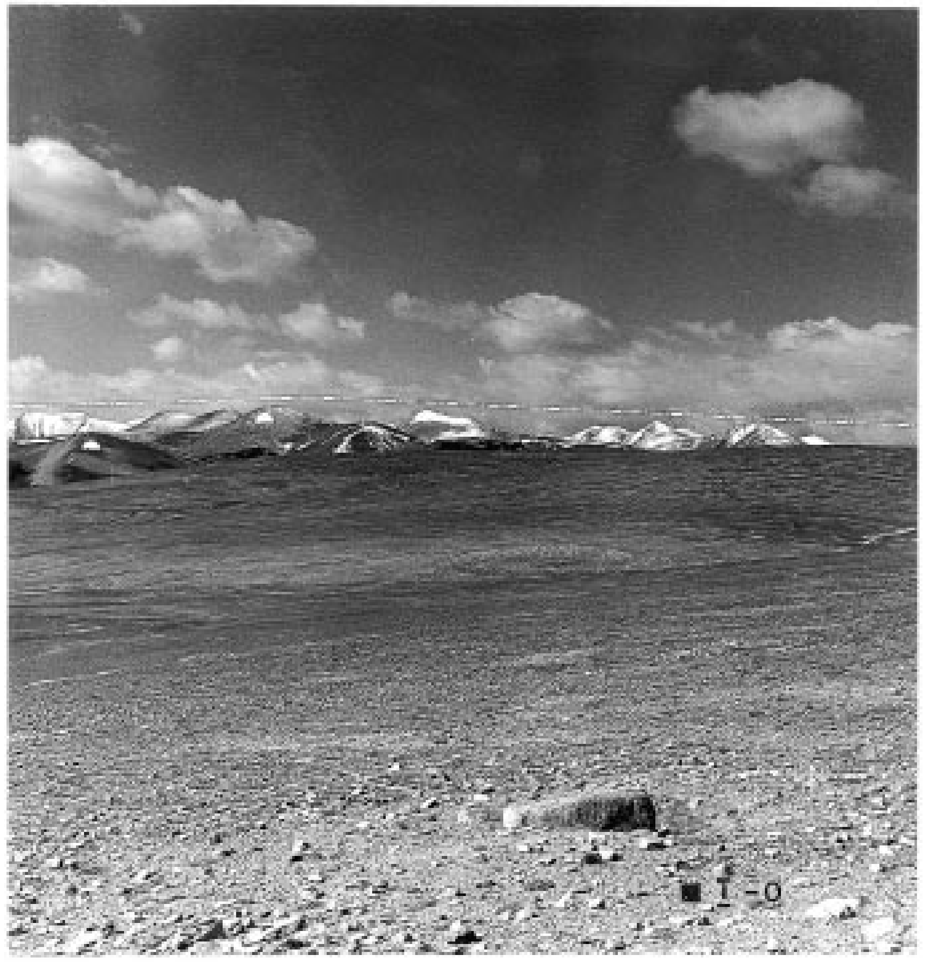


▲ **Photo 55.** From 4530 m asl (Figure 14, No. 30; 38°11′N/75°02′E) looking into the W flank of the Muztagh Ata S-spur. The panaroma reaches from the WNW flank of the main peak (2) on the very left to the N-spur of the massif on the very right, i.e. from an NE direction via E to SE. It shows the historical development of the glaciers from the Stadia VIII to the present (XII–XIII; i.e. 1992) (■). Thus, the history of the glacier margins over the course of the last c. 400 years becomes understandable (cf. for the Tienshan and NW-Karakorum Meiners 1996). The at maximum 300–400 years old ground- and end moraines (■ VIII–IX) are in the glacier-forefields in this panorama only in such places, where, between two adjacent glacier tongues, the ice recedes against the glacier surfaces in the shape of an embayment, i.e. in the area of a medial-moraine-inset (see details in Photo 57 ■ IX, VII). Here, the downward-movement of the ice margin was comparatively the least during the ELA- depressions. The glacier tongue (in the centre of the right-hand two-thirds of the panorama) has in contrast advanced very expansively (■ X) during the last c. 220 years (since the ‘Little Ice Age’, Stadium X), and, interrupted by small advances (■ XI–XII), has again melted back (XII–XIII). These glacier-oscillations reached a few decametres (■ XI–XII) to several hundred metres or even more than kilometres of horizontal distances (■ X). The present orographic ELA in this W-slope of the Muztagh Ata glacier-cover runs about 5000–5200 m asl. Whilst the highest glacier nourishing areas reached c. 7620 m asl (2), the average height of the catchment area of this glacier tongue comes to c. 5800 m. This glacier-tongue-margin with its steepness and summer cover of freshly fallen snow (the photo was taken in June) shows the characteristics of a ‘cold glacier’ with a mean annual temperature colder than –6 to –10°C (= air temperature at the snow-line level) (Chi Jian Mei and Ren Bing Hui (eds.) 1980; Ding Yongjian 1987; Kuhle 1990c, 1994a). These are at the same time the characteristics of semi-arid glaciers, indicating a relative low-precipitation, high- continental climate (ibid). Accordingly, the amount of meltwater in relation to the glacier surface is small and the glaciofluvial activities do retreat. At High Glacial times (LGM) the E-Pamir ice outlet glaciers flowed down to 1500–2000 m below the ELA. Because of this the meltwater-output beneath the snow-line was very important and has strongly affected the shaping, and thus in the narrow valleys – e.g. the Gez valley – has even superimposed the simultaneous glacigenic shaping by the valley glaciers. These marginal areas of present glaciers demonstrate the development of a gemorphological rather featureless ground moraine landscape (see Figures 16, 17) (■) as a result of the overlying cold glacier cover on a plateau-like scarcely activated relief. In this sense there is to point to the featureless glaciogeomorphology of the E-Pamir highland (Photo 58). Photo: M. Kuhle, 13.06.1992.

◀ **Photo 56.** The c. 7620 m high Muztagh Ata (2) seen from SSW (Figure 14, No. 2). In the foreground there are the ground moraine surfaces, freed from the melted glacier ice within the last max. 400 years which, according to their inclination, in the geomorphological sense are left behind without expression (■ VIII, IX, X); (cf. for Tienshan and NW-Karakorum Meiners 1996). On their surface (up to c. 0.5 m in depth) they show slight periglacial shifting of material. This took place concordantly with their primary ground moraine surface. A slight reshaping occurred – dependent on an undercutting by a bottom line in the bedrock (▼) – by way of meltwater erosion (▽). The mountain ridges, still reaching 2500 m further upwards, are covered by c. 150–250 m thick glacier ice. The largest marginal crumblings of the ice cover are c. 100 m high. In this connection one might venture some speculative thoughts: in case this peak (2), which in the upward direction becomes flatter in a dome-like manner, would undergo a complete deglaciation with an ELA increase of at least 2500 m, the ground moraine cover would get more and more thin at a decreasing altitude of the catchment area. At least, there just would occur some local out-broken moraine blocks, close to the summit. As a result of this, we would have the same sight up there as today in the most central high areas of the Ice Age E-Pamir plateau-ice (see Photos 58, 59, 60, 62 and 68 every ☗). Photo: M. Kuhle, 13.06.1992.

▶ **Photo 57.** Same position as Photo 56 (Figure 14, No. 30), seen towards the E to the major summit of the Muztagh Ata S-massif-spur (2). (■) mark somewhat older (VIII) and younger (IX) ground- to medial moraine ridges, having been deposited in historical times before c. 400–180 years. These moraine depositions suggest, that the thickness of the glacier ice, covering the mountain ridges in the background, must have been in its distal areas about 50–100 m thicker than today. Accordingly, the ice of the catchment area (below 2) also cloaked the relief of the mountain ridges somewhat more thickly. This must have led to a more extended cohesion of the glacier surface as a result of the levelling of the underlying relief, going hand in hand with the thickness of the ice. At that time the glacier surface must have had fewer crevasses. Photo: M. Kuhle, 13.06.1992.

▲ **Photo 58.** From 4400 m asl at the western foreland of the Muztagh Ata assemblage (Figure 14 to the left, above No 30; 38°13′N/75°01′30″E) from towards the SW (left edge of the panorama) to the NW (right edge) seen across the E-Pamir plateau. (18) is a 5541 m-high peak, which sits on the plateau, which after the High Glacial deglaciation of the E-Pamir plateau still has shown a Late Glacial (I–IV) cirque-glaciation (○) (Figure 14, No. 27). (○) marks further Late Glacial cirques in similar high peak superstructures (as 18), towering above a glacially round-polished plateau surface (☗). (——0) indicates the High Glacial (LGM) E-Pamir ice-surface, reconstructed with the help of the altitude up to which the glacigenic mountain-roundings stretch. It reached at least 5550 m asl and thus an ice thickness of 1200–1300 m (cf. Figure 14). Besides the round-polished hills and mountain ridges (☗), the short U-shaped- and trough valleys (‘short-troughs’), lying in between, are key-forms of this glacial landscape. (■) shows ground moraine covers with erratic granite- and gneiss boulders (Photos 59–61), which overlie the metamorphic bedrock schists and phyllites in the underground, and must have been transported there by the glacier ice-flow from the Muztagh Ata massif. This ice-thrust and ice-flow within the completely covering E-Pamir-ice can be explained by the more important altitude of the Muztagh Ata massif of 2500 m. Due to the steep incline of the slope and thus enlarged gravity gradient the flow increased. (■ I–0) marks the High- to Early-Late Glacial ground moraine, which has been rolled out into the high plateau up to a greater distance from the foot of the Muztagh Ata (Photos 59–61); (■ III–IV) shows the younger overlying Late Glacial ground moraine cover at a minor distance from the mountain foot (see Figures 9, 10). Photo: M. Kuhle.



◀ **Photo 59.** From 4000 m asl on the E-Pamir plateau at the Subax pass (Figure 14, No. 29; Photo 53 right-hand margin, 38°16′N/74°54′E), facing W. (■ I–0) is the High- to Late Glacial ground moraine cover, which contains erratic granite boulders (left-hand above ■). These have been transported here from the Muztagh Ata massif, situated to the E. As a result of the large, slightly inclined surface at about 4000 m, the glacier ice cover could increase to a level of about 5500 m asl (——) (probably even somewhat higher). This is suggested by the round mountain forms (☁). Extended Ice Age ground moraine is absent there (similarly to the high-lying Scandinavian fjell-landscapes), because this is a sheer glacigenic erosion-landscape. The High Glacial glacier cover was cold-semi-arid (high-continental) and therefore cold-based and broadly frozen to the rock-sub-surface of the high plateau. The simultaneous jerky movements of the ice led to exarations and extractions of rock-fragments, which have been broken out of the bedrock. (——) shows the approximate crest between the ice-run-off to the N (right-hand), down to the Karakol- and Gez valley, and to the S (left-hand), to the basin of Tahman. Photo: M. Kuhle.

◀ **Photo 60.** From c. 3990 m asl, from somewhat N of the Subax pass (Figure 14, No. 29; 38°16′10″N/74°54′E; between the localities of Photos 59, 61) seen towards the WNW (cf. Photo 58 right-hand third). (■ I–0) indicates High- to Late Glacial ground moraine with erratic blocks of massive-crystalline rocks (●), which, isolated from each other, are bedded ('swim') in a fine ground mass (see Figures 11 and 12). (——0) marks the E-Pamir ice surface above the mountains (☁), round-polished by the ice cover during the LGM. (○) indicates Late Glacial cirques (peak 18 is 5541 m high; see Figure 14, No. 27, I–IV), which have somewhat sharpened the higher summits. Peak 18 has perhaps pierced the High Glacial plateau ice cover and because of this already received its crest and sharp form. Photo: M. Kuhle.

▲ **Photo 61.** Exposure of ground moraine at c. 3960 m asl, 3 km NE of the Subax pass (Figure 14 between No. 29 and 24; 38°16′30″N/ 74°56′E; Photos 53, 58–60 ■ I–0), facing SE. This ground moraine cover cloaks a soft-shaped rock threshold of the E-Pamir plateau, which reaches up to c. 4100 m (background). The ground moraine cloak (■ I–0) of this convex full-form proves an extended, completely relief-covering ice-thickness. Therefore, this ground moraine cover has to be classified as High- to early Late Glacial. Towards the N this ground moraine reaches down to at least 3700 m, where it submerges beneath younger Late Glacial glaciofluvial gravels, i.e. sediments of the basin-bottom (Figure 14, No. 24; Photo 53 □ 3–1). The material is very tightly pressed, relatively rich in fine-material (Figures 11, 12) and contains polymict boulders. The dark, edged boulders (○) and the debris stem from the bedrock of the underground (local moraine); the light boulders (granite, gneiss) are regularly rounded and erratic (○). They come from the Muztagh Ata (far-travelled moraine). Several of the erratic boulders are dissected by Post Glacial frost-weathering into fragments with some sharp edges. Post Glacial shifting of debris by solifluction only takes place in the upper 20–40 cm of this 3 m-high exposure (above ——). The covers of boulder clay, in this picture and in Photos 58–60 referred to as being ground moraines (■), can be explained in their topographical arrangement of the positions by no other transport-mechanism as mudflows or long distance solifluction. Photo: M. Kuhle.

▲ **Photo 62.** 3800 m asl, S of the Subax pass, in the incline of the upper Tahman valley (Figure 14 between No. 29 and 32; 38°11 ′30″N/74°55′E; Photo 58 left-hand third, background), facing W across the E-Pamir highland. Polished round by the ice during the High Glacial (LGM), the glacigenic denudation landscape and the E-Pamir ice surface (——0), which has been derived from its morphology, are visible in the background. (■ I–II) mark moraine ridges, built up during the down-melting of the High Glacial ice to the smaller Late Glacial ice cover. They have been pushed together from ground moraine material (Figures 20, 21), when the previously covering plateau ice had already begun to separate in several branches of valley glaciers. Due to this more small-scale differentiation of the ice-run-off – in this place three ice streams flowed together to the Tahman outlet glacier (one of them from the right-hand in the foreground ■, a second between ■ I–II right and left in the centre, and a third joined at ■ on the very left) – these moraine ridges were first formed as medial moraines and lastly as lateral moraines (cf. Photos 65–68). They are built up from important portions of large erratic granite- and gneiss boulders. (■) mark the pertinent ground moraines in the valley bottom, which are very rich in boulders, too; (□) is a recent glaciofluvial gravel track, which was – and still is – washed out of this ground moraine by the periodic meltwater. Photo: M. Kuhle.

► **Photo 63.** From 3630 m asl from the area of the flatly-incised talweg of the Tahman valley (Figure 14 above No. 32; 38°08′30″N/74°58′E; Photo 69 on the left-hand edge in the background) facing E, seen to the Muztagh Ata massif (2). Its foreland (piedmont area) belongs to the E-Pamir highland; the recent glaciers of the SW slope are adjusted to its level at about 4300–4700 m (see left half of Photo 69; 71). Historic to Neoglacial piedmont moraines (lateral- and end moraines) continue at the foot of Muztagh Ata (centre) (cf. for Tienshan and NW-Karakorum Meiners 1996). From this viewpoint they are hidden by the Late Glacial moraines (■ IV ■ III), which have been transported farther into the foreland. This late Late Glacial end moraine landscape looks very irregular and strikingly younger than the featureless ground moraine platform in the foreground (■ 0–II). It has been built up during the High Glacial (LGM) (0) up to the early Late Glacial (Stadium I–II) (Figures 20, 21). The younger, i.e. late Late Glacial (Stadium III) dumped end moraines are adjusted to its surface; that means, the partly very coarse-blocked (○) young landscape of piedmont-moraines (■ III) (Photos 64, 65) has been deposited on the ground moraine, which primarily had covered the E-Pamir high plateau. Due to its higher position on a rock threshold, the older ground moraine material without a younger end moraine cover juts out into the Muztagh Ata massif towards the E in the area of (■ 0–II) (see somewhat left of ■ 0–II Photo 58 ■ I–0). (0——) marks the High Glacial ice level, which rises up from c. 5200 m (below 2) to the right-hand side into the valley, and further into the massif, up to 5500 m. (◓ ◥) indicate glacigenically rounded, truncated, and abraded spurs, which end with upward progression and thus make the ice level (0——) plausible. Photo: M. Kuhle.

▲ **Photo 64.** Exposure of end moraine at 3570 m asl in the upper Tahman valley, here still shaped like a flat trough, in the WSW foreland of the Muztagh Ata (Figure 14 above No. 32; 38°08′N/74°58′E; close to the viewpoint of Photo 63). The moraine has to be classified as being of the Late Glacial Stadium III (Photo 63). In comparison with a ground moraine (cf. Photo 61), the loose interior and superficial fabric, characteristic of an end moraine, is visible here. The ground mass (■) is coarser and not as heavily-compressed; there is a greater portion of larger components and boulders. In a characteristic way, the boulder-portions in this end moraine increase upwards, covering its surface with an approximately degree of 50%. But the degree of roughness of the end moraine surface is also significantly greater than that of the ground moraine (cf. Photo 61). This does not merely derive from the greater quantity of boulders, but also from the fact, that the end moraine boulders at increasing size are 'swimming up' more easily and have therefore multiplied. This means that they are not just pressed to the surface, but are even pressed out of the surface formation, on which they are now deposited in a greater quantity (Kuhle 1991b, p. 130). (As for ground moraines, however, the overlying ice-burden even holds back the largest boulders in the general surface level of the moraine; see Photos 59, 60). The end moraine contains erratic boulders of massive-crystalline rocks from the Muztagh Ata massif as well as metamorphic sedimentary rocks. The boulders are mainly edged to round at the edges. They have been transported here over a distance of about 12–20 km. Since the Late Glacial the boulders, deposited on the end-moraine surface, have undergone heavy frost-weathering – due to the inner Asian highland climate, which is rich in frost-changes. Photo: M. Kuhle.

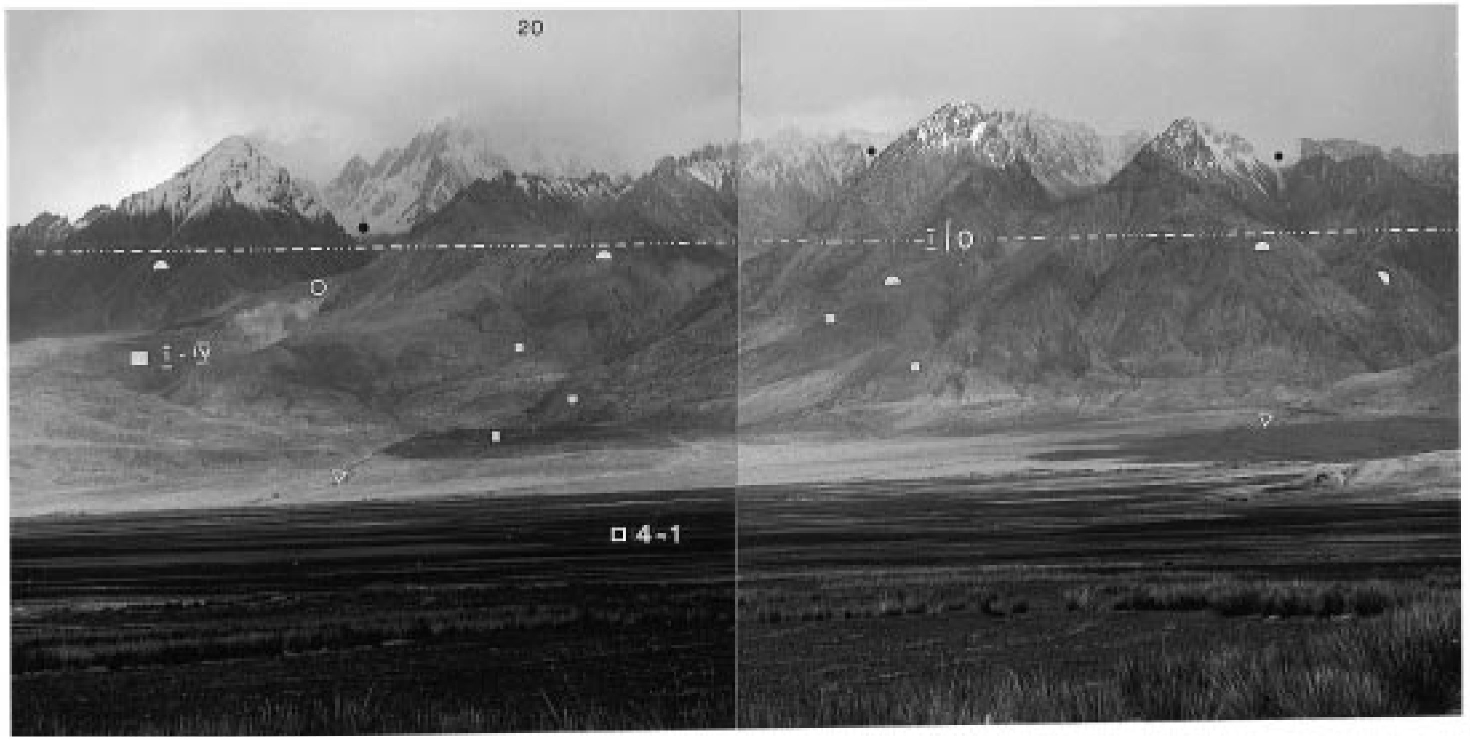
▲ **Photo 65.** From 3550 m asl, from the bottom of the Late Glacial (Stadium III) tongue basin, which crosses the talweg of the upper Tahman valley (Figure 14, No. 32; 38°07′45″N/74°57′45″E), facing ESE, seen to the E-Pamir plateau. The farther view is obstructed by older Late Glacial ground-, medial- and end-moraine accumulations (■ I–II, ■ II, ■). A younger glacier tongue, quickly advancing over a distance of 12 km from the Muztagh Ata massif and its WSW foreland, has encountered and at the same time scoured these moraine hummocks (■ III). (▼▼ white) mark the margin of the glacier tongue, which is preserved strikingly fresh by this ground moraine edge. When the older moraines partly became overthrusted, the large polymict boulders (○) have been integrated into this younger ground moraine and at the same time dislocated. (▼▼ black) indicate finely staggered moraine edges, which provide evidence for a glacier retreat, overlapped by seasonal ice-margin oscillations. Thus, these are a sort of 'wash-board moraines'. Photo: M. Kuhle.

▲ **Photo 66.** From 3350 m asl from the flatly-embedded talweg of the Tahman valley (Figure 14 between No. 32 and 31; 38°05′N/75°E) towards the SW, looking to the soft-shaped mountains of the E-Pamir plateau. (19) is a 5568 m-high mountain, which reaches the ELA. (——0) marks the High Glacial E-Pamir ice level (LGM); it stretches over the mountain ridges (☁), which were polished round by the ice. (■ I) shows 25 m to at least 120 m high ground-, medial-, lateral- and end moraine ridges of the early Late Glacial glaciation (Stadium I) (cf. Photo 68). At this time the E-Pamir ice had already melted down so far that it was separated into a tributary stream network; its surface was broken through by medial moraines. The two Late Glacial ice-streams, joining in this place (one came from the right-hand side, i.e. down the Tahman valley from the NW; the other from the mountains (○) in the SW), at last have even been channelized by these moraine ridges. The ground moraine slopes, rich in fine material, which were heavily compacted by the ice-pressure, show horizontal exaration-rills and related fluidal-textures, so for instance undulation-depressions and lineaments, as traces of passing glacier ice (▼). In places there can also be observed kame-like slope ledges as indicators of a glacier level (↓), decreasing in steps. It is of importance that this is a landscape of combined moraine-types: due to the reduction of the ice-overlay on the E-Pamir plateau from the High- to Late Glacial, they have been modified by the reshaping of High Glacial ground moraines. Therefore the ground-moraine-like high portion of fine material, understandable by heavy grinding, and the strikingly higher degree of compaction than that of primary moraine walls, caused by repeated glacigenic reshaping, is of fundamental importance for this glacial landscape (see also Photo 67). (▽) marks a late Late Glacial fan, built up by mudflows and formed from moraine material, which was received and dislocated by the surge of a discharging ice-dammed lake in the mountains (background). It shows a major portion of granite boulders. The fan was built up at a time, when those mountains had only shorter local valley- and cirque glaciers (○) (Figure 14, No. 28). Photo: M. Kuhle.

▲ Photo 67. From c. 3350 m asl, from approximately the same locality as Photo 66 (somewhat further down the Tahman valley), but in an opposite direction, seen towards the NE to the Muztagh Ata massif (2). Due to the arrangement of their positions with respect to the ELA, to the topography of the prehistoric glacier nourishing areas and to the configuration of the older ground- and younger end moraines, these also more than 100 m-high moraines (as on the opposite valley side, Photo 66) (■) are to be classified as belonging to the Late Glacial of Stadium II (see Figure 14 between No. 32 and 31; cf. Photo 69 ■ III–I). This moraine material (cf. Photo 66), too, has undergone a geomorphological metamorphosis – up to a pedestal-moraine with the characteristics of a ground moraine. In the piedmont area of the Muztagh Ata the moraines have been pushed by local dam-glaciers (cf. Photo 71 ■ III–I) against the transverse flow of the Late Glacial Tahman outlet glacier, coming down from the E-Pamir plateau. Therefore this moraine ridge (■ II) received the position and channelizing function of an orographic left-hand lateral moraine of this outlet glacier. Its steep slopes are exposed by Post Glacial fluvial erosion-rills and reveal a greenish-brownish gleaming fine ground mass. This points to greater portions of sericite, green schist or phyllites. (▽) indicates a further characteristic feature of morphodynamic after deglaciation: a small mudflow-fan, having been transported out of the small V-shaped moraine valley (above ▽). Photo: M. Kuhle.

◀ Photo 69. From c. 3300 m asl from the exit of the side valley (Figure 14, No. 33; 37°55′20″N/75°05′E), which as a trough-valley leads down from the 5568 m-high massif (Photo 66 (19)) towards the NE to the Tahman basin, seen to the Muztagh Ata massif (2), facing N. (■ I) marks an orographic left-hand lateral moraine of the Late Glacial valley glacier, which has left this valley (see Figure 14, No. 33). The pertinent valley-glacier-end has spread to the foreland, i.e. to the bottom of the Tahman basin, in the form of a ‘hammer-head’ (■). However, it does not reach its talweg (Photo 70 □ 4-1). The recent stream (□) cuts the ground moraine (■) (see Figures 22, 23) to a depth varying from some decimetres to some metres. Thus one can recognize that this piedmont glacier tongue reached down to an altitude of at least 3200 m asl. A reshaping of this piedmont area by moraine material, dislocated through mudflows, which has been deposited in flat fans (e.g. on the E margin of the Tahman basin: ▽), is probable. (——0) marks the High Glacial glacier level along the truncated spurs and glacigenically-rounded valley exits (◠ ◢) from the Muztagh Ata (2) via the large S- (20) and SE-spurs (21) of the massif (Photo 70). This ice level ran at 5000–5200 m in the area of (2) (Photo 63 ——). In the area of (20) (further to the right) up to the Tahman basin it dropped to c. 4200 m. With the help of the same indicators (◠) for a pre-historical glacier level (—— -I/0) marks a former ice surface about 3700 m, c. 600 m above the floor of the Tahman basin. Due to the persisting uncertainty of the last High Glacial ice filling (0) of the Tahman basin, there has been taken into consideration a possible ice filling during the pre-last High Glacial (-I) (= Riß-Ice-Age). (■ IV) and (■ III–I) indicate the piedmont moraines (moraine pedestals) of the Late Glacial in the foreland of the Muztagh Ata (Photos 63, 71). Photo: M. Kuhle.

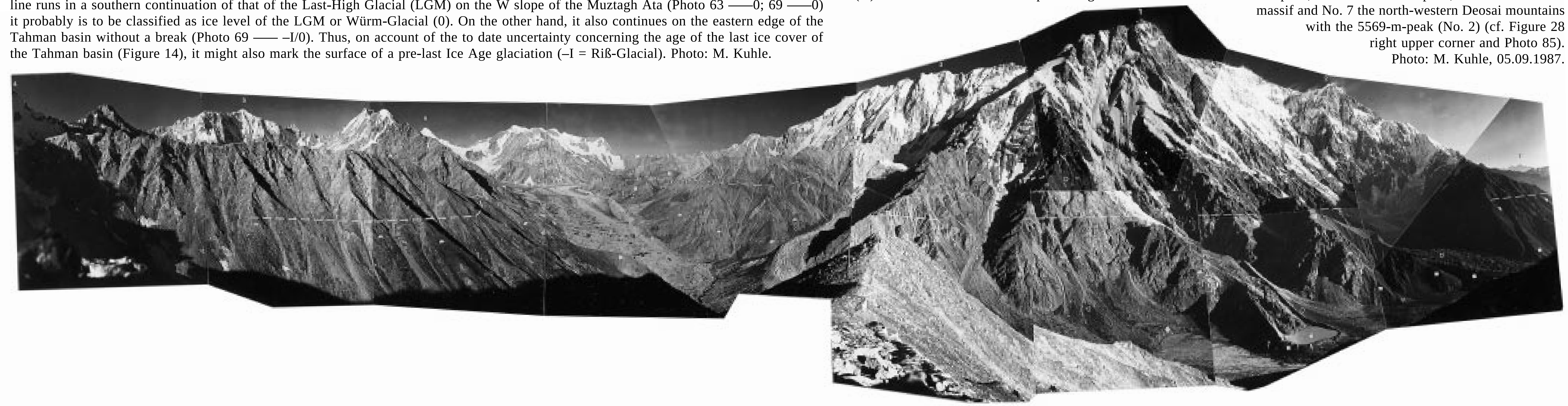
▲ Photo 68. From c. 3700 m asl in the upper Tahman valley (Figure 14 between No. 29 and 32; 38°07′45″N/74°58′E) facing SW across the mountains of the E-Pamir highland, which are polished round by the ice (◠). These mountains were built up from granite and show a geomorphological relationship and similarity of the landscape to the ‘fjells’ of the Scandinavian highland and Spitsbergen (Svalbard), e.g. Dicksonland. This similarity extends as far as to the snow-patches and nivation-ledges, the solifluction covers of minor thickness and the soft depression profiles, which have been periglacially modified since deglaciation. (——0) marks the minimal E-Pamir ice surface, provable by the glacigenically rounded mountains. (■ I) indicates a Late Glacial ground moraine ridge, which was laid down between two courses of the ice run-off down to the Tahman basin. (▼) mark fine edges on its slope, which have either been created by the pressure of the bottom of a tributary stream, flowing off here, or which can be explained as kame-like deposition-edges, deposited against a dead-ice body during the last phase of deglaciation. The reason for this could be a subaerial rinsing of the ground moraine slope towards an ice margin, which has been gradually laid lower. Photo: M. Kuhle.



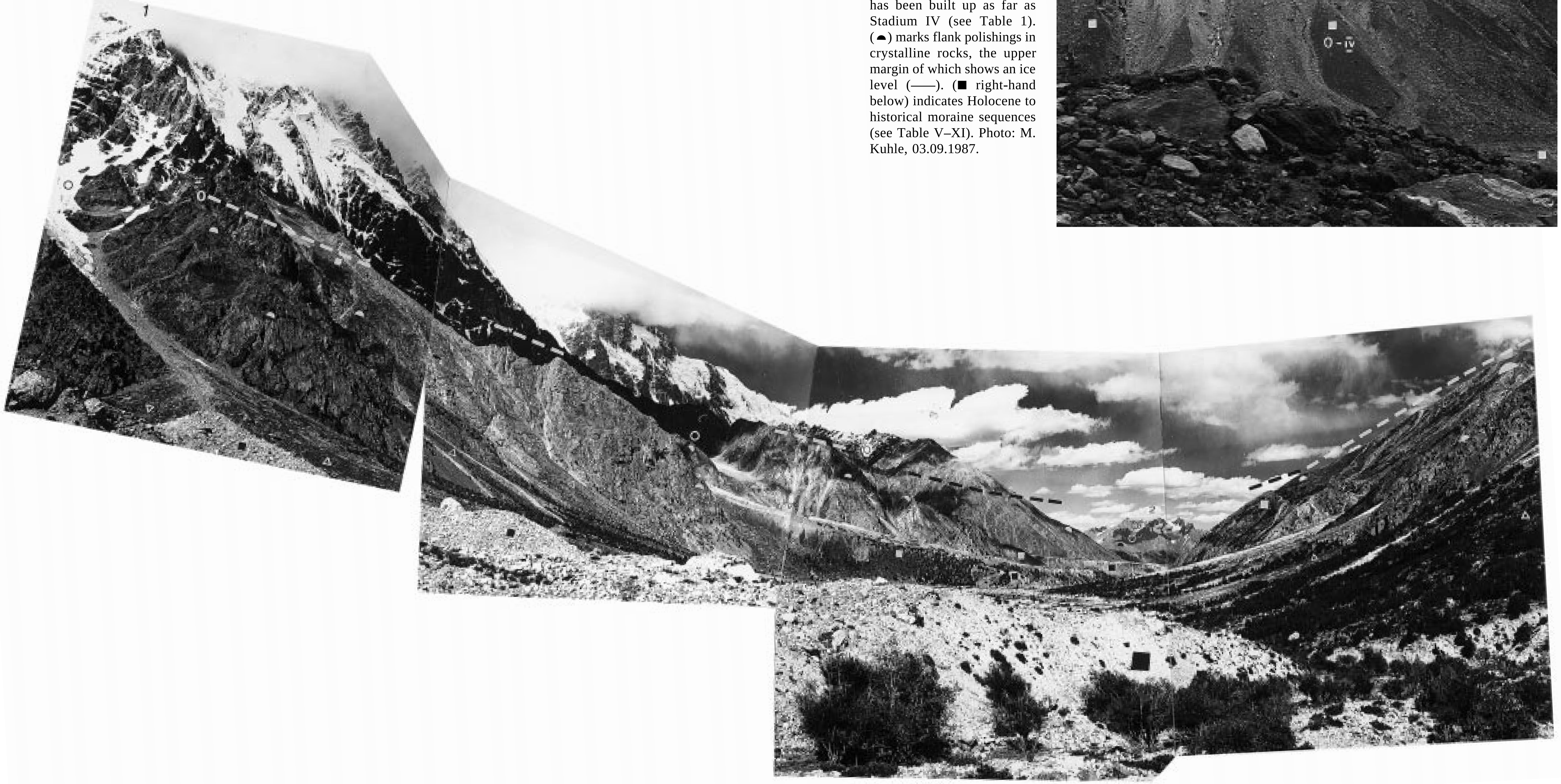
▲ **Photo 70.** Looking from c. 3080 m asl from the bottom of the Tahman basin (Figure 14 right-hand of No 33; 37°56′N/75°10′E) facing N to the S-spur of the Muztagh Ata massif. (20) is the c. 6500 m-high S-satellite peak of the Muztagh Ata (covered by clouds in its upper part). Today this mountain section is still rather heavily glaciated. However, the recent valley glaciers (●) no longer reach the valley exits, visible from here. (○) is a dumped end moraine, which at least contains dead-ice; possibly it is even a 'living' glacier tongue – completely covered with surface moraine – , i.e. a tongue, which is still connected to the actual glacier nourishing area. (■ I–IV) marks the large historical, Neoglacial to Late Glacial complex of piedmont moraines. Below this glaciofluvial gravel field (sander) (□ 4–1), belonging to these glacier positions, High Glacial (LGM = 0) ground moraine is probable; at least ground-moraine- like sediments dip marginally below these gravel fields. Only the oldest Late Glacial glacier ends with their moraines (■) have reached the steep steps below the four hanging trough-valley exits. The reason for this is that the crests of the surrounding mountains, i.e. the glacier nourishing areas of these high valleys (short-troughs), only reach an altitude of 5800–5200 m. (▽) indicates mudflow- and glaciofluvial gravel fans, containing material which has been transported across those steep steps below the hanging troughs. They are still active and therefore adjusted to the basin-bottom (□). The primarily tectonically shaped triangular slopes along the line of the mountain-spurs between the exits of the hanging valleys, have either been polished back by glacigenic flank abrasion in the way of truncated spurs – or at least have been polished round (☗ ◤). (—— –I/0) marks the upper margin of these traces of flank polishing. They run at c. 4700 m (left-hand edge) up to 4300 m (right-hand edge). Because this scour line runs in a southern continuation of that of the Last-High Glacial (LGM) on the W slope of the Muztagh Ata (Photo 63 ——0; 69 ——0) it probably is to be classified as ice level of the LGM or Würm-Glacial (0). On the other hand, it also continues on the eastern edge of the Tahman basin without a break (Photo 69 —— –I/0). Thus, on account of the to date uncertainty concerning the age of the last ice cover of the Tahman basin (Figure 14), it might also mark the surface of a pre-last Ice Age glaciation (–I = Riß-Glacial). Photo: M. Kuhle.

► **Photo 71.** View from the foot of the 5668 m high massif (Figure 14, No. 33) facing N to the Muztagh Ata massif (2). (■ 0–I) marks High- (LGM = 0) to Late Glacial ground moraine, reshaped by mudflow activities, in the western marginal area of the Tahman basin (37°58′N/75°02′E). The moraine material has been deposited in the mountain foreland by the two valley glaciers, which flowed down from the 5568-m-massif towards the NE. Beyond the talweg of the Tahman valley (in the shadow) there are Late Glacial piedmont moraines (■ III–I) in the western to south-western foreland of the Muztagh Ata. Some of the recent mountain valley glacier tongues (●) are adjusted at c. 4300–4500 m asl to the proximal areas (the roots) of this probably up to several hundred metres thick pedestal-(dam-) and dumped end moraines in the mountain foreland. The scour lines of the triangular-shaped slopes between the valley exits (☗ ◤), which have been rounded by the Historic glacier ice, mark a High Glacial glacier level (——0) between 5200 m (below 2), 5000 m (on the very left) and 4700 m asl (on the very right). Photo: M. Kuhle.

▼ **Photo 72.** View from 4702 m asl from the N crest (point 4702 m; 35°16′N/74°36′38″E; Figure 28 right between No. 19 and 23) of the 5584 m peak towards the SSW (left-hand edge of the panorama) via W (upwards the Toshain valley glacier), NNW to the Nanga Parbat peak (No. 1, 8125 m), to the NE (right-hand edge of the panorama) with the Bazhin glacier (for its history see Table 2). The Nanga Parbat S slope forms the orographic left-hand valley flank of the Rupal Gah, falling away 4500 m from the peak (No. 1) down to the valley bottom with its gravel floor (◇). This mountain – i.e. valley flank reaches an altitude of 6000–8000 m on a crest-length of c. 22 km. Besides Nanga Parbat, such summits as the Mazeno Peak (No. 3), Rakhiot Peak (No. 2) and the Chongra Peaks (covered by No. 2) belong to it. The crest of this Rupal valley flank is still today continously glaciated. It has supplied the High Glacial Rupal-Astor ice-stream network with high-yielding tributary glaciers. (——) marks the High Glacial surface of the ice-stream network; (◤ ☗ ◥) the glacigenic flank abrasions and -polishings; (■) are High-, Late- and Post Glacial moraines and moraine material; (□) present glaciers, covered with surface moraine; (○) cirques, cirque cornices and nivation funnels; (▽) debris cones and mudflow fans, combined – in this single case (◆) – with a rock fall. (◇) indicate glacigenically-induced deposits of debris (outwash, sander); (●) is a moraine lake of the Rupal wall-glacier. No. 4 marks the 5584-m-peak; No. 5 the 5950-m-peak; No. 6 the 6325-m-massif and No. 7 the north-western Deosai mountains with the 5569-m-peak (No. 2) (cf. Figure 28 right upper corner and Photo 85). Photo: M. Kuhle, 05.09.1987.



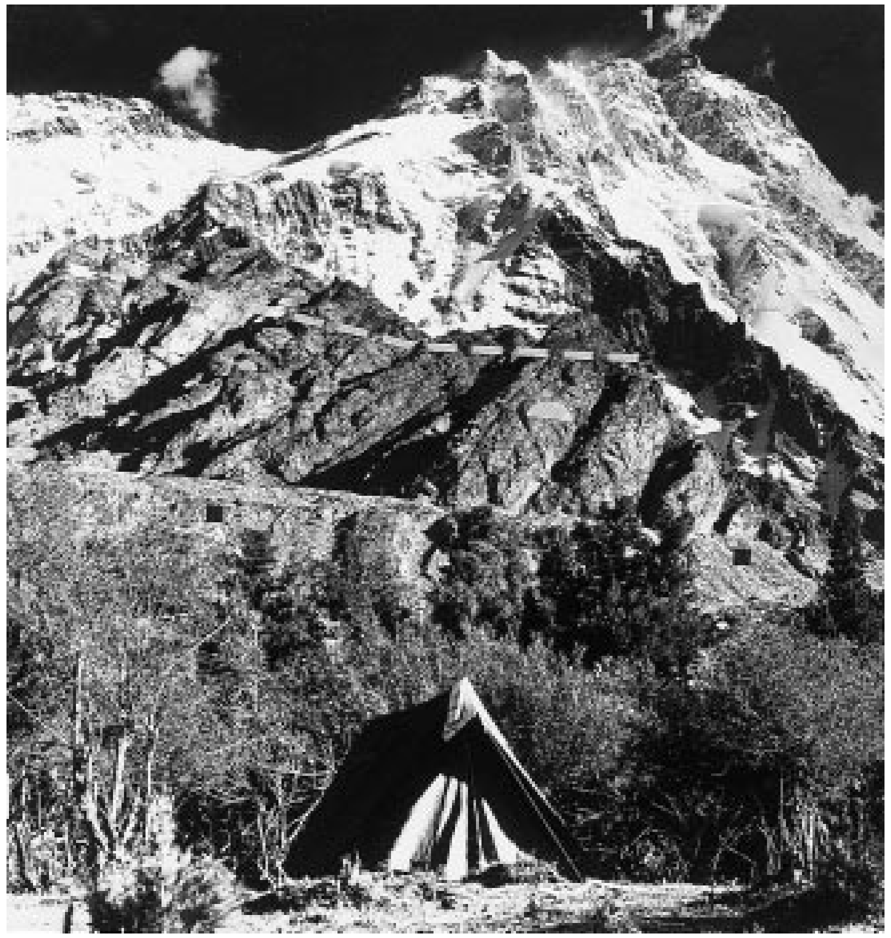
▼ **Photo 74.** From the Shaigir locality in the Rupal Gah from 3660 m asl (Figure 28 between No. 4 and 19) down-valley towards the ENE to the massif of the 5718-m-peak (No. 2) with its cirques and present glaciers (○). The High Glacial trough profile of this main valley has been buried by Holocene debris- (▽) and moraine masses (■), above all from the Nanga Parbat S flank (No. 1), rising more than 4000 m above the valley bottom (x). In this connection mainly the present and recent glacier tongues of this mountain flank (left half of the panorama) have reshaped and dissolved the High Glacial orographic left-hand flank polishing (◣ ◣) up to the polish line (0——). Accordingly, on the orographic right-hand less high valley flank, the High- to Late Glacial flank polishing (◤ ◤) has been entirely well preserved up to the polish line (——). (○) mark Late Glacial (cf. Table 1, Stadia I–IV) cirque forms in the Nanga Parbat flank as well as those, which are still active today. Between the valley-blocking end- and dumped end moraines of the Shaigiri glacier (■ large in the foreground) and the Rupal wall-glacier (second ■ from below) there is a dammed-up historical (x-6) to actual glacial gravel field (cf. Table 1) (cf. Photo 76). The photo proves a destruction of the Ice Age forms by the Holocene glaciation, linked with the relief energy. Photo: M. Kuhle, 02.09.1987.

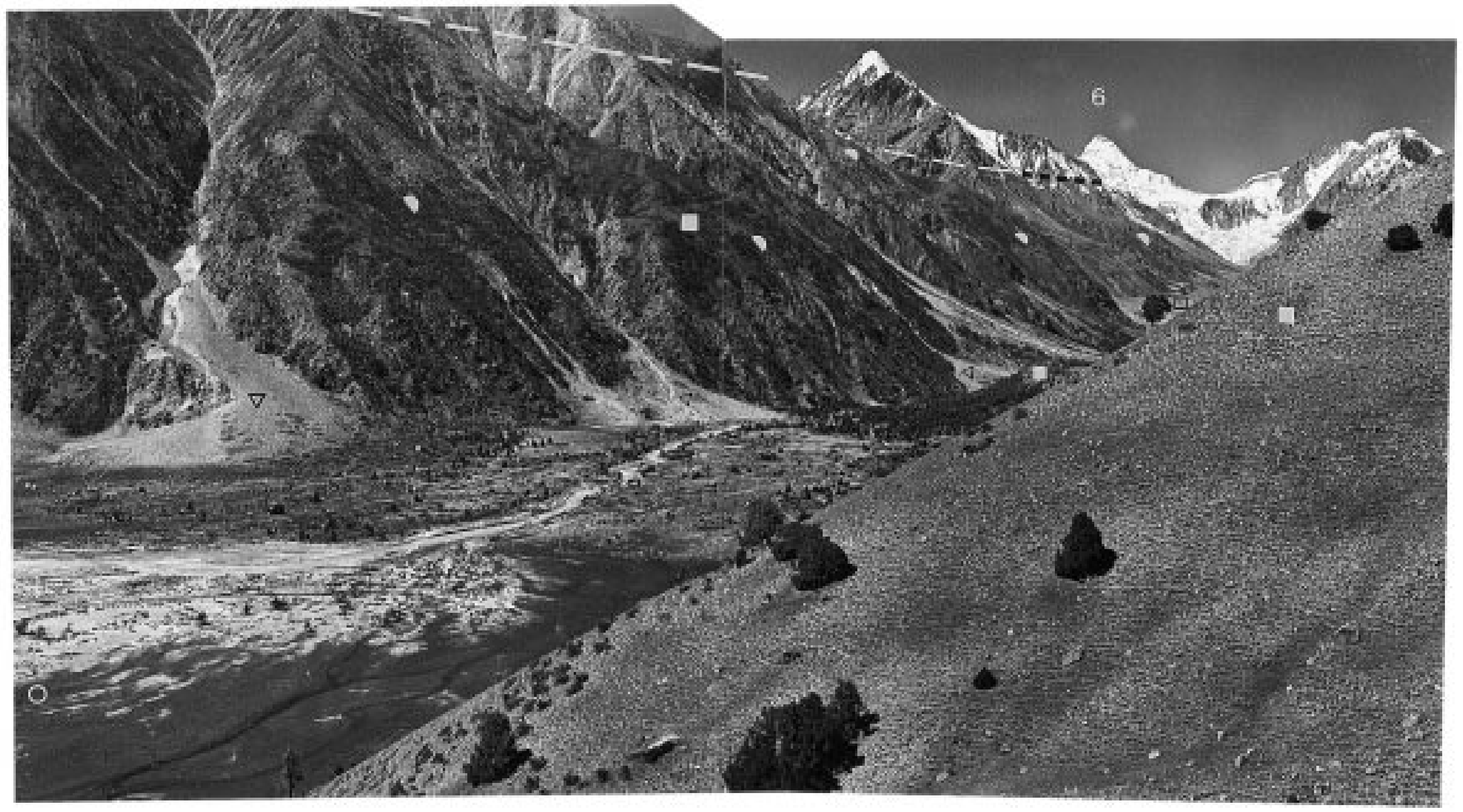


► **Photo 73.** Looking from 4170 m asl into the orographic right- hand flank of the Geshard valley (5950-m-peak-valley) (Figure 28, No. 15) to the 5584-m-peak (No. 4) towards the E (Figure 28, No. 17). (■ left-hand and centre) mark a moraine pedestal (Figure 28, No. 18), which has been pushed out of the cirque (with the present glacier tongue □) against the parent-glacier. It has a High Glacial (LGM) core (0) and has been built up as far as Stadium IV (see Table 1). (◓) marks flank polishings in crystalline rocks, the upper margin of which shows an ice level (——). (■ right-hand below) indicates Holocene to historical moraine sequences (see Table V–XI). Photo: M. Kuhle, 03.09.1987.

▼ **Photo 76.** View from 3575 m asl from the surface of a mudflow fan in the valley floor of the Rupal Gah (Figure 28 left-hand of No. 6), seen up-valley towards the SW. (1) is the 6325-m-peak, (2) a nameless c. 6000 m high spur-peak (Figure 28, No. 12) ESE of the Toshe Gali (5122 m). Both peaks belong to the nourishing area of the Toshain glacier. (3) is a NE satellite of the 5950 m-high Geshard peak (Figure 28, No. 16) between the Rupal Gah and the Geshard valley, joining on the orographic right-hand side. (0——) marks the highest provable High- to Late Glacial glacier polish line, at which the glacial flank abrasions (◥ ◤) suddenly come to an end towards the top. The characteristic of this polish line is that it is much more flatly-inclined in a downward direction than the talweg. This confirms the typical down-valley increase of the ice thickness towards a deca-kilometre-distant position of the snow line of this ice- stream network in the lower Astor valley during the Ice Age. (□) is the Shaigiri glacier, covered with debris of surface moraine, (■) its dumped end moraine. (▽) are young debris cones, which have been – and still are – built up by the crumblings of the valley flanks since deglaciation (during the Holocene). (◇) mark the glacier-mouth gravel-field (cf. Photo 74) of the historical to present (–6; cf. Table 1) Shaigiri glacier, dammed-up by the Rupal-face-glacier. (◆) indicates coarse sharp-edged blocks from the rock slides, which came down from the Nanga Parbat S flank during the last centuries (cf. Photo 72 ◆). Photo: M. Kuhle, 02.09.1987.

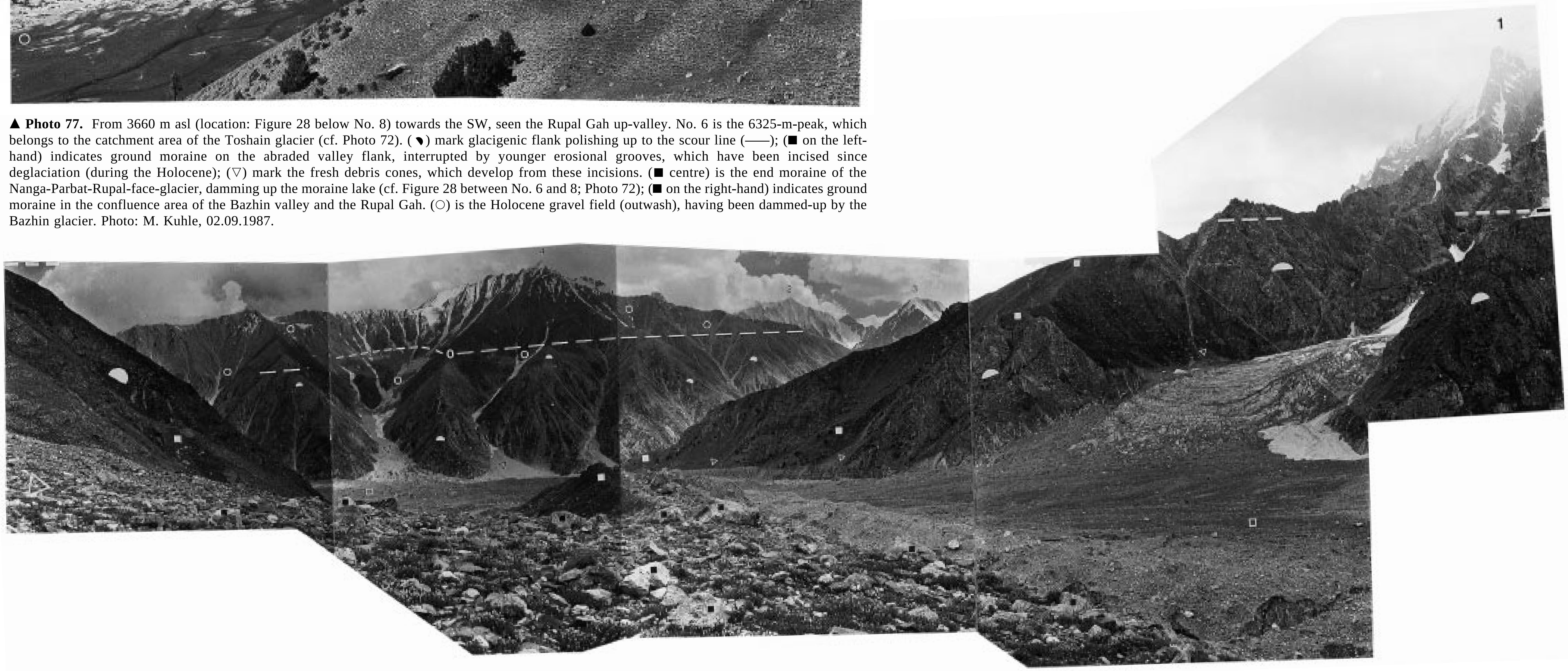
► **Photo 75.** The today only slope-glaciated S flank of the Nanga Parbat (No. 1) seen from 3670 m asl (locality Shaigir) from the valley bottom of the Rupal valley (Figure 28 between No. 4 and 19). (■) marks the orographic right-hand sub-recent lateral moraine of the Shaigiri glacier. (☗) above this present glacier shows phyllites with very resistant quartzites, reworked by Ice Age flank abrasion. Above, there is visible a High- to Late Glacial polish line (——) (cf. Photo 72). Photo: M. Kuhle, 03.09.1987.

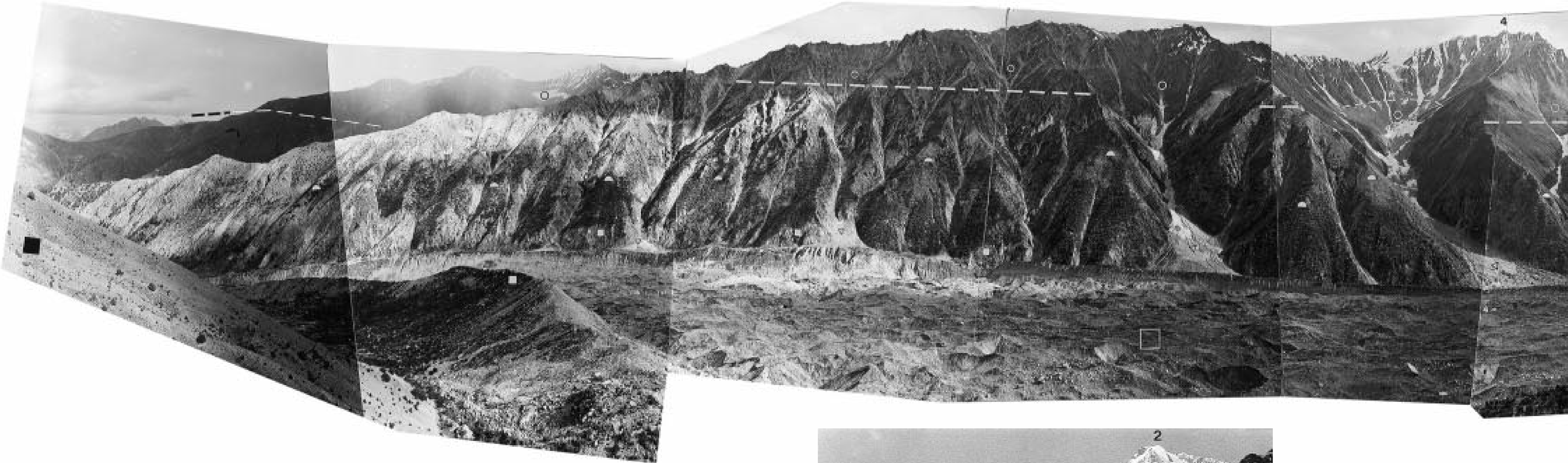




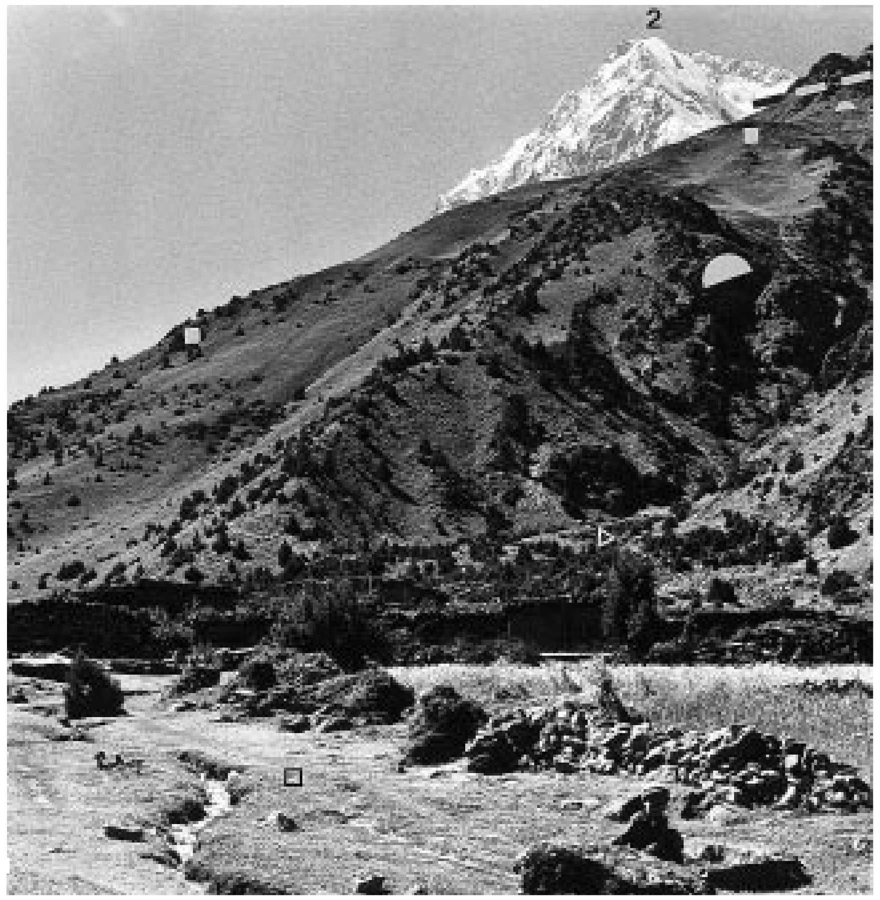
▲ **Photo 77.** From 3660 m asl (location: Figure 28 below No. 8) towards the SW, seen the Rupal Gah up-valley. No. 6 is the 6325-m-peak, which belongs to the catchment area of the Toshain glacier (cf. Photo 72). (◥) mark glacigenic flank polishing up to the scour line (——); (■ on the left-hand) indicates ground moraine on the abraded valley flank, interrupted by younger erosional grooves, which have been incised since deglaciation (during the Holocene); (▽) mark the fresh debris cones, which develop from these incisions. (■ centre) is the end moraine of the Nanga-Parbat-Rupal-face-glacier, damming up the moraine lake (cf. Figure 28 between No. 6 and 8; Photo 72); (■ on the right-hand) indicates ground moraine in the confluence area of the Bazhin valley and the Rupal Gah. (○) is the Holocene gravel field (outwash), having been dammed-up by the Bazhin glacier. Photo: M. Kuhle, 02.09.1987.

▼ **Photo 78.** Seen from 3910 m asl from the orographic left-hand lateral moraine of the Bazhin glacier (■ black) (Figure 28, No. 10) down-valley towards the inflow into the Rupal Gah. The probably more than 6000 m-high Geshard peak (No. 2) is situated in the 5950-m-massif towards the SSW. (3) is the almost equally high NE satellite of the 5950-m-massif (Figure 28, No. 16); (4) the likewise glaciated 5584-m-peak (Figure 28, No. 24); (1) is Nanga Parbat with the Rupal face (SSE face), falling away to the left. From Nanga Parbat an orographic right-hand tributary stream debouches into the present Bazhin glacier. (■ white) mark historical (white below) to Late Glacial (white on the right-hand above) lateral moraine remnants. These glacial accumulations alternate on the valley flanks of the Bazhin- and Rupal Gah with High- to Late Glacial flank abrasions (◥ ◓ ◤). (◥ on the very left) mark backward- and smooth-polished outcropping edges of the strata. (▽ right half) are fresh talus cones. They are deposited against the ice of the modern glacier edge or have been deposited against the recent to sub-recent edges of the Bazhin glacier. Thus, they are to be classified as kame-formations. (▽ left-hand half of the panorama) are talus cones, which either are heaped-up on the glacier-free valley floor of the Rupal Gah or in the orographic right-hand lateral valley (between valley slope and outer slope of the lateral moraine) of the Bazhin glacier. (□) is the surface moraine, which covers the glacier ice. (○) mark High- to Late Glacial cirques and nivation funnels, which have mostly been shaped above or somewhat below the High Glacial ice-stream network surface by local hanging glaciers and snow patches. (0——) is the minimum height of the Ice Age glacier level up to which the flank abrasions and polishings correspondingly reach – at least if one takes in account a larger area. Photo: M. Kuhle, 01.09.1987.

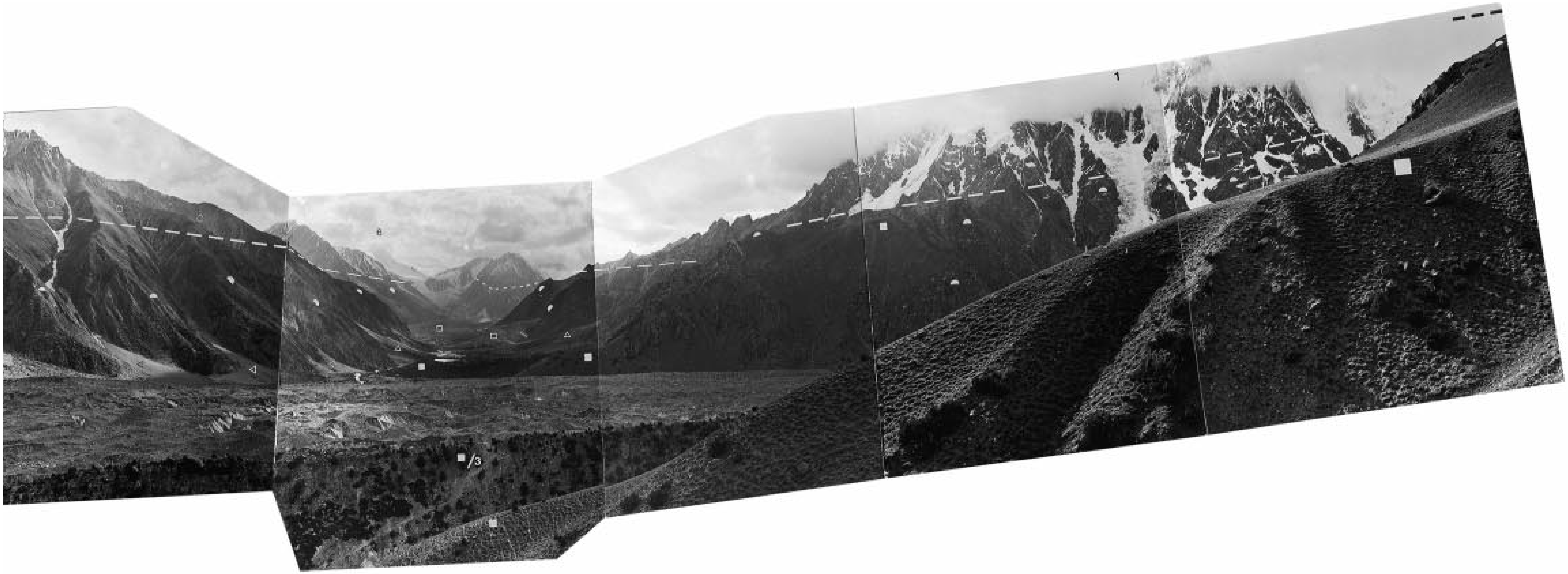




▲ **Photo 79.** From the orographic left-hand flank of the Rupal Gah (Figure 28, No. 9), looking from 3740 m asl from up-valley (in a WSW direction towards No. 6) to down-valley (towards the E; left-hand edge of the panorama). The Bazhin Gah joins the main valley (Rupal Gah) from the very right-hand side. (1) means Nanga Parbat; (6) the 6325-m-peak at the head of the Rupal valley with the upper catchment area of the Toshain glacier; (4) is the 5584-m-peak (Figure 28, No. 24). (□ large) indicates the Bazhin glacier, covered by debris of surface moraine, which debouches from the Bazhin Gah into the Rupal Gah, and (□ in the background) the debris-covered Toshain- (left-hand) and Shaigiri (right-hand) glaciers. (○) mark the recent and Late- to High Glacial cirques and nivation funnels. (——) indicates the reconstructed High Glacial (LGM) level of the ice-stream network up to which the highest flank abrasions (◗ ◓ ◖) can be proved. Further below there are the smoothed rock flanks, polished by the High- to Late Glacial glacier. In parts they are covered with Late Glacial ground- and lateral moraine remnants – the latter in the shape of more or less well preserved terraces (the first four ■ from the right and the first ■ from the left). According to their relative heights from above to below these moraine remnants belong to the Late Glacial Glacier Stadia I to IV (cf. Table 1). The rest of them (■) at low altitudes above the bottom of the Rupal Gah and at shorter distances from the present Bazhin glacier (partly still in a direct ice-contact) are Holocene (Neoglacial to historical) lateral moraines (Stadia V–′VII and VII–XI). Among others this is proved by the C14-dating of sample No. 06.09.87/3 (sample location: ■/3). The dating classifies this lateral moraine as belonging to Stadium X (Little Ice Age) (Table 2). (▽) mark talus cones with activities of snow avalanches and mudflows, and fans, deposited through slope ravines, which have been developed since the Post Glacial deglaciation. Photo: M.Kuhle, 31.08.1987.

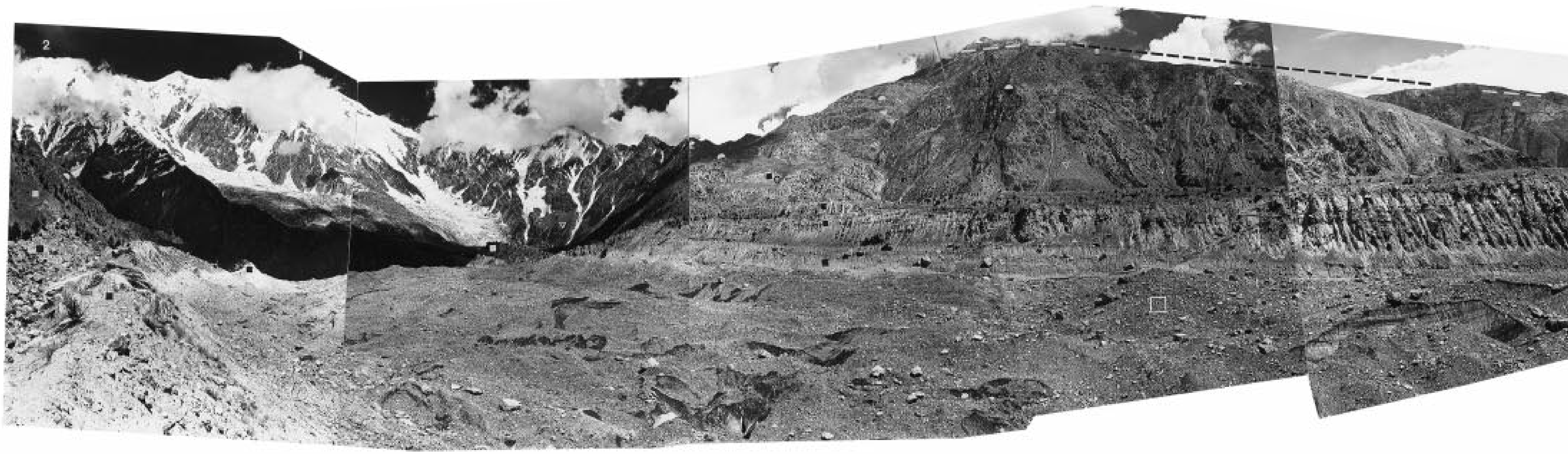


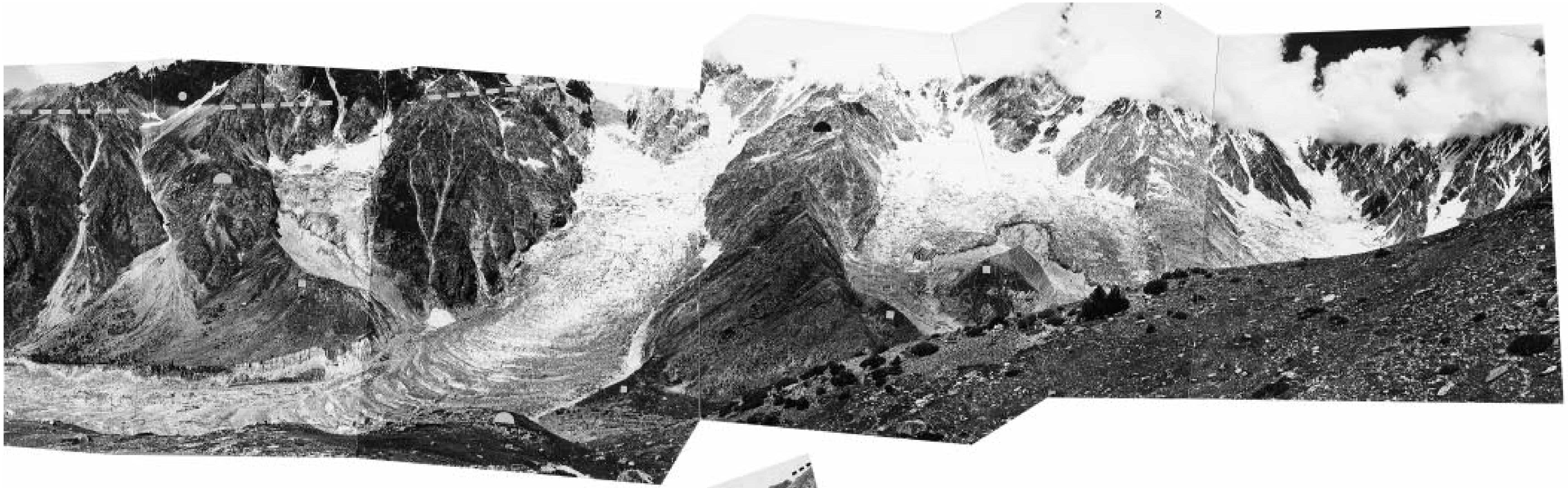
◀ **Photo 80.** From the valley bottom (□) of the Rupal Gah (Figure 28, No. 9) from 3410 m asl seen up-valley towards the WNW into the orographical left-hand flank of the main valley. No. 2 is the summit peak of Nanga Parbat; (■) mark High- to Late Glacial ground- and lateral moraine accumulations, covering the glacially abraded rock surfaces (◖). Since deglaciation there have occurred linear incisions and alluvial debris fans, which were fed by it (▽). (——) indicates a Late Glacial ice scour line. Photo: M. Kuhle, 06.09.1987.



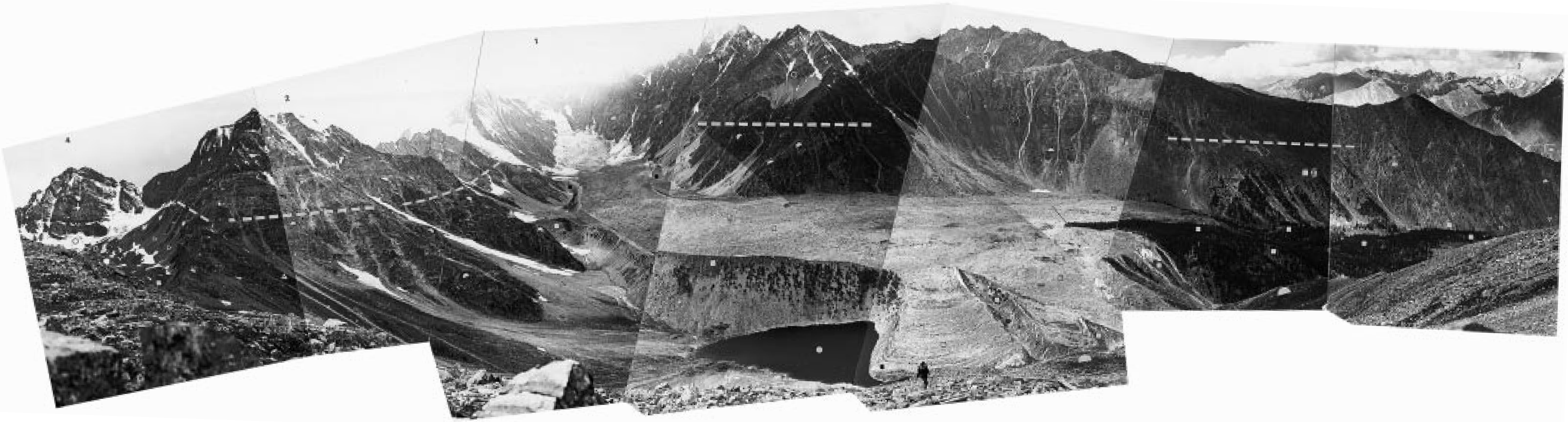
► **Photo 81.** Picture taken at 3040 m asl from the valley floor of the Rupal Gah with the field-terraces of the Rupal settlement (Figure 28, No. 21), down-valley towards the NE. The Chhungphar Gah glacier flows from the NNW into this chamber of the Rupal valley (□ = glacier tongue end at 2855 m asl, covered with surface moraine). (–6) (cf. Table 1) marks the modern Rupal river in its bed, consisting of banks of gravel. It undercuts the glacier tongue end of the Chhungphar glacier erosively and thermally (□). Upon a renewed, but merely insignificant glacier advance (already at an ELA-depression of a few metres to decametres) the Rupal river would become a dammed-up glacier lake (cf. Photo 83). (■■ white below) mark High Glacial (LGM) to Holocene (Stadia 0–V, cf. Table 1) ground moraine depositions on the main valley floor; (■■ black below) Holocene (Neoglacial) to historical lateral moraines (cf. Table 1; Stadia V–XII), the outer slopes of which are covered with centuries-old Juniperus trees. (■ black and white further above) show late-Late Glacial remnants of lateral moraines (Sirkung-Stadium IV) of the then still joined main- (Rupal-) and tributary- (Chhungphar-) glaciers. Further above there are well preserved orographical left-hand flank abrasions (☁) which reach up to a polish line (0——) at 4600 m (below No. 1 = 4676 m high summit of the Sharsingi; Figure 28 between No. 26 and 27). (○) mark High- (○ on the right-hand in the background) to Late Glacial (○ on the left) cirques and nivation funnels. (▽) is a debris slope, built up from fresh break-offs, which is undercut by the Rupal river through lateral erosion. Photo: M. Kuhle, 31.08.1987.

▶ **Photo 82.** Seen from the SSW flank of the Sharsingi peak (4676 m; Photo 81) from the orographical left-hand valley slope of the Chhungphar Gah (Figure 28 left-hand of No. 27) from 3750 m asl to the Chhungphar Gah glacier (two left-hand thirds of the panorama) and the three Chongra glacier tongues (1, 2, 3 from the left to the right in the right third of the panorama) (cf. Figure 28 left-hand of No. 26). The pictures are taken from towards the NW (right-hand edge of the panorama) via W to the S (left- hand edge of the panorama). (2) is the position of the cloud-covered W Chongra peak (6447 m); (3) is the 5584-m-peak; (4) the 5099-m-peak, which forms the orographical right-hand flank of the Chhichi Gah immediately above the terminal of the Dodhar glacier tongue (□ left-hand) (Figure 28, No. 22). (□ right-hand) marks the terminal of the Bazhin glacier, which has melted back from the youngest front moraines; (left from ■) is the Ice Age to Neoglacial ground moraine surface (Stadia 0–V; Table 1), on which are situated the fields of the Rupal settlement (Figure 28, No. 21). The rest of the (■■) mark Late Glacial to Holocene and Historic moraines of the originally connected ice stream network, which dissolved in the Holocene into individual valley glaciers (i.e. in separated valley glaciers). In this context two localities are to be emphasized: 1. (■/1/2 black) is the locality, where samples No. 30.8.87/1 and /2 have been taken (Table 2) on the orographical left-hand lateral moraine ridge of the Chhungphar-Chongra glacier-system (cf. Photo 83 ■/1/2). Accordingly, the glacier advance, which has produced this moraine ridge, is older than 215–255 ± 75–115 YB 1950 (Stadium IX–X, Table 1); 2. (■ II) is a Late Glacial orographical right-hand lateral moraine remnant in the confluence area of the Chhungphar-, Rupal- and Chhichi Gah (Figure 28, No. 29), which – apart from glacial erosional forms, as for instance valley flank abrasions – proves a minimum level of the pre-historic Nanga Parbat ice-stream network (—— from below of No. 4 towards the left edge of the panorama); the rest of (——) mark the upper margin of flank abrasions and truncated spurs, polished back by the ice-fillings (◥ ◒ ◤); (—— bold) accordingly indicates a minimum Ice Age glacier level. (■ 0) is the highly-situated ground moraine remnant, marked in Photo 83 by (■ 0). (●) are Late Glacial to Historic cirques, which in many places are still reworked by the present snow infilling. (▽) are debris cones, developed after the deglaciation, which have been built up by mass movements (falling rock and rock slide), as well as by mudflow and alluvial debris. Photo: M. Kuhle, 29.08.1987.

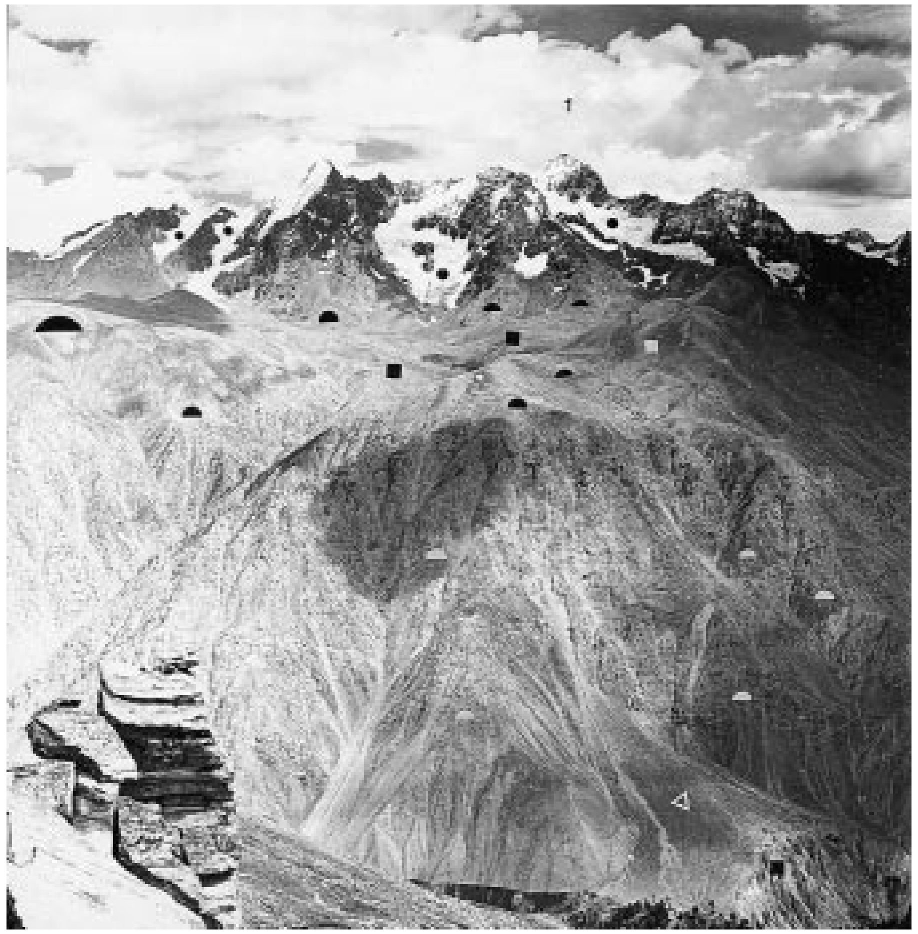




◀ **Photo 83.** View from the most striking sub-recent orographic right-hand lateral moraine of the Chhungphar glacier (Figure 28 right-hand of No. 25) from 3020 m asl. The picture shows the confluence area of the Chhungphar Gah, Rupal Gah and Chhichi Gah, taken from towards the NW (left- hand edge) via N towards the ESE (right-hand edge). (1) is the Chongra peak (6830 m), (2) the Chongra W peak (6447 m), which form the nourishing area of the Chongra/Chhungphar glacier. (□) is the surface of the Chhungphar glacier tongue, covered by debris of surface moraine. (●) marks the glacier tongue terminal, which at the time when the picture was taken, was retreating. In the case of a renewed advance of only some decametres, it will reach the opposite orographical right-hand flank of the main valley (Rupal Gah); (▽▽ are debris cones at the foot of this valley flank). As a result, the side valley glacier will dam-up the river of the main valley, thus forming a dammed-up glacier lake in the area of the Rupal settlement (cf. Photo 81 in the foreground). The lake, probably expanding over some weeks or months, will – as this is characteristic of glacier lake outbursts – discharge abruptly. Within hours this can do a lot of damage to the settlements and their fields down-valley as far as the Astor valley and – given a commensurate lake size – even down to the Indus valley (cf. a.o. Iturrizaga 1996, pp. 210–214; 1997). (■) mark more and more older end-, lateral- and ground moraines upwards the present glacier surface (□). Chronologically their origins reach from the Historic Glacier Stadia (XII–VII; Table 1) via the Holocene (′VII–V), through the Late-Glacial (IV–I) up to the last High Glacial (■ 0). (■ /1/2) is the location of sample No. 30.08.87/1 and 2 (Table 2), the datings of which prove, that the fillings of the valley glacier, fringed by those lateral moraines, which against the older ice-fillings have become much more narrow, are to be classified as belonging to the Historic Stadia IX–X. (▼) indicates a fresh, sharp-edged rock break-off in the glacially polished and rounded valley flank with moraine overlay (■ above of ▼). (▽) are debris slopes and -cones, which since glaciation are in the process of shaping. (◥ ◓ ◤) show well-preserved glacigenic flank abrasions. They are locally combined with overlays of ground moraine (■ 0; Figure 28 below No. 26) and reach up to 4600 m asl (◓ right-hand above ■ 0). (——) indicates the minimum glacier level of this Ice Age ice-stream network, reconstructed with the aid of these flank polishings (cf. Figure 28 LGM ice cover). Photo: M. Kuhle, 31.08.87.



▲ **Photo 84.** From 4160 m asl from the orographic right-hand flank of the Sachen Gah (Rama valley) (Figure 28 right-hand of No. 38), seen across the valley with the Sachen glacier and its tongue, covered with surface moraine (□□). The picture is taken from towards the SSW (4 = Bulan peak, 4910 or 4915 m) via the N towards the NE (3 = 5569-m-peak in the Deosai mountains). (2) is the 4967-m-peak; (1) the 6830 m high Chongra peak (summit in the clouds). Because the snow-line (ELA) runs across its steep face (below 1), there result only very little changes of the surface of the nourishing area from its climatic-dependent altitude fluctuations. Accordingly, the changes of the ablation area, i.e. of the glacier tongues, are also insignificant. Thus, the outline of the Sachen glacier tongue hardly changed in historic times (Stadia VII–XI, Table 1). This is the reason, why the moraine lake (● = Rama lake), dammed-up by the orographical right-hand glacier tongue (□ below), and its fringing, up to 200 m high outer moraine slopes (■ on the left above ●) were painted by A. Schlagintweit on September 11th, 1856, almost in its present shape. (■■) mark the Historic to Late Glacial (XI–III; Table 1) lateral- and end moraines (Figure 28, No. 44), which at increasing age are preserved in a more and more poor and fragmentary form (cf. ■ III) (see also Photo 85). (▽) indicates debris cones, developed since the post-glacial deglaciation, which have been produced polygenetically by falling stones and rock slide as well as by mudflow and snow avalanches. Between the ravines, from which these debris bodies derive, flank abrasions of the Ice Age glacier infilling (◥ ◓ ◤) are preserved up to an upper polish line (——). It marks the height of the minimum level of the High Glacial ice-stream network (see —— fine, on the right-hand of the background). (○) shows cirques and related glacigenic forms at highly-situated valley heads and source basins. Photo: M. Kuhle, 10.09.1987.

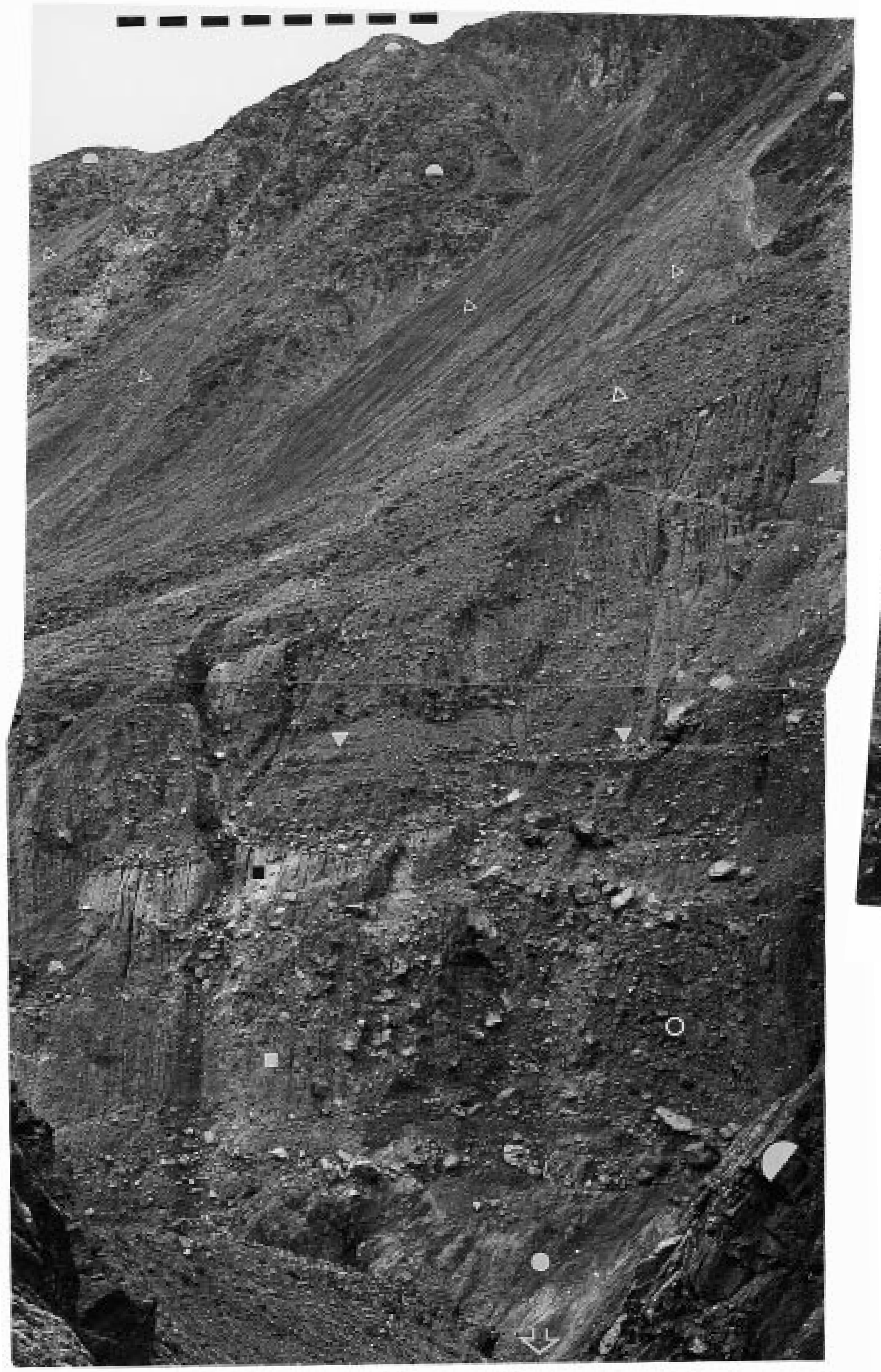


▲ **Photo 86.** Looking from 4232 m asl from the Bulan ridge (Figure 28, No. 38) towards the E to the 5718-m-peak-massif (No. 1), which forms the orographic right-hand flank of the Astor valley (Figure 28, Nos. 33 and 34). (○) marks glaciated couloirs and irregular cirque- and hanging glaciers, (■) their Neo- to Late Glacial moraines, which overlie the hummocky rock-terrace (◓ black) as an extensive cover. (■ white) is the oldest of these local moraines, belonging to a side glacier of this massif, which has still reached the Astor parent-glacier and been superimposed upon it. (◓ black) indicates High Glacial abrasions and roundings on the edge and on the surface of the Tertiary rock terrace; (◓ white) the High-to Late Glacial orographic right-hand flank abrasion, caused by the pre-historic Astor parent-glacier. Photo: M. Kuhle, 10.09.1987.

▲ **Photo 87.** From 1750 m asl from the orographic left-hand flank of the lower Astor valley (Figure 28 left-hand above, No. 63) seen up-valley towards the E. In the background the N-flank of the Burdish ridge with an Ice Age cirque form (○) (Figure 28, No. 55) is visible. It is the orographic left-hand flank of the Shaltar Gah, which joins the Astor valley on the right-hand side below. (——) indicates a particularly perfect Late Glacial orographic right-hand polish line of the Astor ice-stream network. Up to there the remnants of glacial flank abrasion (➘) are preserved in a relative united form. In some places this flank abrasion is interrupted by break-offs and rills of falling rocks (▼). (▽) are the debris-cones and -slopes, developed since the deglaciation of this section of the Astor gorge. Partly there are still preserved remnants of ground moraines (■), which were exposed by the linear-erosion of the Astor river (⇓). The steep form of the V-shaped valley can be explained by backward-erosion towards the hanging-valley bottom of the Astor valley, which derived from the Indus, running at only 1200 m. Photo: M. Kuhle.

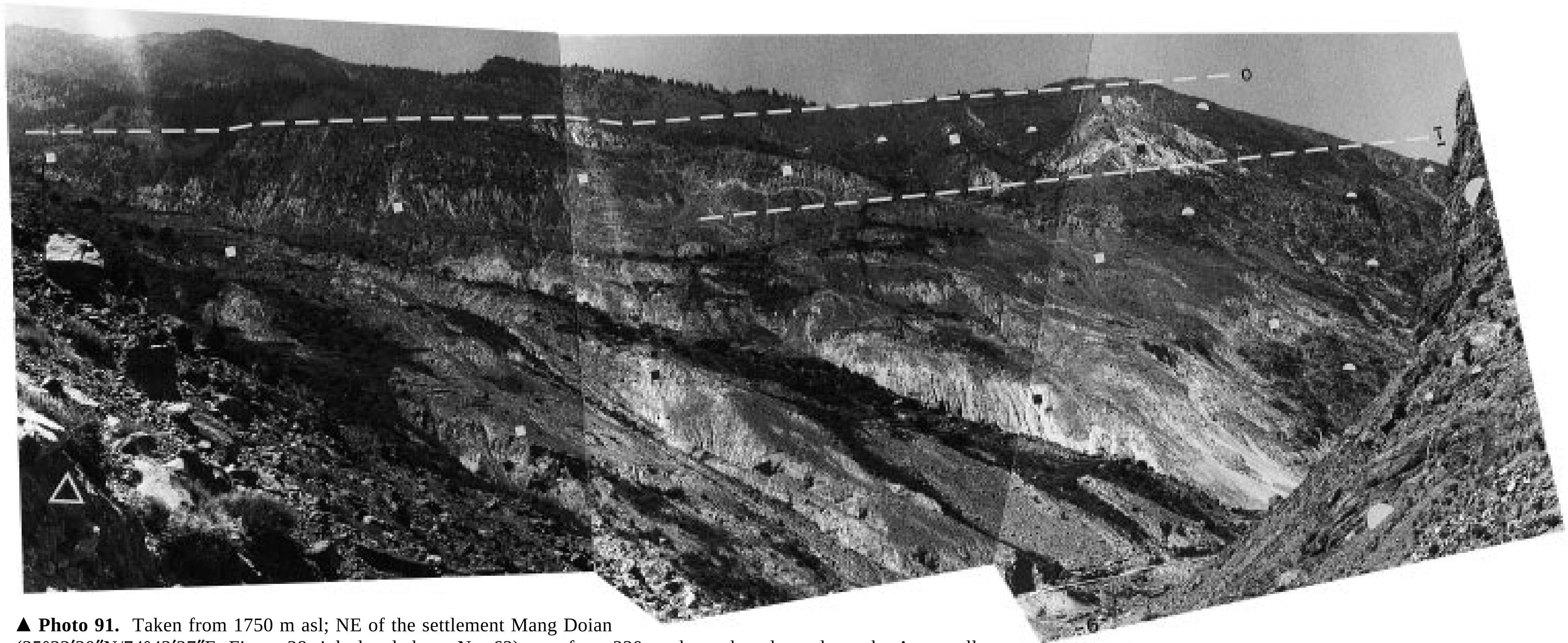
◀ **Photo 85.** In the field-area of the Rama settlement from the valley bottom of the Sachen Gah (or Rama valley) (Figure 28 between No. 41 and 37), which is covered with ground- and end moraines (■ in the foreground), viewed from 3000 m asl down to the Astor valley (centre). The picture was taken from towards the N (left- hand edge of the panorama) via the NE (right-hand of No. 2 = 5569-m-massif of the Deosai mountains) up to the ESE (right-hand of No. 1 = 5718 m-peak). The ground- and end moraines (■ in the foreground and nearer centre) are situated in the farther forefield of the contemporary Sachen glacier at a distance of 2 to 4 km from its tongue. These moraines contain large erratic boulders (●) from the immediate Chongra peak E flank and are to be classified as belonging to the Stadia ′VII–III (Neoglacial to Late Glacial, Table 1). Therefore the lateral moraines of the next older Late Glacial Stadia (■ III–IV) are low compared with those of the adjacent valleys, because they are lying on the edge of a very high (750 m) confluence step leading down to the Astor valley. This means, that during the late Late Glacial this side glacier was already adjusted to a much lower main valley (Astor-) glacier surface. From here it flowed down steeply and thus strongly accelerated in a convex bend with a comparatively insignificant thickness. Accordingly, the ground moraines, which in the meantime have been cut by the glacier stream through backward erosion (■■ centre), have the characteristics of a pedestal moraine or of an 'overthrust-ground-moraine-ramp' (after Kuhle 1982, 1983). It must have been built up when the tributary stream of the Sachen glacier (as a hanging glacier) has been superimposed upon the Astor parent glacier (as a recumbent glacier). This seems very likely because of the far more than 100 m thickness of the ground moraines and the original evenness of the moraines (■ left-hand of the centre). (■ I–II) is an orographical right-hand lateral moraine- and kame-remnant (Figure 28, No. 45), which makes reconstructable the Late Glacial surface of the Astor parent glacier (—— middle-bold). (0—— very bold and very fine) are minimum levels of the High Glacial ice-filling. (◓) marks flank abrasions, (○) modern and glacial cirques and nivation cornices; (■ black) is a local moraine of the 5718-m-massif (see Photo 86). Photo: M. Kuhle.

► **Photo 88.** View from 1600 m asl from the orographic left-hand flank of the Astor valley (Figure 28, No. 60) towards the E into the opposite valley flank. The Astor river (⇓) cuts decametre-deep into the bedrock metamorhites (●) of the valley floor. (–6) are the recent and sub-recent, partly glaciofluvial gravels of Stadium X (cf. Table 1) and younger. On the rock-pedestal (●) primarily deposited ground moraine material lies, i.e. material, which up to now has not been transported down-slope and disturbed (■ black). To this matrix-rich ground moraine there is adjusted ground moraine material, transported down-slopes and more or less dislocated (↘). Further above, High- to Late Glacial ground moraine has been exposed by more or less dense ravine-flushing (■ white). On these highly-situated primarily deposited ground moraine slopes there are spread flat debris cones (▽) of the in situ weathering rock area above. (◓) marks preserved roughened flank abrasions; (——) the highest clearly preserved polish line of the High- to Late Glacial ice-stream network (cf. Figure 28, No. 58). Photo: M. Kuhle.



▲ **Photo 89.** Looking from 1600 m asl into the orographic right-hand flank of the Astor valley (Figure 28, No. 59) towards the N. (⇓) marks the Astor river, cut into the bedrock (●). Somewhat further above glacigenic rock polishings are preserved in the bedrock (◖). On the lying rock-pedestal (●) primary fine-material-rich ground moraine covers (■) are dovetailed with local slope debris, which in parts is edged, less dense and obviously coarser in the matrix (○). (▼▼) indicate a glaciofluvial gravel-horizon, developed stratigraphically above. This happened, when older dislocated, classified and fluvially- levelled ground moraine material has been laid down once more. (▽) mark debris cones, which have developed since the deglaciation (post-glacially). As the exposure (↙) shows, they consist of ground moraine, the matrix of which is rich in fine-material, which has been dislocated down-slope by flushing, but also of sharp-edged local weathering debris. This debris originates from the rock slopes (◓◓), which are smooth-polished by the High Glacial glacier, but already roughened by frost-weathering. (——) indicates the highest provable polish line and the pertinent prehistoric glacier level. Photo: M. Kuhle.

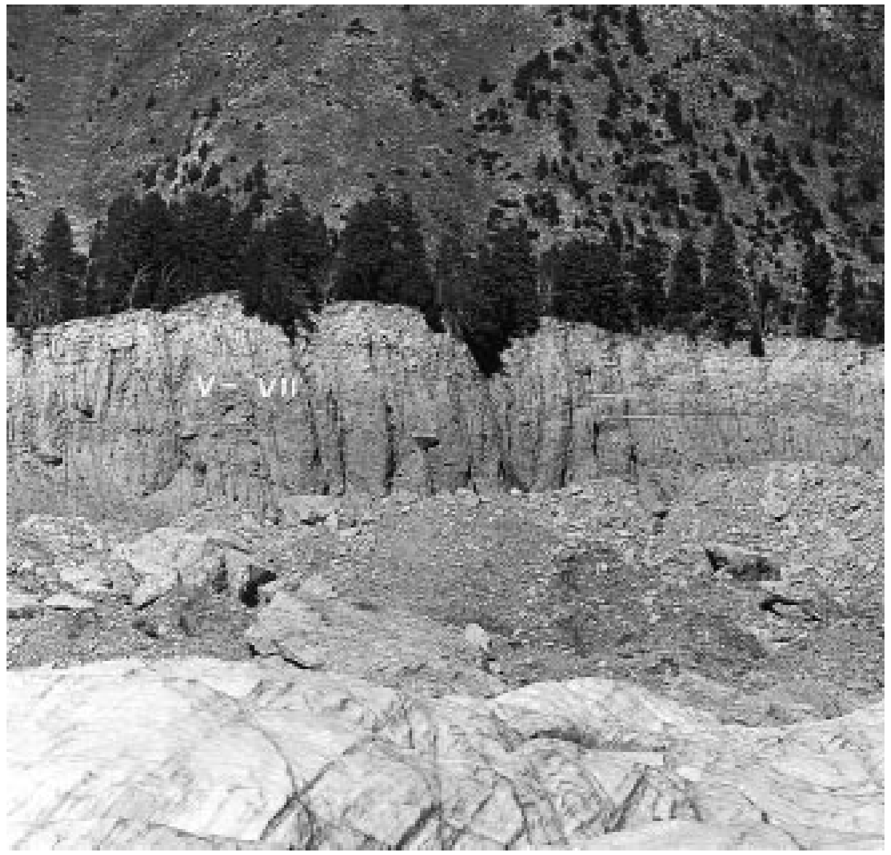
▲ **Photo 90.** From 1570 m asl from the orographic left-hand flank of the Astor valley (Figure 28, No. 60) looking up-valley towards the SE. (■) mark ground moraine remnants on both valley flanks; (■ white) show these ground moraines in decametre-thickness on the orographical left-hand valley flank, where they have been attached to the rocks, which are smoothed by flank abrasion (◖), and sedimented during the High- to Late Glacial (0–I or II; cf. Table 1). (◗) are the High Glacial flank abrasions, laid out on outcropping edges of the strata, which as concerns its structure are very rough. (▼) indicates very fresh and therefore light-looking fractures. (——) is the polish line of the Late Glacial Astor glacier tributary-stream (cf. Figure 28: LGM ice cover), proved with the help of those flank polishings. (⇓) indicates the beginning of the meltwater-erosion into the simultaneously polished trough valley-bottom. The erosion has already taken place subglacially, i.e. during the Ice Age glaciation of the Astor valley. Today, i.e. interglacially, it continues subaerially by the Astor river. Photo: M. Kuhle.



▲ **Photo 91.** Taken from 1750 m asl; NE of the settlement Mang Doian (35°32′30″N/74°42′27″E; Figure 28 right-hand above No. 62) seen from 230 m above the talweg down the Astor valley.
Whilst Photos 87–89 were taken towards the right-hand valley flank, this picture shows the left-hand flank with ground moraines, which are preserved very high up (■■). The material reaches approximately up to the High Glacial glacier level (——0), more than 1200 m above the gravel floor of the Astor river. There it partly forms a lateral moraine edge. Remnants of kame-terraces are preserved at the same level, too. The most down-valley mountain-ridge-head (3066 m) (left-hand of 0) belongs to the 3127 m-high Hattu Pir (Figure 28, No. 87). (——I) marks the Early-Late Glacial glacier level of the 'Ghasa Stadium' (Table 1). In the place, where the outcropping edges of the bedrock are freed from the moraine by postglacial flushing, glacigenic flank abrasions (◓) become visible. On the orographical right-hand side corresponding flank polishings are preserved on the trough wall, which has been concave-polished by the ice (◤ large in the right-hand foreground). (△) indicates fresh edged slope debris, originating from postglacial break-offs. Photo: M. Kuhle.

▼ **Photo 92.** From 4550 m asl from the 'Large Moraine' (Figure 28 right-hand of No. 67) seen towards Nanga Parbat (1) N-face. The panorama was taken from towards the NE (left-hand edge with the Buldar notch, c. 5250 m asl; above III) via ENE and ESE (2 = Chongra 6830 m; 4 = W-Chongra or middle Chongra 6447 or 6455 m; 5 = S Chongra 6428 or 6448 m) via S (1 = visible is only the 7816 m-high Nanga Parbat N peak) and SSW (3 = Ganalo peak 6601 or 6608 m) up towards the W (7 = S-Jiliper peak 5206 m). (■ IV) is a large complex of medial moraines of the youngest Late Glacial (cf. Table 1), which still today – at a more than 100–800 m decreased glacier surface – is completely fringed by ice-streams (cf. Figure 28, No. 67; Photo 99). Here the upper Rakhiot glacier with its nourishing area is visible, to which belongs the Nanga Parbat face with its ice balconies and ice avalanches (1), breaking away from these balconies (cf. Photo 93). The eastern glacier-tributary-streams coming down from the three Chongar peaks (No. 2, 4, 5), which are linked with the so-called Rakhiot-firn, are connected. (IV right-hand) marks a large granite boulder from the Nanga Parbat face on the 'Large Moraine' with a seated person for comparison; (IV left-hand) shows a second granite boulder. The recent glacier margins undercut the 'Large Moraine' with such a power, that the moraine debris slopes (right-hand i.e. left-hand below IV left and right) are unstable and today in the process of heavy movements and backward-erosion. More stable moraine material, as for instance in the form of earth pyramids (here dark and serrated) (left ■ of IV), partly breaks through the moving debris of these moraine slopes. In the nearer future this backward-movement of the slope will lead to the fall of the two large boulders (IV). The also Late Glacial lateral moraine III, bound to a somewhat lower course of the ELA, will be moved backwards, too. (◤ ◓) mark remnants of glacigenic flank abrasion, which provide evidence of a higher glacier level. They have been reworked inevitably by the extreme frost weathering along the black/white boundary, but also by falling rocks and avalanche erosion. Due to the inherent law according to which the areas below the ELA are elevated the most, the raising-up of the ice level during the Ice Age was the less in these nourishing areas of today's still glaciated valleys. Photo: M. Kuhle, 08.10.1995.

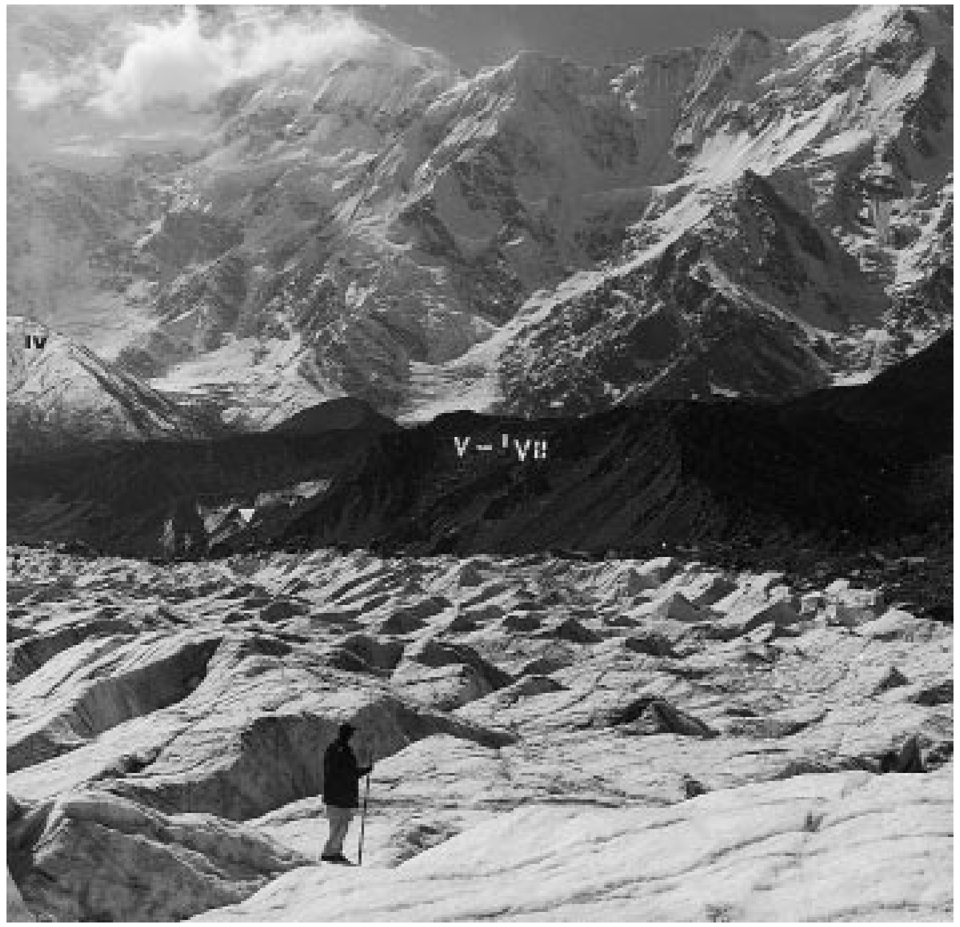
◀ **Photo 93.** View from 4650 m asl from the orographic left-hand flank of the Rakhiot (Tato) Gah (valley) from the Jiliper peak NE crest (Figure 28, No. 69), facing SE. The Nanga Parbat N-face falls away 3300 m from the highest visible point, the N summit II (7785 m), down to the Rakhiot glacier at the foot of the ‘Large Moraine’ (■). Half-way up the wall the thick flank-ice breaks off as an ice balcony at a kilometre-long front. One piece is breaking off as a large ice avalanche. Besides the primary glacier nourishing by snowfall on the Rakhiot firn (left-hand edge in the background) a secondary glacier nourishing by such avalanches occurs. Here, it takes place down to below the snow-line (ELA). Nearly all day (cf. avalanche in Photo 96, left-hand below No. 1), but also during the night, ice avalanches come off this wall. The largest, however, as for instance the one which the author was able to observe in October 1995, come down in the early afternoon. This is the time when the wall becomes completely shady in radiation weather situations. During these minutes the ice, getting colder and more brittle, contracts, and the coherence diminishes with increasing viscosity. In spite of a reverse gradient of more than 100 m (■), the ice-powder of this avalanche has overrun the entire ‘Large Moraine’. (◢) marks High- to Late Glacial flank abrasion. Photo: M. Kuhle, 10.10.95, 14°°.



◀ **Photo 95.** Looking from 3660 m asl from the tongue of the Rakhiot glacier (35°21′N/74°35′05″E; Figure 28 left-hand above No. 72) towards the W across the glacier. There is pure ice in the foreground. The ice behind is overlain by surface moraine; due to the protection against ablation, it forms a higher ridge than the pure ice does. Again further backward, covered with a mixed forest of conifers and birch trees, the left-hand lateral moraine is exposed. It belongs to the Neoglacial Stadia V–′VII (cf. Table 1, Nauri- to middle Dhaulagiri-Stadium). The oldest juniper trees, growing on its outer slope up to the moraine ridge (cf. Photo 103) are supposed to be some hundred years old. The wall-like steepness of the visible inner slope of the moraine confirms its undercutting by the lateral erosion of the modern glacier. The levelling and slight banking (═) of the moraine proves its multi-phase development by moraine- accumulations and moraine-depositions, bound to the advance of several Stadia (cf. Schneebeli and Röthlisberger 1976). Photo: M. Kuhle, 10.10.1995.

▲ **Photo 94.** From 4360 m asl from the E edge of the ‘Large Moraine’ (Figure 28 right-hand of No. 67), seen looking down-valley on the Rakhiot glacier. Picture ranging from towards the NW (left-hand edge) via NNE (6 = Buldar peak, 5633 or 5602 m), ENE (2 = Chongra peak, 6830 m) and WSW (4 = W Chongra or middle Chongra, 6447 or 6455 m) towards the SSE into the Nanga Parbat N-face (right- hand edge). (——) indicate the High Glacial glacier level (0 = LGM); below there are preserved glacigenic flank polishings and – abrasions (◓ ◢ ◥). III and IV are Late Glacial lateral- and medial moraine remnants, proving that the pertinent ELA has already run above 4500 m (cf. Table 1). (■) shows a medial i.e. orographic left-hand lateral moraine slope (‘Large Moraine’), exposed up to an altitude of some hundred metres, which creates earth pyramids and – further below – falls away to the Rakhiot glacier in a straight line. These fresh, i.e. today still active forms, have been brought about by the undercutting of the present to sub-recent ice-stream. (□) are outwash slopes, clinging to the ‘Large Moraine’ on its lee-side (see Photo 99, IV / /). They represent a sander- deposition, giving this medial moraine complex the characteristics of an ice marginal ramp (IMR or ‘Bortensander’; KUHLE 1990a,e). Photo: M. Kuhle, 09.10.1995.

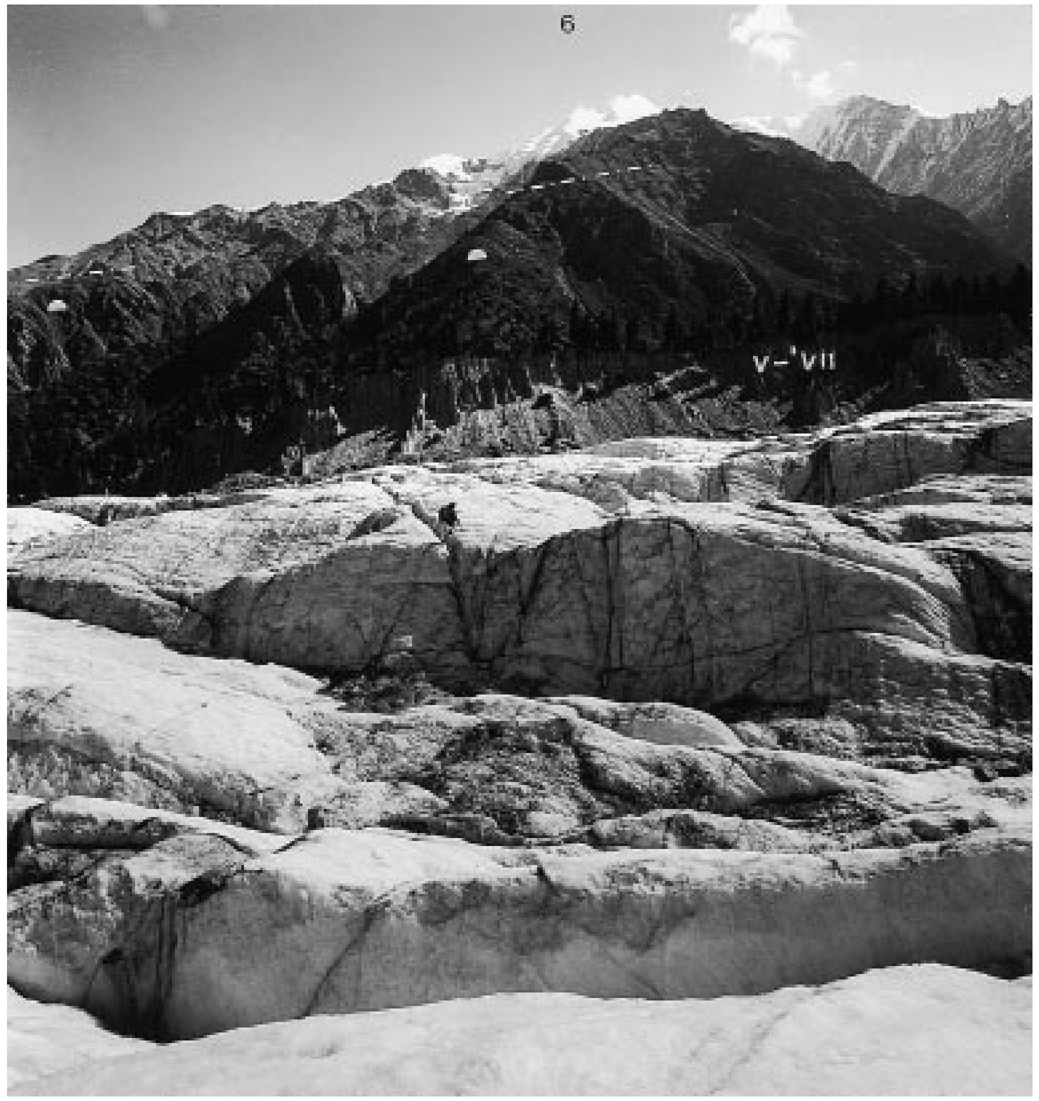
▲ **Photo 96.** 360°-panorama taken from 3980 m asl from the medial moraine between W-Rakhiot glacier (▼▼ on the very left and on the very right) and Ganalo glacier (□ = orographic right-hand lateral moraine of this glacier) (Figure 28 left-hand below No. 68), looking across the Nanga Parbat N-flank (1) and the Rakhiot valley (panorama-centre, facing downwards to the N). The completely covered medial moraine has been classified as belonging to the Neoglacial Stadium V (Table 1). Here, above the timberline, these dwarf scrubs and the grass form the climax- stadium of the vegetation. (■) marks the 'Large Moraine', placed in the youngest Late Glacial (IV) (Figure 28, No. 67). It wears an autumnal cover of freshly fallen snow. (III) are lateral moraine remnants of the next older Late Glacial Stadium (Table 1, Dhampu Stadium) (Figure 28, No. 69 and 70). Whilst the recent Rakhiot glacier also shows pure ice in its ablation area (valley glacier below No. 4, 2, 6 in the centre), the Rakhiot W-glacier is covered by surface moraine (▼ on the very right and on the very left). The latter is due to the increased debris-supply caused by the ice-avalanche-feeding from the Nanga Parbat N-wall (ice avalanche see left-hand below No. 1). (▼▼ diagonally right-hand below 1) is a freshly moved glacier margin area, where the slightly advancing right-hand tributary tongue of the Ganalo glacier breaks through its own right-hand lateral moraine and then flows towards the adjacent W Rakhiot glacier. (◤ ◒ ◥) mark High- to Late Glacial flank abrasions, which indicate with their upper margin the minimum altitude of the maximal Ice Age glacier level (0——). (7) = S-Jiliper peak; (6) = Buldar peak; (2) = Chongra peak; (4) = W-Chongra peak; (5) = S-Chongra Peak. Photo: M. Kuhle, 06.10.1995.



▲ **Photo 97.** From the tongue of the Rakhiot glacier at 3670 m asl (35°21′N/74°35′07″E; Figure 28 left-hand above No. 72) looking across the ablation area of the Rakhiot glacier up-valley towards the SSW. The undulating surface condition of the sheer ice is a result of the interference of glacier crevasses, shear planes and solar radiation, forming ice-pyramids. In the background there is the Nanga Parbat-Ganalo peak N flank. IV marks the late-Late Glacial 'Large Moraine' (Figure 28, No. 67). The Neoglacial moraine complex V–′VII (cf. Table 1) was shaped originally as a medial moraine between the Rakhiot glacier, W-Rakhiot glacier (▼) and Ganalo glacier (Figure 28, No. 68). The latter has been the first glacier, the tongue of which has reached no confluence with the Rakhiot glacier, but has reshaped the moraine inset concerned into a pedestal-, dam- or dumped end moraine (cf. Photo 96 □). The back-melting tongue of the W Rakhiot glacier (▼) (cf. Photo 96 ▼ right-hand edge of the panorama) has later been separated from the parent glacier. Today it comes to an end at a distance of somewhat more than 200 m from the Rakhiot glacier (cf. Photo 98). Here, the modern Rakhiot glacier forms an outer bank, at which it undercuts this moraine complex (V–′VII). This process makes the c. 200 m-high slope unstable up to its upper edge. Photo: M. Kuhle, 10.10.1995.

▲ **Photo 98.** View from 3810 m asl looking towards the tongue terminal and the glacier mouth of the W-Rakhiot glacier (Figure 28 above No. 67) facing SSW (cf. Photo 97 ▼). The sheer ice is covered by autumnal freshly-fallen snow. The true glacier tongue surface wears a decimetre- to metre-thick debris cover (surface moraine) (cf. Photo 96 ▼ on the very left and on the very right). A striking frontal moraine is absent. Only very large granite boulders (person to compare the size) as components of a featureless dumped end moraine indicate the sub-recent lowest glacier margin. The smaller moraine blocks (foreground) are sharp-edged as well and round at the edges and facetted as rounded. In the talweg area the glacier meltwater stream (foreground) has partly flushed out the morainic fine material matrix between the blocks. Photo: M. Kuhle, 07.10.1995.

▲ **Photo 99.** Panorama taken from 4585 m asl from the orographic left-hand flank of the Rakhiot valley (Figure 28 above No. 69) across the entire valley and the Rakhiot glacier. Direction: facing SW (right-hand edge) via SSE with the Ganalo peak (3 = 6608 m) and Nanga Parbat (1 = 8125 m), via E with the Chongra peak (2 = 6830 m) and NNE down-valley up to the Indus valley (background) towards NNW into the left-hand Rakhiot valley flank (left-hand edge). (7) is the S-Jiliper peak (5206 m) with its N-exposed small hanging glacier, which flows down to c. 4500 m and thus confirms an orographical ELA about 4850 m asl. (6) means the 5633 m-high Buldar peak, the W-exposed hanging glaciers of which (left-hand below No. 6) reach down to 4500–4950 m. They prove an orographical ELA about 5050–5100 m. From these two orographical snow-line altitudes there can be established a climatic snow-line at c. 5000 m asl. (▼) indicates the ablation area of the W Rakhiot glacier, covered by surface moraine; (□) that of the Ganalo glacier. The lateral moraines, still clinging immediately to the present glaciers, are of a Neoglacial (V–'VII) to Historical age (VII–XI) (Table 1). III and IV are Late Glacial moraine remnants of the Dhampu- and Sirkung Stadia. (//) mark outwash ramps, which have been transported glaciofluvially down the steep outer slope (on the lee-side). They give the 'Large Moraine' the shape of a medial moraine of the 'ice marginal ramp' type (IMR or 'Bortensander' after Kuhle 1989 and 1990a). These outwash forms, being syngenetic with the moraine depositions, prove that the simultaneous snow-line (ELA) was lying higher than the 'Large Moraine', i.e. about 4560 m asl. This confirms, that the 'Large Moraine' originally did not come into being as a subglacial deposit, i.e. as a ground moraine, but has kept its present form since its inception. On the way down, due to their lateral moraines, the Neoglacial to Historical glaciers became more narrow compared to the wider valley-profiles. There have been filled younger (Holocene) debris cones (▽) into the lateral valleys since the Post Glacial deglaciation. (◥ ◓ ◤) indicates high (LGM = 0) – to Late Glacial flank abrasions; these have developed in the right half of the panorama to a great extent above the ELA and in the left half for the most part below the ELA. The gneiss-rock-head, from which the panorama was taken (◓ large black, in the foreground), has also been overflowed by the Ice Age ice stream. (——0) marks the level of the glacial Rakhiot glacier as an orographic left-hand side glacier of the Indus parent-glacier (Figure 28). Photo: M. Kuhle, 09.10.1995.



► **Photo 100.** From 3670 m asl from the orographic right-hand third of a Rakhiot glacier cross-profile (Figure 28 left-hand above No. 72) seen across the ablation area of the glacier with its sheer ice ridge (person to compare the size), the vertical standing shear planes (black veins) and the inner moraine, coming out there. V–'VII are the Neoglacial lateral moraines, covered by mixed forest of conifers and birch trees (cf. Photo 103) on its outer slope up to the crest. (◓) are High- to Late Glacial flank abrasions, interrupted by today still glaciated side valleys. These lead down from the 5633 m-high Buldar peak (No. 6). (——) marks with an upper margin of these glacial flank polishings (◓) an Ice Age glacier level, which is in particular clearly preserved. Photo: M.Kuhle, 10.10.1995.

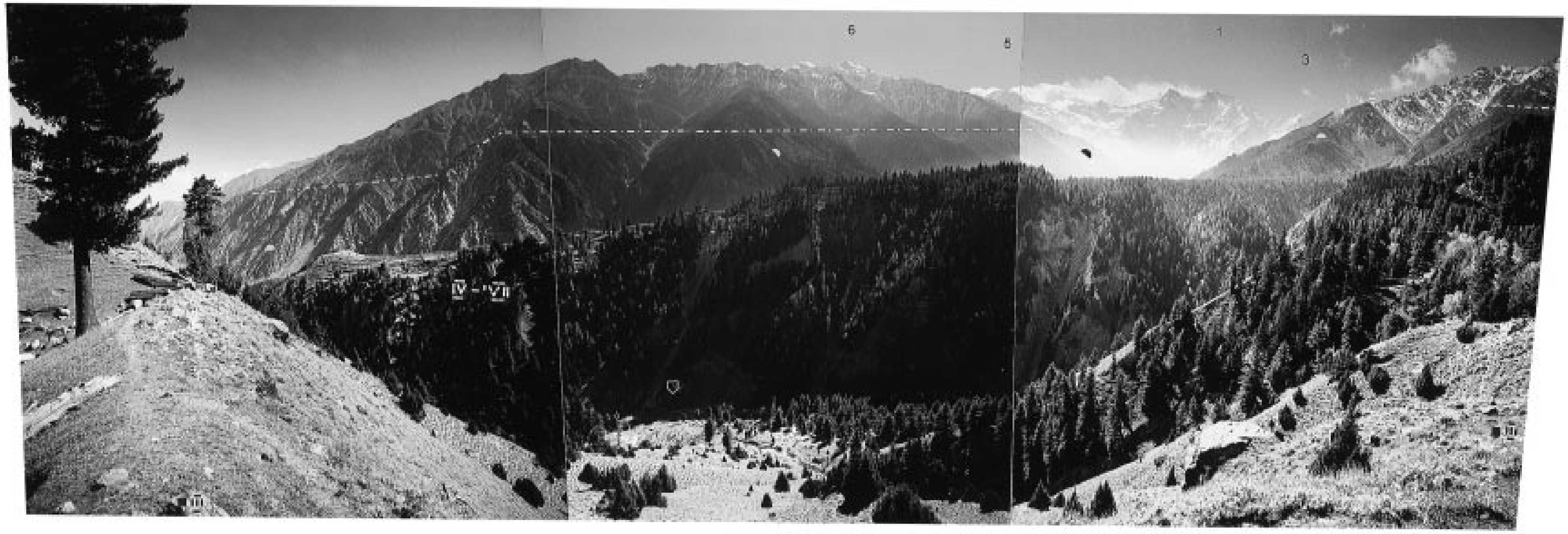
◀ **Photo 101.** View from 3330 m asl across the 'Fairy Meadow' (□) (Figure 28 above No. 71), seen a Late Glacial (Stadium IV) to Neoglacial (Stadium ′VII) orographic left-hand lateral- and end moraine landscape (■■) of the Rakhiot glacier (see Photos 104–106, 110) facing Nanga Parbat (1). Direction: SSE. (5) = S Chongra peak (6447 m); (6) = Buldar peak (5633 m). The 'Fairy Meadow' (□) is a glaciofluvial gravel floor, which has been deposited between two lateral moraine ramparts (■■) by marginally down-flowing meltwater in the lateral valley. In the meantime this process was brought to an end and the gravel floor is covered by an alpine turf. Today the locality is seasonally used as a pasture. The framing coniferous woodland has reached its location-specific climax-stadium for centuries at least, if not longer. The largest moraine blocks, which are scattered here, show extensions of several metres (e.g. in the farther foreground). From the background to the centre there stretches the Rakhiot glacier, beginning as a valley glacier stream below the Nanga Parbat N-wall (below No. 1) in the area of the snow-covered hill of the 'Large Moraine'. (◥ ◤) indicates the trough valley slopes of the Rakhiot valley (Tato Gah) with flank abrasions, which have in part been polished-out concavely by the High- to Late Glacial ice infilling. Photo: M. Kuhle.

▼ **Photo 102.** Looking from 3770 m asl, i.e. from the highest preserved orographical right-hand lateral moraine ridge of the Rakhiot glacier (Figure 28, No. 72) across the Tato Gah from downwards of the Nanga Parbat as far as the Indus valley. Direction: from towards the E (left-hand edge of the panorama) with a glaciated crest of the Buldar peak (6) across the S with the Nanga Parbat (summit in the clouds) and the W (right-hand of No. 7 = S-Jiliper peak) into the left-hand flank of the Rakhiot valley, up to the N along the right-hand lateral valley of the Rakhiot glacier (V) up to the Indus valley (background on the right edge). (3) is the Ganalo peak; (5) the S Chongra peak. The location, in which the picture was taken (Photo 96 IV–′VII), is at the same time the location of sample Figure 33 (sample taken in the centre of the foreground at the moraine-exposure). Below the oldest Neoglacial moraine (V = Nauri Stadium) was deposited against the moraine (IV on the very left) (late-Late Glacial Sirkung Stadium). From the moraine ridge (left-hand of V) down to the present level of the Rakhiot glacier surface, the levels of all younger Neoglacial and Historical Stadia of this valley glacier are paced through. In part they are marked on the opposite glacier- and moraine edge with V–′VII (cf. Table 1, Neoglacial). On these lateral moraines grows a mixed forest of birch trees and conifers, the timberline of which runs at about 3900 m asl. (IV centre, background) are further late-Late Glacial lateral moraine remnants (IV below the Nanga Parbat wall = 'Large Moraine'). (▼) marks the tongue of the W Rakhiot glacier, (□) that of the Ganalo glacier with its dumped end moraine. (◠ ◥) indicates the High- to Late Glacial flank abrasions, which are mainly preserved on truncated spurs. Above there runs the High- to Late Glacial polish line (——), which indicates the highest provable pre-historic glacier level. (◠) on the right-hand of No. 7 is the locality of Photo 99. Photo: M. Kuhle, 10.10.1995.

◄ **Photo 103.** View from 3570 m asl from the orographic left-hand Neoglacial (V–′VII) lateral moraine (Figure 28 between No. 78 and 72) seen the Rakhiot glacier downwards facing N. The moraine is covered with full-grown conifers and birch trees in a forest soil of insignificant thickness. The exposure shows polymict facetted blocks, edged and with round edges, in a relatively coarse-grained (silt-sand) matrix. Nevertheless, the pore volume of the matrix is strikingly small (which is typical of moraines), but larger than that of ground moraines of an otherwise similar composition. XI is a youngest sub-recent, i.e. several years old lateral moraine rampart, which is still in the process of forming. It is partly underlain by ice and deposited against the Neoglacial moraine-complex (V–′VII). The steepness of the older inner slope of the lateral moraine proves the dominance of its wearing down by lateral erosion of the Rakhiot glacier during (at least) the last decades (cf. Photos 95 and 102 V–′VII). In themeantime, however, the moraine rampart XI announces a change of the moraine balance towards an increasing moraine debris accumulation. Probably this has to do with a thickening of the surface moraine in the marginal areas of the Rakhiot glacier (□) (cf. Photos 95, 99) during the glacier's retreat over the last decades and an at present slight advance (see Photos 104, 105), which accumulates this material marginally and towards the lateral moraines. Photo: M. Kuhle, 10.10.1995.

► **Photo 104.** From 3280 m asl from the orographic right-hand valley side (Figure 28 above No. 73) looking across the terminal of the Rakhiot glacier (▲) and the down-valley Historical (Stadia VII–XI) and Neo- to Late Glacial (IV–′VII) moraine sequence. Panorama up-valley facing S (left-hand edge) via W into the left-hand flank of the Rakhiot valley (or Tato Gah) up to the NNW, seen down-valley along the Neoglacial to Historical inner moraine slope (right-hand edge). (▲) marks glacier ice, coloured black by the incorporated debris of the inner moraine; further to the left above, the ice is nearly completely covered by the grey surface moraine (□). The front of the glacier tongue is relatively steep, thus announcing a glacier advance (cf. Photo 105). Concerning the chronology of the moraines compare Table 1. The orographic left-hand moraines IV–′VII mark the moraines of the 'Fairy Meadow'-generation. On this moraine terrace (right-hand of IV–′VII) there is situated the 'Fairy Meadow' (below the second ◥ from the left) (cf. Photo 101). In the immediate glacier forefield somewhat more than 10 years-old trees as pioneer vegetation are growing. The down-valley catabatic glacier wind hinders their growth. Plants, larger than dwarf scrub, are not able to get a foothold here, because the inner slopes of the Historical moraines (■ in the right and left foreground) are still too mobile. The rounded boulders especially produce – insofar as they are loose – an unstable slope surface. In contrast, on the moraine ridge of the same age trees are already growing (right-hand edge of the panorama). The glacier stream covers the ground moraine planes of the glacier forefield, left behind by the ice, with a gravel field (sander) (○). (◤ ▲ ◥) mark the glacigenic flank abrasions; (——) the highest provable polish line and thus the Ice Age glacier surface. (—— on the very right) is the 3822 m-high valley shoulder of the locality 'Bezar Gali' on which the author has observed large erratic boulders (cf. Photos 107, 108). Photo: M. Kuhle, 10.10.1995.

◄ **Photo 105.** From the innermost moraine ridge of the 'Fairy Meadow' moraine generation (IV–'VII) (Figure 28 IV–'VII left-hand of No. 76; Photo 104 edge of the moraine IV–'VII, below ☗ on the very right), seen from 3310 m asl up-valley facing S to the Nanga Parbat (1). (3) = Ganalo peak; (■) = 'Large Moraine' at the valley head in the source area of the Rakhiot valley glacier. The glacier tongue runs down to 3200 m (see Photo 104). Its front is steep, thus announcing an at least slight glacier advance. The orographic left-hand lateral moraine terrace (IV–'VII), exposed far down in this place, is situated with its upper ridge about 300 m above the talweg of this valley cross-profile (left-hand edge). The visible moraine material (cf. also sample Figure 34 from the base of this moraine complex) shows a relatively coarse-grained matrix. The reason for this is the coarse-crystalline bedrock of the catchment area of the Rakhiot glacier. Nevertheless, the microfabric is typically glacigenic, i.e. the matrix is dense and there exists – related to its grain size – an only small pore volume. (◥ ◤) mark truncated spurs with glacial flank abrasions. Due to its Late- and Neoglacial and Historical lateral moraines the bed of the down-flowing Rakhiot glacier has been narrowed to about one third against the width of its High Glacial out-polished trough valley (◥ ◤). Photo: M. Kuhle, 05.10.1995.



▲ **Photo 106.** View from 3330 m asl from a Late Glacial lateral moraine rampart (■ III) in the orographical left-hand valley flank (Figure 28, No. 80) across the Rakhiot valley. Direction: facing NE (left-hand edge of the panorama) down-valley, via SE to the Buldar peak (No. 6 = 5633 m) and SSE up-valley to Nanga Parbat (No. 1) up to the S into the left-hand Rakhiot valley flank. (5) = W- and S-Chongra peak (6447 m); (3) = Ganalo peak (6601 m). On the surface of the left-hand lateral moraine rampart (■ III) large moraine blocks are visible. The big tree on the very left stands on the outer slope of the moraine rampart, which falls away to a lateral valley. IV–'VII is the large orographical left-hand lateral moraine complex of the 'Fairy Meadow' generation, which has been built up from the late- Late Glacial up to the end of the Neoglacial (Table 1) (Figure 28, No. 71). This complex has been isolated from the orographical left-hand flank of the Rakhiot main valley by a left-hand fluvial, steep V-shaped side valley (⇓). (☗ ◥) shows glacigenic truncated spurs and flank abrasions up to a scour line (——) at c. 4600 m asl up-valley. Photo: M. Kuhle.

▲ **Photo 107.** 360°-panorama taken from 3822 m asl from the mountain shoulder ENE of the locality 'Bezar Gali' in the orographical left-hand flank of the Rakhiot valley (Figure 28, No. 81). (1) = Nanga Parbat, situated from here approximately in the S; (2) = Chongra peak (6830 m) in the SE; in front of it below the Buldar peak (5633 m). Towards the ENE the orographical right-hand polish line (i.e. the Ice Age valley glacier level) of the Buldar Gah can be recognized (—— thin, on the very left); on the right-hand side above (3), the glaciated Lichar crest, rising there to more than 5000 m, is to be seen (3 = Lichar peak, 5035 m). (4) is the glacigenically sharpened 5559-m-peak of the north-western Deosai Mountains, visible in the NE. In the foreground there stretches the ground moraine cover (■ 0) with erratic granite boulders (↓), which are rounded at the edges and facetted or only rounded on one side. (Persons for comparison of the size). From this ground moraine the sample of Figure 35 has been taken. Apart from the material's nature the material transport by solifluction from the slope has to be ruled out, because this accumulation-surface lies away from every slope foot and has numerous counter slopes (cf. Photo 108 ■ 0). In places, classic forms of roches moutonnées from the bedrock with a flat windward- and a steeper leeside slope break through the ground moraine overlay (☗ above ■ 0 in the centre). Here, the orographical left-hand upper margin of the ground moraine cover indicates (—— 0 bold) the minimum altitude of the High- (LGM) to Late Glacial Rakhiot glacier level (cf. Photos 110, 111 —— bold on the left). The Bezar Gali ridge (above —— bold) rises by only 380 m up to 4221 m and – from its shape – was no local glacial catchment area for this moraine. In addition, this slope is convex in the horizontal profile and thus unable to concentrate ice, flowing down the slope (cf. this locality in Photo 110 ——0 bold). (■) marks the 'Large Moraine' from which on the present Rakhiot glacier becomes visible; (——0 thin) is the Ice Age glacier level, provable by means of flank abrasions (◥ ☗ ◤) on the opposite right-hand valley side at the same altitude. Photo: M. Kuhle.

◄ **Photo 108.** At 3800 m asl from a position, shifted only c. 200 m to the E against that of Photo 107, looking towards the NNE (in the background the Karakorum summits of the Haramosh group). In the foreground and the centre the hummocky High Glacial ground moraine landscape (■ 0) is recognizable with some deposited erratic granite boulders (e.g. ↓) and several polished rock ridges (☗). In the farther centre (left-hand) there are visible the thinly-stratified metamorphite bed-rocks, which also occur in the basement rock of the ground moraine. Their strata fall away steeply to the E. Photo: M. Kuhle.

► **Photo 109.** View from 3720 m asl from the orographical left-hand flank of the Rakhiot valley, seen the main valley upwards (Figure 28 between No. 80 and 81). (1) = Nanga Parbat; (2) = Chongra peak (6830 m); (4) = W-Chongra peak (6447 m). The three (☗) on the left mark truncated spurs in the orographical right-hand main valley flank, caused by the Ice Age Rakhiot glacier. (◤) on the right is the left main valley flank, which has been polished up to at least 4000 m, i.e. horizontally, by the glacial Rakhiot main valley glacier (Figure 28, No. 80). The Late Glacial lateral moraine ramparts and -ledges (I–II; III–IV) have been deposited by an E-exposed glacier tongue at a time when the main valley glacier (Rakhiot glacier) already no longer had its highest (High Glacial, LGM = 0) surface level, but had dropped here to below 3600 m (to the left-hand edge of the picture). This tributary glacier, flowing down this side valley, originated from a cirque with a catchment area of c. 4300 m. It provides evidence of a Late Glacial orographical ELA between 3700 and 3900 m asl (cf. Table 1). On the moraine terrace (III–IV) the 'Bezar Gali' pasture is situated. Photo: M. Kuhle.

▲ **Photo 110.** Looking from 4070 m asl from the orographical left-hand valley flank (Figure 28, No. 80) across the Rakhiot valley. View from towards the N (left-hand edge) across the mountain ridge of the 'Bezar Gali' (background) (cf. Photo 107), via ESE into the opposite valley flank with the Buldar peak (6) and via SSE (1 = Nanga Parbat) to the S (right-hand edge of the panorama). (■ on he right) marks the 'Large Moraine'; left from it the Rakhiot glacier is running. (□) is the 'Fairy Meadow' and the pertinent late Late Glacial to Neoglacial moraine generation, stretching up to IV–'VII (cf. Table 1). IV indicates a likewise pertinent corresponding lateral moraine remnant on the opposite right-hand valley side (see Photo 113). (◥ ☗ ◤) shows the High- to Late Glacial flank abrasions, brought about by the then Indus ice-stream network. (——0) marks the provable glacier level of that time down to the Indus valley (0——fine, on the left). (——0, bold) is the pertinent pre-historic ice level above the ground moraines (■ on the left) on the valley shoulder of 'Bezar Gali' (cf. Photos 107, 108). Photo: M. Kuhle.

▲ **Photo 111.** From 3730 m asl from the upper Rakhiot valley (Figure 28, No. 68) seen down-valley up to the Indus valley. Directions: from towards the NNW (left-hand edge) to the NNE (right-hand edge); the Indus valley bottom can be seen right in the N. The Rakaposhi-Haramosh range (S-Karakorum) is recognizable in the background : (1) = Rakaposhi (7788 m), (2) = Diran (7266 m), (3) = Miar- and Rhuparash peaks (max. 6824 m), (4) = Malubiting (7458 m). (◣ ◢ white) are the flank abrasions on the slopes of the Rakhiot valley. Their upper margins mark the highest provable High-(LGM = 0) to Late Glacial polish lines (——bold). (■ on the left above) indicates the Ice Age ground moraine on the valley shoulder of 'Bezar Gali' at 3800-3830 m asl (Figure 28, No. 81; Photos 108, 109). (■ centre at the bottom) are the moraines in the 'Fairy Meadow' area ('Fairy Meadow' generation = Stadia IV–'VII; cf. Table 1). The two IV (centre at the bottom) show orographical right-hand remnants of lateral moraine terraces of the late-Late Glacial Rakhiot glacier (see Photo 113). (—— fine) is the minimum High- to Late Glacial Indus main glacier level, reconstructed by means of ice scour lines. The glacigenic flank abrasions (◣ ▲ ◢ black), marked there, occur in many places in the neighbourhood of ground moraines and Late Glacial lateral moraine ledges (Figure 28 above No. 93, 94, 95). Above the Indus valley floor there rise two hills, polished round by the Indus glacier (▲ black ▲ and white, panorama centre at the bottom). The difference in level (from —— bold to fine) shows that the side glacier was steeply connected with the main glacier by a confluence step. (↘) is the direction of a subglacial meltwater discharge from the 'Gor Gali'-saddle (2840 m asl; Figure 28 above No. 106) during the Late Glacial. Photo: M. Kuhle.

► **Photo 112.** From 3720 m asl from the left-hand Neoglacial lateral moraine of the Rakhiot glacier (Figure 28, No. 68) seen across its glacier tongue in a NNE direction the Indus valley upwards to the Karakorum. (2) = Diran (7266 m), (3) = Miar- and Rhuparash peaks (max. 6824 m). These Karakorum mountains show a flank glaciation with high-altitude valley-glacier tongues of a few kilometres in length (e.g. the Nanga Parbat massif with the Buldar- and Rakhiot glaciers), which nowhere reach down lower than 3000 m asl. This means, that their present glaciation comes to an end at c. 2000 m above the bottom of the Indus valley. In the foreground and the middleground there can be recognized the transition from the present sheer ice to the glacier ice, covered with marginal surface moraine, up to the lateral moraine (V–'VII), which has been undercut by the marginal ice. This moraine was built up in the course of the Neoglacial (see Table 1) and is covered with fully developed mixed high altitude forest. The lateral moraine complex, which was built up by moraine overwhelmings and moraine juxtapositions in the course of thousands of years, towers above the actual glacier tongue about 30–50 m. IV indicates late-Late Glacial remnants of lateral moraine terraces; for IV (black) cf. Photo 113. Photo: M. Kuhle, 06.10.1996.

► **Photo 113.** View from 2800 m asl from the orographical left- hand flank of the Rakhiot valley (Figure 28 centre, between No. 74 and 80) across the talweg of the Rakhiot valley (with the glacier stream of the Rakhiot glacier at c. 2500 m), looking into the orographical right-hand flank towards the E. The late-Late Glacial lateral moraine terrace (IV) situated there, is 300 m high. This remnant begins on the right-hand at 2828 m (highest point of the terrace) and falls away to the left along with the valley (cf. Photos 114, 115, further down-valley). (▲ ▲) mark older (older than Stadium IV) High-(= LGM = Stadium 0, see Table 1) to Late Glacial glacigenic flank abrasions; (——) is the pertinent polish line, which makes it possible to prove the minimal maximum, i.e. Ice Age glacier level altitude. Photo: M. Kuhle.

◀ **Photo 114.** Looking from 2350 m asl from the orographical left-hand Rakhiot valley side to the opposite lying settlement Tato, facing E (Figure 28 left-hand of No. 77). The settlement is located with its fields in a moraine terrace landscape (■), the material deposition of which is of a High- to Late Glacial age (Stadia 0 to IV). The ground moraine depositions (0–IV), which are exposed at the base-level of the glacigenic accumulations, owe their first set-up on the valley bottom near the talweg to the High Glacial Rakhiot glacier, which has filled the entire valley up to (——0). The rest of the moraines of Stadium IV, forming with their three remnants one and the same moraine level, likewise overlie older ground moraine material of Stadia I, II and III. The moraine remnant III might also contain groundmoraine of at least the next-older Stadium II. It is sure that the Rakhiot glacier of Stadium III has reached the level III in this valley cross-profile as the last Late Glacial glacier. The surface of the glacier of Stadium IV no longer reaches as high up. The level of the older glaciers of the Stadia 0-II reached higher than III. Thus, their ground moraines might be included. Since the ground moraines are increasingly reworked and dislocated slope-downwards by the glacier oscillations in the steep higher parts of the valley flanks, only three – or just one – older moraine positions are pointed out here as being included, namely those of the Stadia (I–IV) and (II–III). Due to the most stable position there, the High Glacial ground moraine (0) has in all probability been preserved in remnants on the flat valley bottom, overlain by the younger ground moraines of Stadia I–IV. (☗ ◤) are the orographical right-hand flank abrasions with their typical small-extended rounded rock heads. Photo: M. Kuhle.

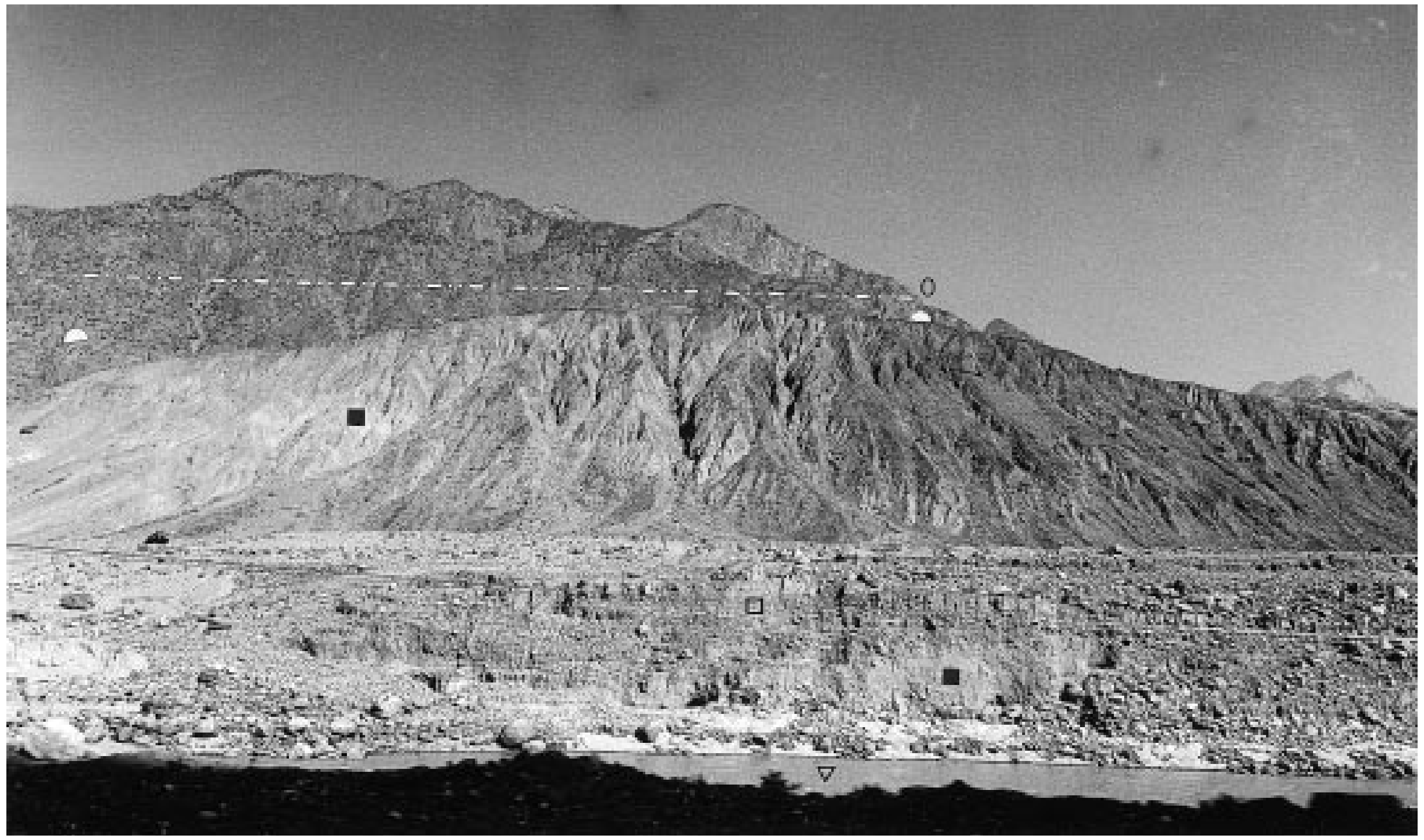
▲ **Photo 115.** From 2100 m asl from the left-hand flank of the Rakhiot valley (Tato Gah) (Figure 28 left-hand above No. 74) seen somewhat up-valley into the right-hand valley flank, facing SE. On this valley flank ground moraine of the Late Glacial Stadium IV (IV centre) has been preserved, which runs out upwards in the ridge of the pertinent lateral moraine. (IV right-hand) indicates the moraine remnant in Photo 114. (■) are corresponding ground moraine remnants on the orographical left-hand valley side. The down-valley continuation of this lateral- to end moraine landscape up to the Rakhiot- (or Tato Gah-) gorge, is shown in Photos 116 and 117. (☗ ◥) mark the High- to Late Glacial flank abrasions, which have rounded or truncated the outcrops of the strata of the bedrock metamorphites (phyllites). (——0) is the minimum altitude of the Ice Age glacier level. In this valley cross-profile there already existed at that time a united glacier surface with the adjacent Buldar glacier tributary stream and the Indus parent glacier (cf. Photos 116–118 ——0). Accordingly the ridge, which separates the Rakhiot- from the Buldar valley, has been rounded (☗ on the very left) (Figure 28 left-hand above No. 91). Photo: M. Kuhle.

► **Photo 118.** View from 1530 m asl from the junction of the Rakhiot valley (or Tato Gah) from the orographical left-hand flank of the Indus valley (Figure 28 below No. 82; Figure 13)). Direction: from towards the WSW (left-hand edge) down the Indus via N directly into the orographical right-hand flank of the Indus valley (right- hand of 8), via NNE up the Indus, via E into the orographical right-hand flank of the Tato Gah exit up to the S, looking into the Tato Gah (Rakhiot valley) upwards (on the very right). (■■) mark ground moraine remnants on the main valley bottom (Indus valley); in parts they are many decametres thick. (■ right, below No. 8) is such a thick ground moraine remnant, the concave bow of which preserves the shape of the then glacier sub-bottom. In the places, where those ground moraine overlayers are absent, the bedrock has been polished round by the glacigenic flank abrasions (◥ ◤). (↙) is the centre of the mountain slide break-off, where in the year 1840 the 2850 m high mountain spur at the end of the Lichar crest slid down in a front of 1 km at the top and of 2 km at the base and a height of 1300 m. Its rock- and moraine masses had dammed up the Indus until the year 1841 (cf. Kick 1996, pp. 80/81). Such crumblings of great dimensions, or even mountain slides, are typical of trough valley cross-profiles, which have been steepened by the valley glacier. (☗ ☗) mark roche-moutonnée-like features of the glacigenic ground polish. (——) indicates the minimum altitude of the High- to Late Glacial glacier level, provable by moraines and flank polishings. (8) = T. P. Gor Gali (-peak, 3037 m). (□) are kame-like glaciofluvial glacier-lateral-sediments. (▼) = position of the Hattu Pir (3127 m); (▽) point 1781 m asl; (⇓) behind this mountain ridge there is a Late Glacial lateral moraine ridge, culminating at 2850 m asl, and the 'Dead Valley', a then lateral valley of the Indus parent glacier. (●) indicates a steeper fluvial slope ravine, which has been incised after the deglaciation. Photo: M. Kuhle.

▲ **Photo 116.** View from c. 2000 m asl from the orographical right- hand flank of the Rakhiot gorge (Tato Gah) (Figure 28 right-hand below No. 75), seen down-valley to the Indus valley, facing NNE. (IV) is the ground moraine remnant of the late Late Glacial, which has been preserved as far down as this gorge (cf. Photo 115). The farthest down-flowing tongue tip of the pre-historic glacier, which belonged to this ground moraine remnant of Stadium IV, reached the position at c. 1700 m asl (▼). (◥ ◓ ◤) mark the glacial flank abrasions in the side valley exit (fore- to middle ground) and in the main valley (background). The crumbling away of the polished rocks, occurring relatively very fast in the bedrock phyllites, has again roughened the valley flanks since deglaciation. The glacigenic flank abrasions have reached the ridge (◓ on the very top, right), which separates the Rakhiot valley from the Buldar valley as well as the summit of the T. P. Gor Gali (8 = 3037 m) (Figure 28, No. 106). Accordingly, these two culminations have been overflowed by the High Glacial glacier (——0). (▽) indicates the 2840 m high saddle Gor Gali, which has also been overflowed by the edge of the Indus parent glacier. (■ larger and smaller) show ground moraine depositions of up to more than a decametre-thickness in the orographical right-hand Indus valley flank. (●) are small hanging valleys or large slope ravines, having been eroded by the water since the the Post-High Glacial deglaciation of these slopes. Photo: M. Kuhle.

► **Photo 117.** Looking from 1550 m asl from the orographical left- hand flank the Rakhiot- (or Tato-)gorge (Figure 28 between No. 75 and 82) upwards, facing S. (IV below) marks the ground moraine remnant in Photo 116 (IV), (IV above) that in Photo 115 (IV on the left). (▼) is the lowest pertinent ice margin position at c. 1700 m asl. (◥ ◤) are the valley flanks, which have been abraded by the Rakhiot glacier tributary stream from the High Glacial up to the Early-Late Glacial (Stadium 0–I). (0——) means, that the pertinent glacier level was situated above those valley flank ridges; at which exact altitude cannot be shown in this Photo. The gorge had already developed by fluvial linear erosion through Ice Age subglacial meltwater and later on has been undercut subaerially during the Post Glacial up to the present (Interglacial). Its subglacial set-up is provable by means of the gorge profile, which is steeply incised into the V-shaped valley bottom. The slope steepenings (seen from above to below) begin below the valley shoulder forms (↙ ↘). Those poorly preserved valley shoulders (↙ ↘) are the remnants of an older glacier valley bottom. The strikingly steep valley shape here, in the confluence-step area to the much lower lying Indus valley (cf. Photo 118), owes its relatively good state of preservation to the insequent (or resequent) valley formation, i.e. the talweg has been incised (or eroded) against the direction of dip of the metamorphic stratified rocks (sediment rocks) (which slope down approximately to the S, cf. Photo 118). Photo: M. Kuhle.

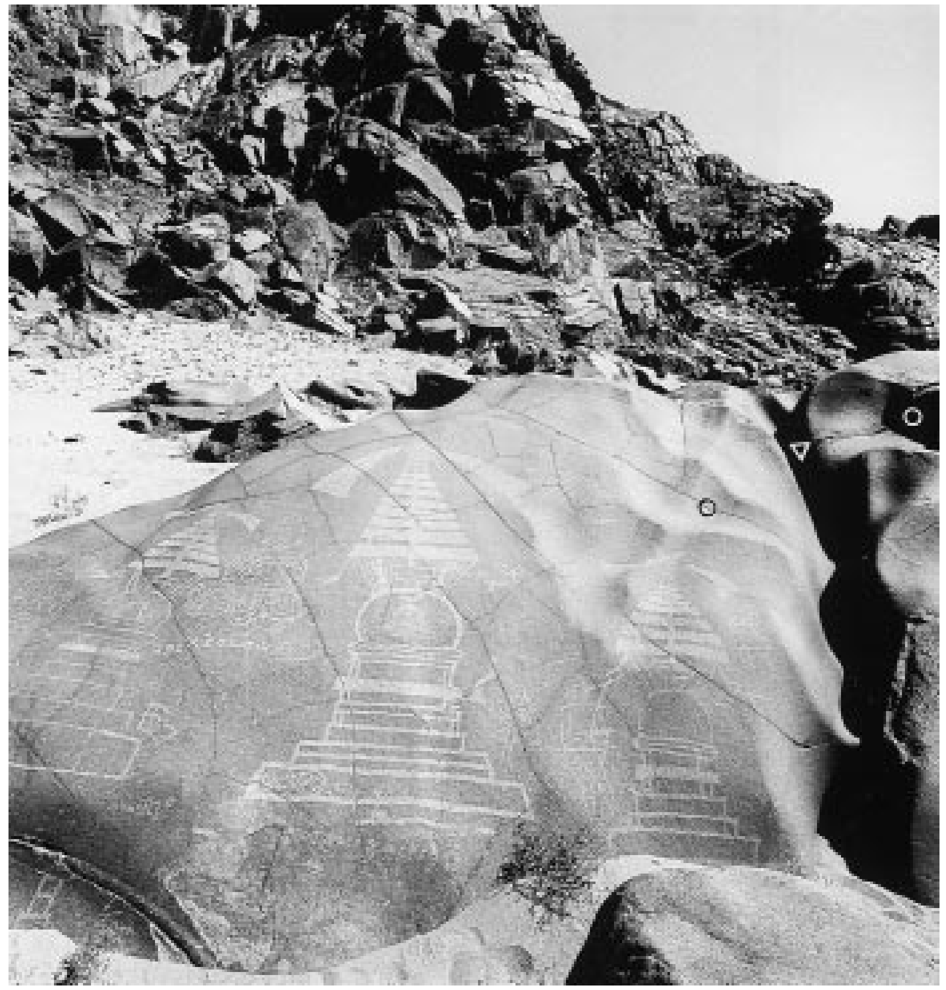
◀ **Photo 119.** From 1260 m asl, c. 130 m above the Indus river, seen from the left-hand valley side (Figure 28, No. 82; Figure 13) towards the WNW; view downwards into the orographical right-hand valley side. (☁ ◢) are roches moutonnées (foreground) and bedrock metamorphites, polished by the High- to Late Glacial Indus glacier. (8) indicates the approximate position of the T. P. Gor Gali peak. (■■) are ground moraine depositions of several decametres in thickness. The original form of the ground moraine cover has been cut by Post Glacial fluvial erosion. With it the ground moraine cover was dissolved into the separate ground moraine complexes (■). After heavy rains their further dissection by ravine rinsing takes place, thus forming earth pyramids. Photo: M. Kuhle.



▲ **Photo 121.** From c. 1155 m asl from the orographical left-hand side of the Indus valley, c. 10 km up-valley of the Bunar Gah junction (or the locality Ame Ges) (35°24′30″N/74°25′E; Figure 13) NW of the Nanga Parbat massif, facing NNW, looking into the right-hand Indus valley flank. (■) marks decametre-thick ground moraine remnants, attached to the rock flank (☁), which has been polished by the glacier. (0——) indicates the highest unambiguous polish line and thus the minimum height of the Ice Age Indus glacier level. (Probably the maximum Indus glacier was even some hundred metres thicker). (□) are fluvial gravel sediments, partly containing remnants of non-reworked ground moraine material. On the gravel terraces lie blown sand covers (eolian sand hazes). (▽) is the Indus river with a low water stage. (□ –6 – –8) indicates the recent to subrecent river bed of the Indus, i.e. its high water bed. Its gravels are to be understood as being glaciofluvial outwash (gravel fields or sander) of the recent to subrecent Karakorum- and Nanga Parbat Glacier Stadia X–XII (cf. Table 1). Photo: M. Kuhle, 27.09.1995.

◀ **Photo 120.** Looking from c. 1150 m asl from the orographical left-hand side of the Indus valley, 16 km up-valley the junction of the Bunar Gah (or of the locality Ame Ges) (35°28′N/74°27′40″E) NW of the Nanga Parbat massif, facing NW into the right-hand valley flank. (■ top) marks a ground moraine terrace of c. 100 m in height and ground moraine thickness. The terrace has been eroded by the Indus river (▽). (■ below) shows a basal ground moraine material, cut by the modern high water bed of the Indus river, on which the river has irregularly deposited metre- to decametre thick fluvial gravel (□). Above the ground moraine terrace the valley flank has been polished by flank abrasion of the High Glacial Indus main glacier (☁). The upper margin of these well preserved glacier polishings suggests the course of a polish line and thus the minimum altitude of the ice level of that time (——0). Photo: M. Kuhle.

▲ **Photo 122.** Seen from 1146 m asl from the junction of an orographical left-hand side valley, the Bunar Gah, which leads down from the pasture-settlement of Koliap into the Biji Gah, SW of the Nanga Parbat massif, looking into the Indus valley (35°24′N/74°19′E; Figure 13), facing S. The Bunar valley, viewed upwards here, is connected to the present northwestern glacier area of the Nanga Parbat massif with the more than 10 km long Diamir glacier by its largest orographical right-hand side valley, the Diamir Gah. (■) is High- to Late Glacial ground moraine material of the Indus main glacier (cf. sample Figure 37), dissected by the tributary stream (▽). The ground moraine also contains local moraine with granite boulders (left of the people with a horse in the foreground) from the Nanga Parbat massif, which might have been transported here by this side glacier. (□ on top) is a younger gravel-cover on top of the ground moraine. It has been sedimented by the glacier stream of the side valley as glaciofluvial gravel field (sander). (◖) marks a mountain spur ridge, which has been completely rounded by the pre-historic glacier ice. (——0) is a High- to Late Glacial polish line, which suggests the minimum altitude of the pertinent glacier level. In the places, where these polish lines are marked (——), the Ice Age Bunar glacier debouched into the Indus glacier (cf. Photo 125). The modern Bunar stream (▽) has dissected a c. 2 m thick gravel cover (□ below) and under it a several metres-thick ground moraine on the valley bottom. Thus, a youngest terrace has been formed, on which the caravan stands. Photo: M. Kuhle.

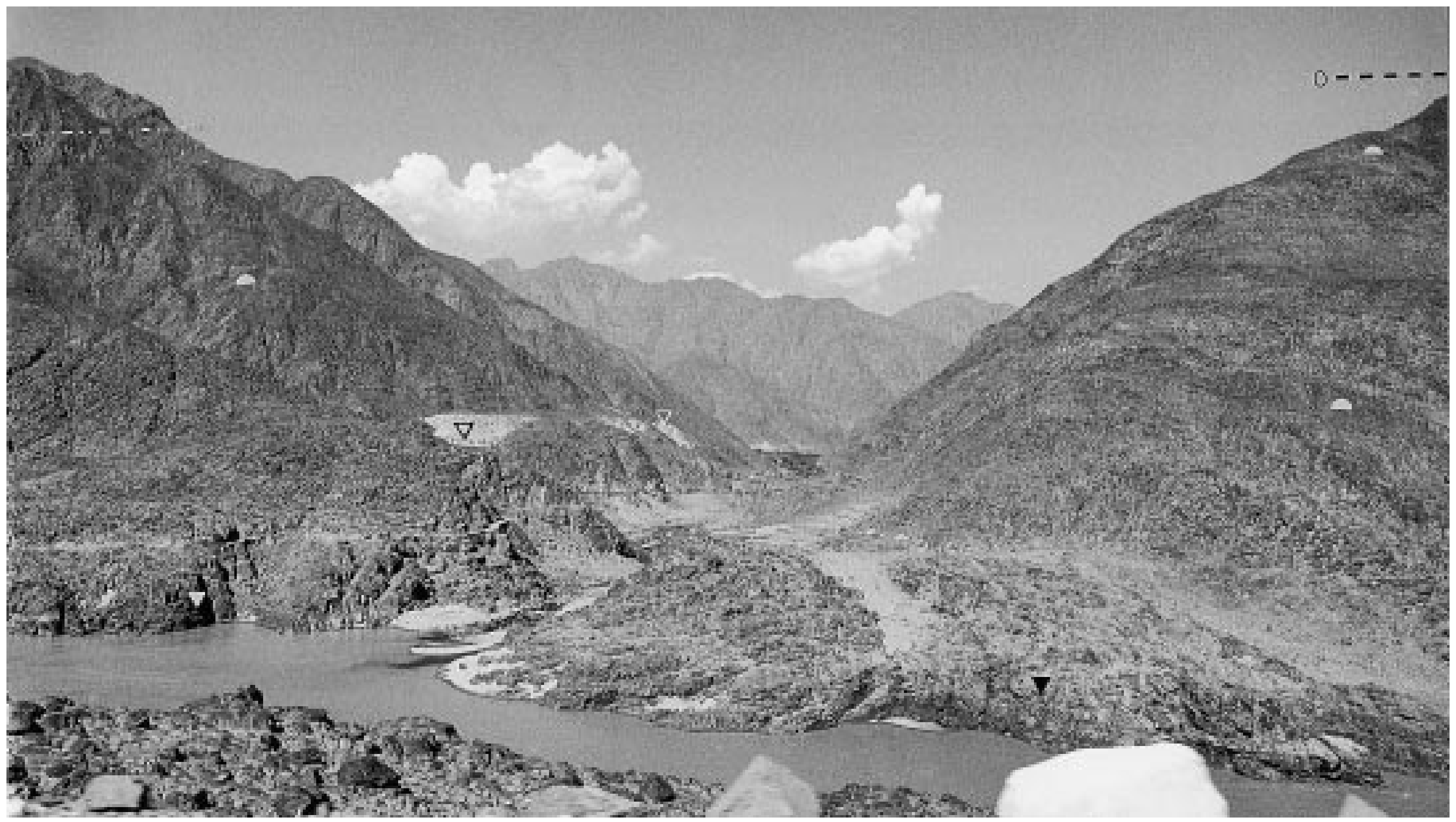


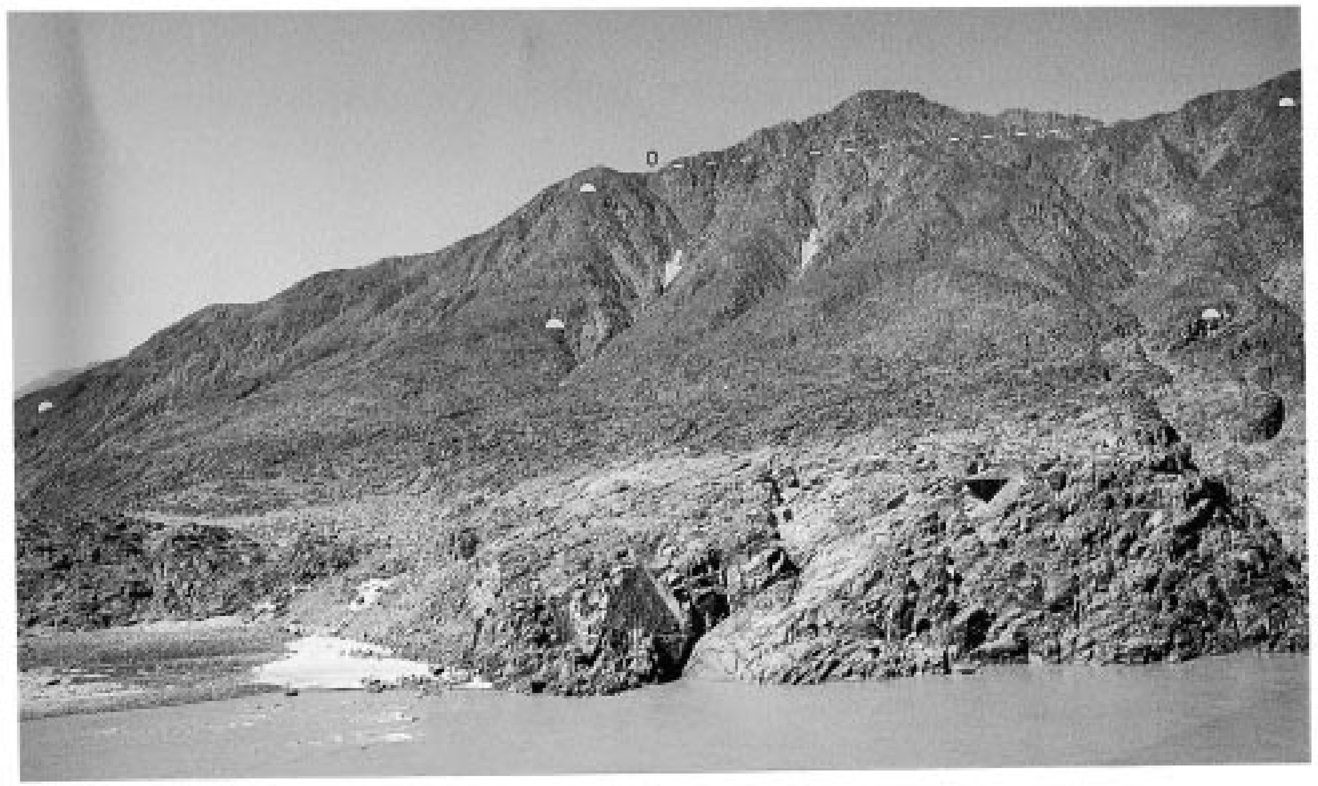
▲ **Photo 123.** At c. 1130 m asl in the orographical right-hand flank of the Indus valley in the valley chamber of Chilas (3 km to the E of the settlement: 35°26′N/74°08′E; Figure 13), 30 to 40 m above the Indus, looking towards the N, facing the right-hand valley flank. Here occur coarse-bedded (thick-stratified) metamorphic siltstone- and quartzite- (phyllite) bedrocks, which in the background are weathered, immediately bound to the cleft. In the foreground a rather large polished rock surface is preserved, on which can be recognized Buddhist rock engravings. These engravings are at least several hundred years old and roughen the dark iron-manganese crusts. As a result of ascending solutions (mineralized water) these crusts form the rock surfaces. The ascending solutions derive from the arid climate in this section of the Indus valley. Solar radiation and atmospheric aridity lead to that capillary water ascent. Probably these iron-manganese crusts are thousands of years old (cf. Haberland, W., 1975, among others). First, fluvial miniature-forms as e.g. small rock-depressions and rock-‘bowls’ (○ black) and signs of potholes (○ white) and rill-rinsing (▽) have been set in this rock surface (cf. Photo 124). They are characteristic features of very fast flowing, hydrostatically confined water. Such features derive only from cavitation corrasion and are typical of the effect of subglacial meltwaters. The present subaerially down-flowing Indus river does not produce such forms. Thus the following conclusion must be drawn: these forms have been developed during the last High- to Late Glacial at least 2500 m below the then snow-line and below the Indus glacier by hydrostatically confined meltwater. Here, so deep below the ELA of that time, the quantity of meltwater was very high. Photo: M. Kuhle.

◀ **Photo 124.** From 1120 m c. 20–30 m above the Indus river on the orographical left-hand valley side in the valley chamber of Chilas (2.5 km E of the settlement: 35°25′55″N/74°07′45″E; Figure 13), seen up-valley towards the E. In the foreground there is a High- to Late Glacial roche moutonnée of the then Indus glacier, formed in metamorphic siltstone (quartzite). In its surface potholes have been eroded (○) through cavitation corrasion by the Ice Age subglacial meltwater. The present rock surface wears an iron-manganese crust and anthropogenic rock engravings. As a result of frost- and insolation-weathering the crust crumbles away in a sharp edge (cf. Photo 123). Photo: M. Kuhle.

◀ **Photo 125.** From c. 1050 m asl downwards the Indus valley, c. 7 km away from the settlement of Chilas (35°26′N/74°01′E; Figure 13), looking from the orographical left-hand valley side up-valley across the valley chamber of Chilas. (1) = Nanga Parbat (8125 m) with the WNW-exposed Diamir flank. The mountain is seen in an ESE direction. (■ I) indicates a Late Glacial ground- to lateral moraine of Stadium I (= Ghasa Stadium, cf. Table 1); it is located at the exit of an orographical left-hand small side valley (western parallel valley of the Thak Gah and side valley of Chilas). Whether a separate High- to Late Glacial glacier flowed down to the Indus main glacier from this side valley, or whether a branch of the main glacier flowed into the side valley, could not be investigated until now. (——) marks the minimum altitude of the High Glacial glacier level. Continuous glacigenic flank abrasions have been observed up to there(◓ ◓ ◓). (□ 5) shows a kame-terrace, consisting of glaciofluvial gravel of a lateral sander. This sander was deposited between the valley slope and the orographical left-hand edge of the glacier. It also indicates a minimum altitude of the Ice Age Indus glacier level (——). From this gemorphological context of syngenetical forming one may conclude that this kame is to classify as being of the Last-High Glacial (gravel field No. 5). However, it might also belong to the Early-Late Glacial (gravel field No. 4; cf. Table 1). These are definitely characteristic meltwater accumulations (sander, gravel fields) at this altitude of more than 2000 m below the Ice Age ELA (3600 m; cf. Figure 28). (–0 – –1) are terrace-shaped remnants of Neoglacial gravel fields. During the Holocene they have been deposited on the bottom of the Indus valley at a time, when the valley was no longer reached by the glacier ice. (–2 – –6 □) are Late-Neoglacial to Historic gravel fields. Their level lies only some metres above the modern Indus level. (◇) is an originally glacigenic roche moutonnée, having been reshaped by subglacially down-flowing glacier meltwater (cf. Photos 123, 124) as well as by Indus water, which has flowed down subaerially since deglaciation. Due to this reshaping the roche moutonnée has lost its smooth-polished surface. (■■ in the foreground) are scattered granite-, gneiss-, quarzite- and other metamorphic boulders, which have been transported here with the Indus high waters (as for instance in the year 1840/41, when the Indus had been dammed up by a mountain slide (cf. Photo 118) at the settlement of Lichar and afterwards discharged; cf. Kick 1996, pp. 80/81). These blocks have no iron-manganese crust. (△) is an orographical right-hand alluvial fan, which during the period from the Neoglacial to the Historic time (i.e. within c. the last 3000–4000 years) has come down from a right-hand side valley. Photo: M. Kuhle.

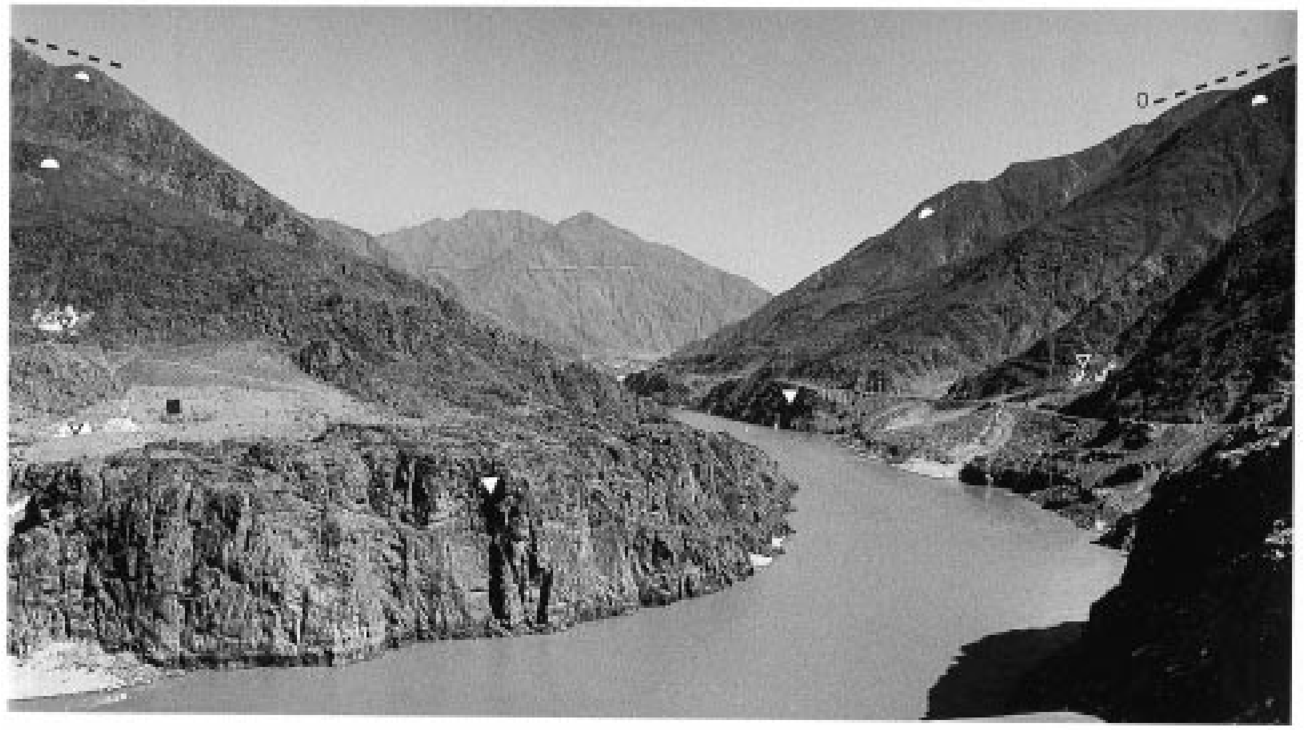
▲ **Photo 126.** From c. 1030 m asl from the orographic left-hand flank of the Indus valley, c. 20 km down-valley of Chilas (c. 35°28′N/73°55′E, between the settlements of Balugush and Thor; Figure 13) looking to the N into the orographical right-hand Indus valley flank. (□) is a more than 100 m high gravel-body, which has been accumulated as a kame from the joining side valley in an orographical right-hand glacier lateral valley between the Indus glacier and the valley flank. Thus, these are the still preserved remnants of an alluvial debris fan, which the tributary stream has deposited against the ice or the morainic glacier edge. (▽) = lake sediments of a marginal moraine- or glacier dammed lake, which has been developed at a still further lowered valley glacier surface. (◓ ◓) are glacigenic flank abrasions. The well, i.e. continuously, preserved polish line (——0) marks the minimum altitude of the Ice Age Indus glacier surface. (○ black) and (○ white) are rather large erratic granite- i.e. metamorphic boulders, which travelled here with the Indus high waters. They were taken up by the high water from up-valley moraine depositions and transported farther. Photo: M. Kuhle.





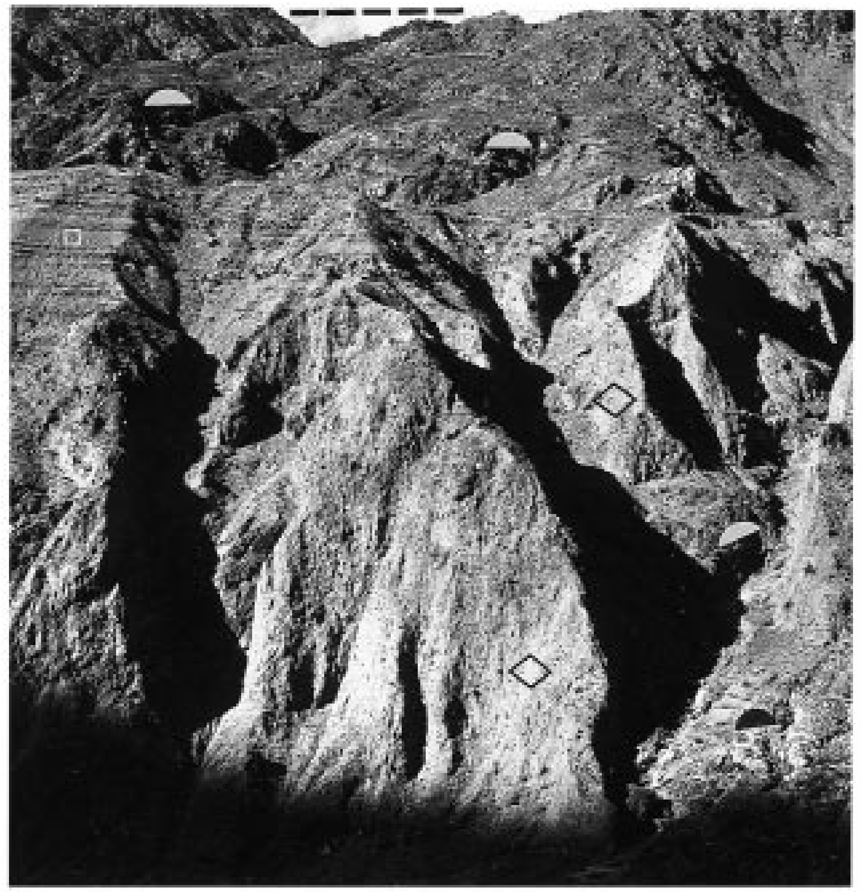
▲ **Photo 128.** From c. 1000 m asl, about 2 km down the Indus valley from the junction with the Domot Gah (c. 35°31′30″N/73°45′E; Figure 13), seen towards the NNW into the orographical right-hand flank of the Indus valley. Here, too, the valley has a trough- or U-shaped cross-profile, the flanks of which are concavely polished and smoothed (◓) by flank abrasion of the High Glacial Indus glacier. These flank polishings have been interrupted by ravine rills (↓), which have newly been reworked and deepened interglacially and postglacially, i.e. since deglaciation. (0——) is the minimum altitude of the Ice Age glacier level, proven by a continuously preserved polish line up to this height. (▼) indicates an outer slope of the Indus river, from which results the steepened lower slope, developed by fluvial undercutting of the flat glacigenic trough-valley slope, situated above. In the foreground flows the suspension-rich Indus river in its low water bed. Photo: M. Kuhle, 27.09.1995.

◄ **Photo 127.** Looking from c. 1020 m asl from the left-hand side of the Indus valley (35°32′N/73°46′E; Figure 13) into an orographical right-hand side valley, the Domot Gah (in the Darel area), facing upwards. The photo was taken towards the NNE. This S-exposed valley leads down from the 4939 m-high Sochni Gali. During the High Glacial it had a glaciation on its own down to at most 2200 m asl (cf. Porter 1970; Kuhle 1989a, pp. 271/273 and the contrary interpretation of Haserodt 1989, Figure 1, p. 197). Accordingly, the Domot glacier tongue was far from reaching this junction into the Indus valley at a 1200 m lower altitude. (◓ ◓) mark the flank abrasions of the Ice Age Indus glacier on the orographical right-hand slopes of the Indus valley up to the height of a continuously preserved polish line (0—— white and black). This line indicates at the same time the minimum altitude of the Ice Age main valley glacier surface. (▼) are steepenings of the rock-bank of the Indus river. Here, at these fluvial parts of the outer slope, the Indus has undercut the rocks, which were round-polished by the glacier (◓), either already subglacially or after the deglaciation. (▽) are liminic sediments of a lake, which has either been dammed-up by the down-melting Indus glacier, by a mountain slide down the Indus, or by a large mudflow fan (the remnants of the last two are already worn away). The last interpretation applies in principle to all dammed lakes in the Indus valley. Thus it offers for instance an additional interpretation to Photo 126 (see above) and Photo 129 (see below). Such damming-up of lakes by mudflows took place e.g. in the course of the last 15 years at least twice in the Ghizar valley near Singal, northwest of Gilgit. The potential Late Glacial glacier dammed lake has been dammed up here far into the Domot Gah. Photo: M. Kuhle.

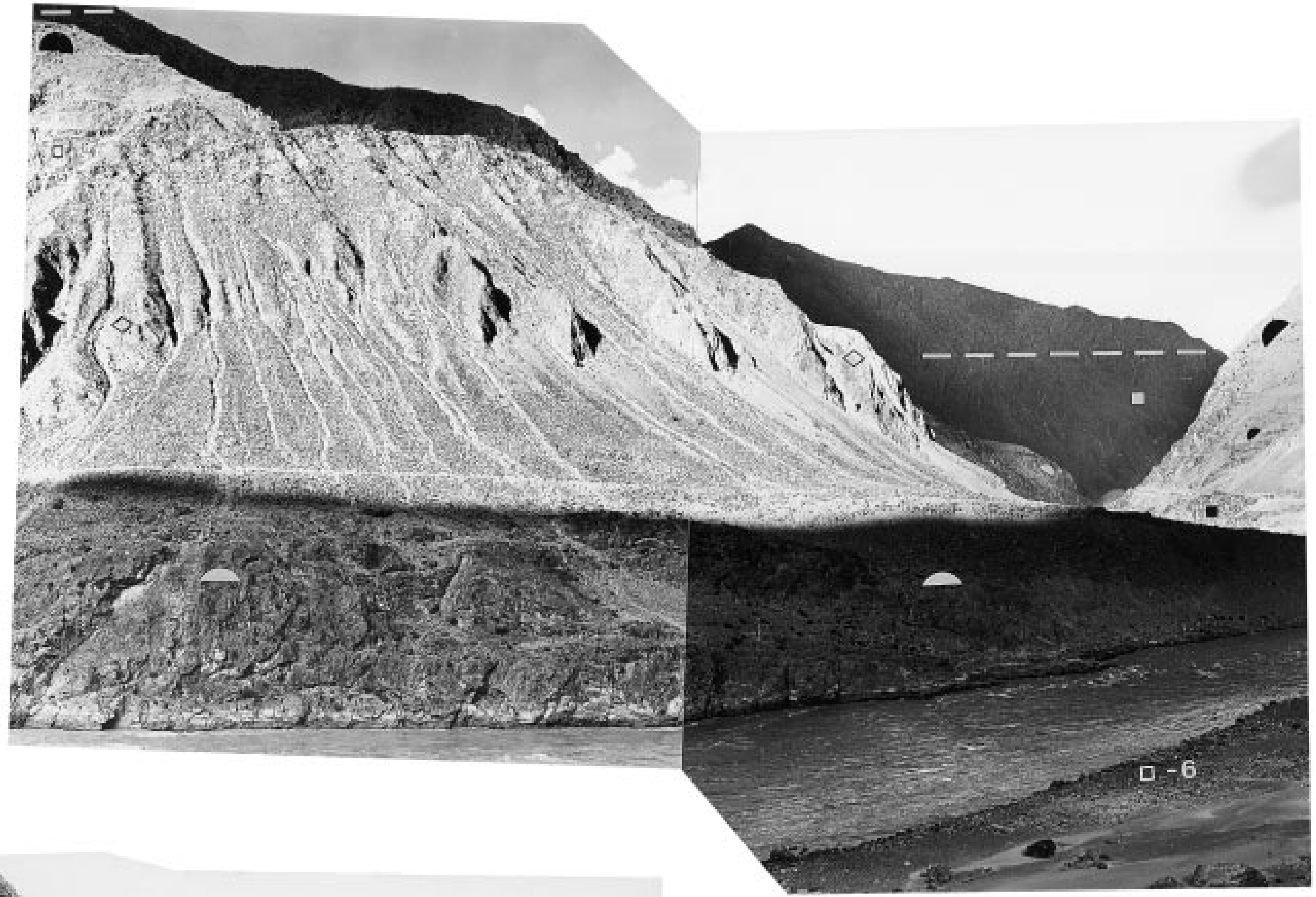


▲ **Photo 129.** From c. 1010 m asl, 11 km Indus valley downwards from the junction with the Domot Gah (c. 35°34′N/73°40′E; Figure 13), facing E, seen up the Indus valley. With the help of this very well preserved glacigenic valley trough profile, the enormous Late Glacial glacier thickness up to an altitude above sea level of only 1000 m and lower (cf. Photos 130–132) becomes clear. (—— and ——0) indicate the highest continuous polish line, i.e. up to there reach the flank abrasions (◓ ◓) and truncated spurs between small side valleys and large interglacial slope ravines, which have not been completely reshaped by the flank polishing of the Indus glacier. (▼) mark the box-profile, eroded into the bottom of the glacier valley cross-profile by the Indus. Probably this has been brought about largely by the down-flowing subglacial meltwater during glacial times. (■) is a ground moraine remnant. (▽▽) are remnants of limnic sediments. They may originate from dammed lakes, which have been dammed-up by mountain slides and mudflow fans or by the ice infilling of the Post-High Glacial Indus glacier. In the last case they would have been glacier marginal lakes. Photo: M. Kuhle.

► **Photo 130.** From c. 1000 m asl, about 5 km up-valley from the settlement of Sazin, facing N into the right-hand side of the Indus valley, looking towards a moraine exposure (35°33′N/73°29′E; Figure 13). It is a lateral moraine (◇), in the build-up of which a heavy mountain slide from the orographical left-hand Indus valley flank has been involved (see also Photo 131 ◇). The indication of this mountain slide is due to Prof. Dr. M. Winiger (personal communication of April 1994 in Bonn). Therefore the moraine is to be termed as a mountain slide moraine. The mountain slide surged over the valley glacier, filling its lateral valleys. The material of the mountain slide partly has been dislocated by the glacier and integrated into the lateral moraines. This is proved by the dense packing of the material, i.e. a pore volume, which is too small for a mountain slide (◇). (□) are glaciofluvial gravel layers, originally sedimented in the orographical right-hand small lateral valley of the Indus glacier between the ice stream and the valley flank. The relatively sudden discharge of a lateral lake (cf. the limnic sediments in the Photos 126, 127 and 129) might have taken part in the fluvial transport of these gravel- and debris components. The run-off of a mountain slide dammed lake, however, has to be ruled out, because this can take place only through a narrow incision into the mountain slide in the form of linear vertical erosion, and therefore solely at a lower level; it could not leave behind gravel covers on the top. At the base of this moraine there is bedrock, which has been round-polished by the glacigenic ground polishing (◓ right-hand below). The rock slope above the lateral moraine terrace has been polished by the glacigenic flank abrasions (◓ above), too. This glacigenically-shaped slope (◓ above) reaches up at least to the marked polish line (——). The ground polishing underneath the moraine as well as that glacigenically-shaped slope, reaching up much higher than the moraine, provide evidence of a Post-High Glacial to Early-Late Glacial age of this lateral moraine (perhaps Ghasa Stadium I) and make clear, that the High Glacial Indus glacier must have flowed much further down-valley than the valley glacier end, related to these moraines (cf. Photo 132). Photo: M. Kuhle.



▶ **Photo 131.** From c. 990 m asl, about 1 km further down-valley, looking at the same right-hand Post- to Late Glacial moraine complex (◇ on the right) shown in Photo 130, seen diagonally up-valley towards the NE. Immediately upwards the Indus valley from the part of the lateral moraine, visible here (◇ right), this moraine comes to an end. Instead, a round-polished rock ridge (◥ in the background) can be recognized. Corresponding orographic left-hand flank polishings (◤◤ black) can be observed on the trough valley flank, lying opposite. (■■) mark ground moraine remnants on the rock-bottom and on the valley flank. (☗ white, in the middle ground) is the rock-bottom below the lateral moraine, smooth-polished by the glacier (◇); (□) indicates the glaciofluvial gravel cover on the mountain slide lateral moraine; above, a glacigenically polished slope has been shaped by flank abrasion (☗ black on the right) up to the polish line (——). Thus (——) at the same time marks the minimum altitude of the High Glacial Indus glacier level. (□ –6) is the subrecent to modern gravel bed of the Indus, which to a great extent is still fed today by glacier meltwater (cf. Table 1). Photo: M. Kuhle.



▼ **Photo 132.** From about 870 m asl, c. 15 km down the Indus from the settlement of Sazin, somewhat up-valley of the Kandia Gah (valley) junction, from the orographical left-hand valley side (35°32′N/73°18′E; Figure 13) viewing the Indus valley from upwards (right edge of the panorama) to downwards (left edge). The photo was taken facing ENE (right) via NNW into the opposite valley side (centre) towards the WSW down-valley (left). (◥ ☗ ◤) indicates glacigenic flank abrasions, which even in this very low-lying Indus valley cross-profile reach up more than 150 m above the valley floor. The continuous polish line (——) at the same time marks the minimum altitude of the High Glacial glacier tongue level. (▼) are fresh, i.e. Post-Glacial crumblings, which took place after deglaciation. (▽) shows a flat (i.e. only insignificantly thick) debris cone, which has been deposited on the Ice Age glacigenic flank polishings (centre, white ☗) during the Holocene. (■) is a more than 10 m-thick and c. 120 m long ground moraine remnant, undercut by the high water of the Indus river. In this ground moraine exposure (right-hand of ■) large far-travelled boulders, partly rounded, rounded at the edges i.e. facetted, 'swim' in a fine ground mass (see Figure 37). This accumulation-remnant (■) is situated at the foot of a convex smoothed rock slope (◥) without a small side valley, slope-groove or ravine. It has been preserved here in an inner bank position of the Indus. (➝) marks the position of another ground moraine remnant on the other side of the river, from which has been taken a sample (Figure 37). Up to now the author could not definitely determine the down-valley lowest ice margin position of the Last-Glacial Indus glacier. Photo: M. Kuhle.

▶ **Photo 134.** View from 4800 m asl from the Bayan Har pass (c. 34°07′30″N/97°39′E; Figure 138; 5 mm left of the Animachin) in E Tibet, looking into the N 'Bayan Har pass valley' (the outlet of which joins the Huang Ho (river)) downwards. The photo was taken facing NE. (□) marks the ground moraine cover, which the High Glacial (LGM) inland ice has laid over the Bayan Har pass. Today the material is overgrown with alpine meadow vegetation on which are set grass- and turf hummocks (tufures). At this time (in early summmer) the permafrost table lies under a several decimetre-thick thawing layer horizon (cf. Photo 38). (☗) are mountain ridges, about 5000 m in height, which are round-polished by the inland ice. The ice might have flowed across this area from the SW towards the NE. (——) is the postulated ice surface, which has completely covered all points of the relief. Photo: M. Kuhle.

▲ **Photo 133.** From 4720 m asl on the Tibetan plateau, in the area of its E margin (34°35′N/99°27′E) between Bayan Har (Payen Kola Shan) in the WSW and Animachin (Anymachen) in the NE (cf. Figure 1, No. 2; Figures 38 and 39) looking towards the SE. This section of the plateau margin rises up to 5404 m asl and has no present glaciation in the catchment area. The hill ridges have been completely polished round by the High Glacial inland ice (◒). They show all geomorphological characteristics of glacially streamlined hills. On their surface, which consists to a great extent of out-cropping rock, either the remnant of a ground moraine overlay or a maximally centimetre-thick spread of Post Glacial broken frost debris can be noted. (■) marks ground moraine in small polished depressions. Due to its loamy matrix, but also to the permafrost table (cf. Photo 138), stagnant snow meltwater occurs on this ground moraine. Since deglaciation fluvial grooves (↓ on the right) have been incised into the flat slopes, in which the snow meltwater runs down. But larger fluvial forms, as for instance small valleys, in the meantime also restored their interglacial V-shaped talweg through the subaerial snow meltwater run-off (↓ on the left). (——) is the minimum altitude of the completely covering inland ice surface. Photo: M. Kuhle, 07.06.1981.

► **Photo 135.** From 4610 m asl, likewise in the area of the Payenkola Shan (Bayan Har) but further to the N than Photo 134, c. 17 km SE of Chalaping (cf. ONC-map G 8, 1:1,000,000) in the eastern section of the Tibetan plateau (34°10′N/97°44′E; Figure 1, No. 17), seen towards the E. The plateau is covered by a metre-thick ground moraine (□). Wherever the descending water has eroded small streamlets into the ground moraine cover or small deflation depressions have been inset, medium-sized and large light granite boulders (up to several metres in length) are exposed. The boulders are rounded or facetted. These are far-travelled erratic boulders, which have been transported here from the SW by the inland ice. There is bedrock of sandstone series in the underground. Photo: M. Kuhle.

▲ **Photo 136.** View from 4580 m asl N of the Bayan Har on the Tibet plateau W of the Animachin(34°11′10″N/97°46′10″E; Figure 39 c. 1 cm left of the Anymachen (or Animachin)), approx. 13 km SW of Chalaping, seen towards the E across a ground moraine cover (□). In places the large light granite boulders, which ‘swim’ in a fine ground mass, lie up to the ground moraine surface and – visible from afar – break through the cover of meadow vegetation. These boulders are far-travelled and come from the SW; probably they originate from the bedrock granite of the Bayan Har massif. The boulders can be proved to be erratic here, because they overlay bedrock sandstones (cf. Chinese Geological Map 1:1 500 000, sheet 3). (◒) are glacially streamlined hills of red-brown sandstones, polished round by the inland ice (LGM = Stadium 0; Table 1). The ground moraine cover and the glacially streamlined hills provide evidence of an ice, which has completely covered the relief. (——) marks the minimum altitude of the Tibetan inland ice, derived from these facts. Photo: M. Kuhle.

▼ **Photo 138.** From c. 4515 m asl in E Tibet, in the plateau area of Bayan Har (Figure 38; c. 5 mm left of the Animachin), about 16.5 km SW of Chalaping (34°09′40″N/97°43′50″E), seen towards the N across a monotonous ground moraine landscape (□). In the foreground a c. 3.5 m-deep exposure of this ground moraine is shown, which contains erratic granite boulders (the light ones, which are rounded at the edges). (▼) is the at least 1.5–2 m-thick permafrost table; above it (□ white) the c. 1–1.5 m-thick active layer up to the surface-level of the ground moraine. The loose material above (with the shovel leaning against it) has been accumulated artificially (excavation). In this place the exposed permafrost melts. Therefore the pool of stagnant water in the exposure ditch came into being. Such continuous permafrost provides evidence of annual mean temperatures of colder than –6° to –8°C in this section of the Tibetan plateau. Photo: M. Kuhle, 27.07.1994.

◀ **Photo 137.** View from 4570 m asl, E-Tibet (Figure 38; c. 4 mm left of the Animachin), approx. 12 km to the SW of Chalaping (34°12′N/97°46′20″E), facing SE. (◓) marks a glacially streamlined hill from bedrock phyllite, which has been shaped by the inland ice. (□) is a ground moraine landscape, stretching up to the horizon (background). In places where rain- and snow meltwater flows down today (as for instance in the foreground), the ground moraine is cut decimetre- to metre-deep. As a result the fine ground mass (matrix) is flushed out and large erratic granite boulders (■ black) are exposed. This far-travelled boulder, which is round at the edges and facetted, is associated with small edged boulders of local moraine from sandstones and phyllites (■ white), which were transported not very far. In the underground there is such a series of bedrock sandstone- and phyllite. (— —) is the minimum altitude of the High Glacial inland ice surface (LGM = Stadium 0; Table 1). Photo: M. Kuhle.

▶ **Photo 140.** On a very flat pass at 4200 m asl, c. 4 km S of the settlement of Yehmatan in NE Tibet, approx. 70 km NNE of the granite-mountains of the Bayan Har (34°39′30″N/98°02′40″E; Figure 39: 135 km W (left) of the Anymachen), looking across ground moraine planes (□; from the fore- to the background). The panorama was taken from towards the NNE (left-hand edge) via E and S (second ◓ from the right), up to the SW (right-hand edge). Large, light erratic granite boulders, including big sanidine-crystals, only relatively seldom break through the ground moraine surface (rucksack in the foreground to compare the size). Such boulders have been transported here over a distance of at least 60 km from the SW and at the same time had even to overcome some counterslopes (see background in the right half of the panorama: ◓ ◓). These granite boulders ‘swim’ in isolation very far from each other in the fine ground moraine matrix, and with it lie on the bedrock metamorphites in the underground, which have been polished by the inland ice. (◓ ◓) mark mountain ridges, which are round-polished by the High Glacial (LGM = 0; cf. Table 1) inland ice. These are hills from metamorphic rocks (crystalline schists, phyllites), which have been shaped by the ice to glacially streamlined hills. (——) is the hypothetical inland ice surface. Photo: M. Kuhle.

▲ **Photo 139.** From 4290 m asl, in a basin-shaped valley in E Tibet, which has been flatly inset into the plateau (Figure 38; c. 4 mm to the left, below the Animachin; about 34°17′N/ 97°53′10″E) 4 km NNE of Chalaping, looking towards the E. This N-sloping valley is flanked by glacigenically round-polished mountain ridges from metamorphic sedimentary rocks (◓). In places somewhat younger, i.e. Late Glacial (Stadium I–IV, cf. Table 1) moraine remnants (□) rise above the High Glacial (Stadium 0) ground moraine cover (■). Separate large, light erratic granite boulders tower above this ground moraine cover. They are several metres long. One of them (the second from the left) juts out of the moraine surface up to 2 m. The stream in the talweg of the valley (in the back of the foreground) flows at most 1 m^3/sec water. Accordingly, it has only superficially and slightly washed out the ground moraine on the valley bottom and covered it with a thin gravel field (○). However, there is no doubt that the very large granite boulders have not been transported by the stream in this sandstone area, but by the High- to Late Glacial Tibetan inland ice. (——) marks the minimum altitude of its surface. The ice has covered the entire relief. Photo: M. Kuhle.

▲ **Photo 141.** From 4110 m asl on the S-edge of the Yen Yougo basin, S of Yehmatan (34°39′49″N/98°04′E; Figure 38 left-hand below of the Animachin) in NE Tibet, seen towards the SE across the plateau. The exposure (with rucksack in the foreground) shows typical ground moraine with a loamy ground mass, including polymict boulders; among them are local components from phyllites and quartzites (↑ black) as well as far-travelled granite boulders (↗ white). (☗) are round-polished phyllite ridges. They have the shape of classic glacially streamlined hills. (□) indicates ground moraine, covered – but not completely – with meadow vegetation. (——) is the hypothetical inland ice surface. The ice has completely covered the relief. Photo: M. Kuhle.

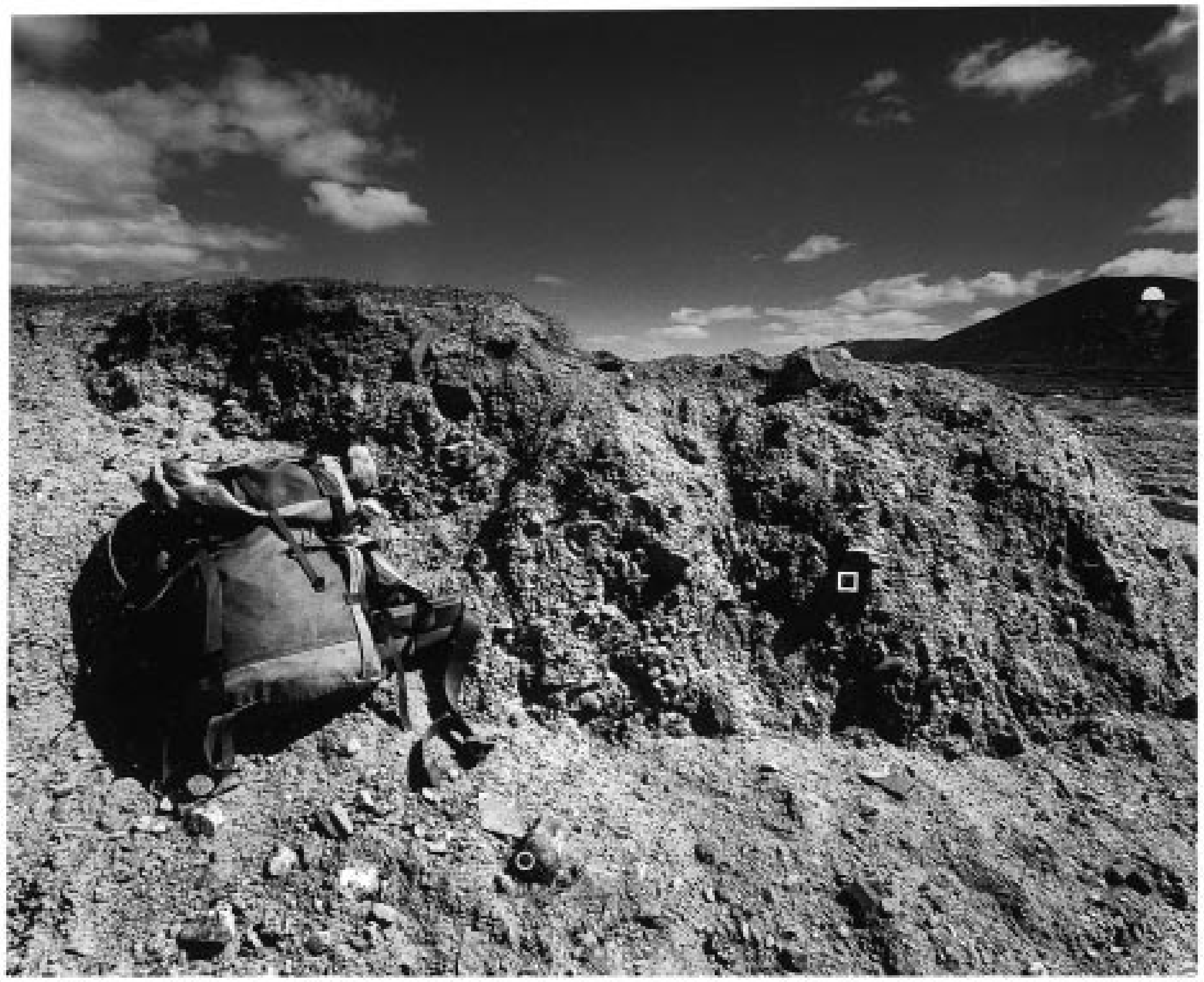
▲ **Photo 142.** From c. 4100 m asl, SE of the settlement of Yehmatan in NE Tibet (34°39′50″N/98°04′01″E; Figure 39: c. 130 km W of the Anymachen), panorama taken across the basin of Yen Yougo. Direction: facing ENE (left-hand edge) via E towards the S (right-hand edge). Here, c. 75–80 km N of the bedrock granites of the Bayan Har in a region with metamorphic sediment rocks, as phyllites and quartzites, large far-travelled light erratic granite boulders (rucksack next to the largest block) from granite of the Bayan Har are provable in this relief-covering ground moraine (□). These blocks are rounded to rounded at the edges. They often have one, two or even three planed and polished sides, which are characteristic for moraine blocks, facetted by the glacier transport. (☗) indicates the fringing hills of the basin, round-polished by the Last-High Glacial inland ice (LGM). The basin was completely filled with the ice. (——) is the inland ice level, belonging to this ground moraine cover laid down here and to the glacially streamlined hills. (Zhou Shangzhe, 1995, pp. 230–240, agrees with the author's interpretation of an Ice Age inland ice for this region; cf. Kuhle 1982e and 1987b). Photo: M. Kuhle.

▼ **Photo 143.** From c. 4100 m asl in NE Tibet (34°39′49″N/ 98°04′E; Figure 1, No. 17) looking to the S edge of the Yen Yougo basin (= basin of the white cow), facing S. The loam-rich ground moraine cover of the basin bottom (□), in which 'swim' erratic granite blocks (■), stretches up to the round-polished fringing heights (☁) of the basin. These boulders were transported here from the S, from the Bayan Har region, over a distance of more than 70 km (cf. Photo 134). The boulder shown here is rounded at the edges and facetted, i.e. it has been flat-polished on several sides. The individual boulders are situated very far away from each other and isolated by the fine matrix of the ground moraine (cf. Photo 144). (——) is the hypothetical surface of the inland ice (LGM or Stadium 0 in Table 1), which has completely covered the relief of the plateau (Figure 38 left-hand below the Animachin). Photo: M. Kuhle.

► **Photo 144**. Same locality as Photo 143 from c. 4100 m asl, looking towards the SE. Exposure of the upper 70 cm of the ground moraine cover in the Yen Yougo basin. The laboratory analyses show the characteristic bimodal grain size distribution curve (histogram), very frequent for ground moraines, with a significant fine grain size peak in the pelitic (clayey to loamy) material (□). The second peak is situated in the psammitic (sandy) portion. In addition to the far-travelled erratic granite boulders (e.g. ↖ white), phyllite boulders (e.g. ↘ black) are contained, which are isolated from each other by the matrix. They have been torn out of the local rock ground by the glacier ice of the ice sheet or were transported over only a small distance. In this place quartzite boulders were also found, which provide evidence of a glacier transport by the glacigenic striations of their surfaces (cf. Photo 145). – It ought to be stressed that all moraines introduced here (Photos 133, 135–137, 139–143), occur extensively, that means, they are not bound to a valley or basin. They occur so far away from any mountain foot, that *they cannot have been deposited by mountain glaciers*. Photo: M. Kuhle.

► **Photo 145.** Striated quartzite boulders of the ground moraine cover in the Yen Yougo basin on the plateau in NE Tibet (4100 m asl; 34°39′49″N/98°04′E; Figure 38: c. 3–4 mm to the left below the Animachin) (cf. Photos 142–144). Taking of the sample: M. Kuhle; Laboratory Photo: F. Sailer.

▼ **Photo 146.** From c. 4150 m asl, WSW of the settlement of Haschi Scha (or Huashi-hsia, according to the ONC-map 1:1,000,000 G-8, 1973; or in dialect: 'Hatsche Tai', according to the personal communication of a Tibetan in 1981) on the plateau in NE Tibet (Figure 1, No. 2: left-hand, somewhat above the Animachin; 35°06′30″N/98°50′20″E) facing NE. In the background a mountain ridge of limestone can be noted, polished by the Tibetan ice sheet (LGM = Stadium 0 in Table 1) (▲). Below the hill is situated the above-mentioned settlement. In the foreground the ground moraine cover (till) (□), deposited ubiquitously, is exposed. The rucksack serves to compare the size of the 85 cm-high exposure. In this location a sample for grain size analyse was taken from the matrix at a depth of 30 m, above (□). It confirms the ground moraine character (till) of the clayey-loamy ground mass. In this matrix far-travelled granite erratics from the 70–90 km distant granite region in the SSE, SW of the Animachin (Chinese Geological map 1:1,500,000, sheet 3) 'swim', as well as limestone- and quartzite boulders. The last-named are frequently striated (e.g. ○). The granite boulders probably have been transported here from the region in Photo 133 with a component of the inland ice, flowing down to the N. The boulders involved are partly edged (local moraine), partly rounded at the edges and facetted. A mountain glacier transport of this till cannot be taken into consideration because no mountains, superimposed upon the Tibetan plateau, are in the vicinity. Photo: M. Kuhle.



► **Photo 147.** From c. 4160 m asl in NE Tibet, looking across the ground moraine floor (till) (□) of the basin ENE of Haschi Scha (or Hatsche Tai, cf. Photo 146) (35°08′N/98°55′E; Figure 1: above the Animachin) facing ENE. (▲▲) are glacially streamlined hills of Cretaceous limestone, round-polished by the High Glacial ice sheet. The ice has completely covered the relief. (——) is the hypothetical glacial (Ice Age) surface of the inland ice. In the foreground the ground moraine is exposed, which, as a result of the syn-genetical pressure of the superimposed load, is typically dense-packed (□; rucksack to compare the size). The analyse of the samples taken (grain size distribution) confirms the characteristics of the till, which is already macroscopically visible here. In addition to local lime-stone blocks this ground moraine contains granite blocks. Calcite-containing bedrock limestone is in the underground. Accordingly, the granite components are erratic and far-transported. Photo: M. Kuhle.

► **Photo 148.** At c. 4160 m asl in the basin ENE of the settlement of Haschi Scha (cf. Photo 146) (c. 35°07′30″N/98°53′30″E; Figure 1: left-hand above the Animachin) in NE Tibet, exposure of ground moraine on the High Plateau (□). The important portions of fine material of the till, which contain – isolated from each other – limestone-, phyllite- and erratic granite blocks, are visible. The blocks in this picture are just decimetre-sized. Due to the great portions of fine material it is impossible to mistake this material for a fluvial gravel body. But a mudflow sediment cannot also be taken into consideration, because of the extensive distribution in approximately the same thickness, the featureless flat surface condition and the lack of catchment areas, belonging to a mudflow. (↖ ↖) mark shear planes, dipping against the direction of flow of the inland ice, where layer after layer of the internal composition of the till has been torn and shorn away by the overflowing ice. Photo: M. Kuhle.

▲ **Photo 149.** From c. 4200 m asl, looking down the large valley, which leads from the NE Oh La (pass) down to the N, to the settlement of Sujung and the basin of Heka (according to ONC 1: 1,000,000 map G-8) (Figure 1, No. 2, above the Animachin; Figure 38: left-hand above the Animachin; 35°32′30″N/99°31′E), facing N downwards. A ground moraine cover (□) with large granite blocks is preserved on the valley bottom and the orographical left-hand valley slopes. The mountain spur in the area of the orographical right-hand valley side has been round-polished by the High Glacial glacier ice (◤). Channelized by this valley, a northern outlet glacier of the High Glacial (LGM = Stadium 0, cf. Table 1) Tibetan ice sheet and its ice stream networks in the surrounding mountains (here the E Kuenlun) (Figure 38, I2) flowed down to the N towards the basin of Heka to the lowest ice margin. (This ice margin was situated at 3400 m asl according to Kuhle 1982e, Table 1, basin of Ho-k'a', p. 74, and 1987b, Figures 2–4, pp. 253–255; Figure 13 on the right below, p. 302, pertinent text of the map see Figure 9, p. 275; Table of the snow-lines: II and III, p. 308). (——) marks the minimum ice thickness down to the valley bottom, reconstructed with the help of the indicators mentioned, i.e. the minimum altitude of the outlet glacier level. Photo: M. Kuhle.

► **Photo 150.** From c. 3700 m asl in the valley in NE Tibet, which leads down from the Oh La (pass) towards the N to the settlement of Sujung (cf. ONC-map 1:1,000,000 G-8) (cf. Photo 149) (view point c. 35°45′–47′N/99°33′E; Figure 1, No. 2: above the Animachin; Figure 38: left-hand above the Animachin), looking down-valley to the N towards Sujung. In the background (behind ▽) the basin of Heka (or Ho-k'a') can be seen. (□) is the metre- to decametre-thick ground moraine (basal till; cf. Photo 151) with which the entire valley cross- and longitudinal profile is cloaked. This locality has been already investigated by the author on July 7th, 1981, and described and classified as being the last High Glacial (LGM = Stadium 0; cf. Table 1) landscape of the moraine- and ice margin position of an outlet glacier (Kuhle 1982a; 1982e, pp. 69/70 and Table 1 p. 74; 1987b, Figure 4, p. 255, Figure 13 right-hand corner below, p. 302, with the text of the map of Figure 9, p. 275; Table of snow-lines, p. 308, II and III). In the fine ground mass of loam, silt and sand (○) are partly incorporated large to very large polymict erratic boulders in isolation from each other (three people to compare the size), as for instance quartzite-, granite-, rhyolite- and porphyry-blocks. Their morphograms can be taken from Photo 151 (■). (▽) marks a fluvial outer slope of the stream in the valley talweg, which has undercut and exposed the ground moraine since the Late Glacial deglaciation (after Stadia I–IV). (——) indicates the minimum altitude of the Ice Age outlet glacier, which has left behind these glacigenic accumulations. However, the erosional form of this valley is typically glacigenic and wears the characteristics of a trough valley with round-polished spurs between the joining side valleys (◤). Photo: M. Kuhle.

▲ **Photo 151.** The same locality as Photo 150, looking from 3690 m asl into the right-hand valley flank towards the W. This slope has been formed in Last-High Glacial to Late Glacial ground moraine (□), many metres thick. The exposure (○) shows the upper 3.2 m of this till cover. The material is very densely-packed and – insofar as it concerns a ground moraine – rich in large to very large polymict boulders (■). These are exposed in the fore- to middleground and thus allow their forms, which are scarcely rounded, but mostly rounded at the edges or facetted to be recognized; one and the same block has irregular forms on its different sides, as this is typical of ground- and end moraines (cf. Photo 150). Photo: M. Kuhle.

fied as belonging to the *Last Ice Age* (LGM). These investigations and their results are discussed against the backdrop of the author's model of the *rise of the Ice Ages,* considering the *uplift of Tibet above the snow-line* and its extreme *energy-effective* inland glaciation at *subtropical* latitudes as the *precondition and impulse* of the Pleistocene Ice Ages.

6. On the Overall Picture of the Tibetan Ice Age Glaciation by means of Mathematical Deductions and Glacial-Climatic Models, derived from the Empirical Data and Field Observations

In the conclusions (2.7; 3.8; 4.3 and 5.1) of the chapters dealing with the reconstructions of the Ice Age glaciations in the E-Pamir, in the Nanga Parbat massif and lower Indus valley, in N- and in S-Tibet, the importance of the particular detailed empirical results, with reference to an overall evidence of the *connected ice-stream network and inland glaciation* of Tibet and High Asia during the High Glacial (LGM), was made clear. As far as this is concerned, the observations of this work agree with the author's

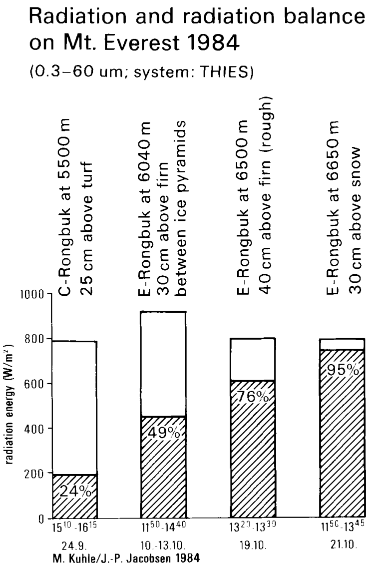


Figure 50. These measurements have been confirmed by the measurements of the radiation balance in the course of two other expeditions in central-, E- and W-Tibet, each of them carried out over three months; more than 12,000 data were obtained from seven different positions of the measurement-station (among others Kuhle and Jacobsen 1988; Kuhle 1989a). The measurements show that the very intensive subtropical radiation (still 800–1000 W/m^2 in autumn) is reflected into space by the debris-, alpine meadow- and turf-surfaces of Tibet, which today are free of ice, maximally at just 24% (left-hand columnar diagram); however, on the snow surfaces of the glacier feeding areas, which have covered the entire Ice Age Tibet, the reflection amounted to maximally 95% (right-hand columnar diagram).

concept, following his detailed investigation of the marginal- and central areas of Tibet with respect to their pre-historic glacier ice cover (Kuhle 1980–1996). In this contribution the test-areas No. 14; 6; 2 and 17; 18; 16 in Figure 1 are introduced. Concerning area No. 9 new C14-datings are presented.

Figure 38 is the *large-scale conclusion* of the detailed observations in the separate test-areas. The idea of the glaciation presented by this figure, has not been corrected by these new investigations, but rather it *has been confirmed*. The same applies to Figures 39 and 40, showing the *cross-profiles of the ice sheet in a generalised form*.

In this context the criticism of the author's interpretation of the inland ice has to be contradicted vehemently. This criticism states that the ground moraines and erratics on the Tibetan plateau, which provide evidence, might also be traces of a merely local mountain foreland glaciation. The ground moraines and erratics on the Tibetan plateau, presented in this work, are situated *far away* from the glaciated mountains and mountain-groups of today. Consequently a local glacier, flowing down from a mountain valley, could not have reached the locality concerned on the plateau over a distance of decakilometres. With an inverse argument this means that if such a valley glacier could have reached so far on to the plateau, an *extended piedmont ice* must already have developed beforehand, which was larger in its width than in its direction of flow. Such piedmont ices were formed in the Early Glacial, i.e. during the *ice build-up*. During a time of further ELA-depression, i.e. uplift of Tibet, they descended from the adjacent mountain-groups and coalesced into an ice sheet (cf. Kuhle 1994a, p. 269). From that point of view the ground moraines observed as well as the incorporated erratics, provide evidence of *mountain foreland glaciers which coalesce into an inland ice.*

According to the theory presented during 1981–1987, which has in the meantime been further revised, primarily the Late Tertiary to Early Pleistocene *uplift*, typical of High-Asia, has led to the heavy glaciation of the test-areas investigated and to the *complete ice covering of Tibet* (Kuhle 1995). Figures 41 and 44 pick out four areas in the west of Tibet, in the area and near to the investigation areas, dealt with (Figure 1, No. 14, 6 and 16). They exemplify the *increase* of the surfaces of the *glacier feeding areas* through the uplift by 600 and 1200 m (i.e. relative ELA-depressions). The three maps, which correlate the surface-covering from the c. 30 regions where the calculations of these glacier feeding areas have been carried out, can be compared in Figure 45. Already at a downward shift of the ELA in relation to the relief by –600 m (Figure 45 II), the surfaces of the feeding areas (black signature) are so extended that the mountain- and piedmont-glaciers of adjacent mountain groups must have coalesced into large ice complexes (see above). This ought particularly to be taken in consideration, because the glacier ablation areas have enlarged the overall glacier surfaces by a further third (glacier feeding area in relation to glacier ablation area c. = 2:1, i.e. AAR = 0.66). An ELA depression of –1200 m relative to the relief (Figure 45 III) has led to a 3/4-covering by glacier feeding areas, including the ablation areas, for a total glaciation. These are *minimum estimates*, which are *far behind the real conditions*, since the self-reinforcing effect of the ice build-up through the ice thickening has not been taken into account. This thickening enlarged the surfaces of the glacier feeding areas and thereby the ablation- and overall glacier surfaces. The author therefore estimates that the Tibetan ice sheet at an ELA depression of only 1000 m in relation to the relief, has completely covered the plateau (cf. Figure 38).

If the precipitation in the Early Würm or Wisconsin (first phase of the LGM = Stadium 0, cf. Table 1) had dropped to c. 1/4 (25%) of the contemporary mean annual precipitation in Tibet (cf. Kuhle 1989a), i.e. the uplift of the plateau or the *cooling down* had allowed *only just* 100 mm of precipitation per year, an inland ice would, within 10,000 years, have developed at an ELA of 4250 m asl *relative to the present altitude* of the plateau, which had been of the thickness shown in detail in Figure 46. In this case the inland ice reaches a thickness of 1.0 to 1.8 km. The case corresponds approximately with case III in Figure 45. As a function of these glacier thicknesses, the same conditions of the ice accumulation lead to a differentiated *ice run-off*, presented in Figure 47. This Figure also shows the *surface height* of the *cupola-shaped* inland ice. With its three largest run-off centres the inland ice cupola rises to more than 6500 m asl (6.5 km). The but little scaled-down outlines of Tibet are drawn by the 6000 m-isoline. The ice run-off of the western, over 6500 m-high ice cupola, northward into the Tarim basin has obviously been the *most important* of these. In this area Trinkler (1930b) and De Terra and Paterson (1939) were able to provide evidence of traces of an extensive Ice Age glaciation on the W Tibetan plateau, whilst Norin (1932), De Terra (1932) and Hövermann and Hövermann (1991) have found these traces from the Kuenlun down to the Tarim basin. (Review of the literature of authors, who have established a local ELA depression of more than 1000 m by means of their glacier reconstructions cf. Kuhle 1988k, Figure 3). The author's field observations in this area in 1996 (Figure 1, No. 20) confirm these results. However, due to the adjacent field investigations (Figure 1, No. 5) it *must be doubted* that the N outlet glacier according to Figure 47 (bold arrows) actually flowed down to below 1500 m asl, to form an extended piedmont glacier on the S edge of the Tarim basin, as is also shown in Figure 46 (Kuhle 1994a). Probably the precipitation of 100 mm/yr applied to the Ice Age by the model calculation, has still been *over-estimated*.

Figure 48 shows the inland ice cover at an ELA, which had dropped to 4500 m asl *in relation to the present relief altitude*, i.e. by 250 m less. This probably best describes the conditions of the empirically registered Late Glacial of the glacier Stadia I to II (cf. Table 1; in Figure 45 a condition between map II and III), which still existed c. 17,000–15,000 years ago. This intermediate condition of size, thickness and run-off must also have run through time and time again *during the ice build-up* in the Pleistocene Early Glacials up to the High Glacials (cf. Kuhle 1995). It is remarkable that even at this ELA, which is high by comparison with Figures 46 and 47, according to the model the Tsangpo valley in S Tibet has been *completely glaciated*, which means it has been infilled from the N and S, i.e. from the direction of the ice centres I2 and I3 (Figure 38). Up to now this *could not be clearly proved* by field observations (Kuhle 1988i; 1991d). Therefore in Figure 38, which summarizes the empirical results, the Tsangpo valley was *left free of ice* in the E (right above) of the Shisha Pangma up to the Namcha Bawa as a border between I2 in the north and I3 in the south. Consequently, the High- (cf. also Figures 46 and 47) to Late Glacial precipitation was probably also *less* than 100 mm/yr in this S section of Tibet.

Whilst the considerations and model-calculations, derived here, are based on *empirical field observations* in High Asia, i.e. stem from an immediately regional induction, a simulation of the Northern Hemisphere Continental Ice Sheets over the Last Glacial-Interglacial Cycle has recently been modelled by Marsiat (1994), where *without regional field findings* from Tibet a kilometre-thick inland ice also occurred. Only the nature of the relief, known from the atlas-maps, had been taken into account. Though this result is only calculated on the basis of a model, it is nevertheless based on another reference-system and is thus an *independent confirmation* of the Ice Age existence of the Tibetan ice.

In contrast one should mention here the *numerous authors* of the Chinese Quaternary Glacial Map of Tibet (1991) Shi Yafeng, Zheng Benxing, Li Binyuan, Zhang Qingsong among others, who due to their empirical field observations *reject* the author's findings of an Ice Age Tibetan ice sheet. The only exception in this group is Zhou Shangzhe, who *follows the author* (Kuhle 1982e; 1987b, Figure, p. 302) for NE Tibet in the area of Chaling Hu (Ngoring Lake) Mato, Huashihhsia (ONC-G 8) and Oh La and enters one part of the ice sheet into this map (cf. Zhou Shangzhe 1995, Figure 3, p. 238).

In Figure 49 an equal area projection of the Tibetan ice sheet, reconstructed by the author (cf. Diercke-Weltatlas 1988–1996; 1988, p. 224 below;

Brockhaus 1988, vol. 6, p. 240; World Atlas of Snow and Ice Resource 1996/97), was put alongside of the inland ices of the Last Ice Age, already known before, in order to show *its much lower, subtropical latitude*, nearer to the equator. Figure 50 explains the resulting climatic effect and its dimensions. Due to its latitude, the incoming radiation energy per area (W/m^2) in Tibet is at least *four times as great* as in the Ice Age inland areas N of 50° latitude. Today at least 3/4 (76%) of this energy is changed into long-waved heat radiation and *heats up the earth's atmosphere* (Figure 50 left-hand columnar diagram). *During the Ice Age*, at the time when the Tibetan debris- and vegetation areas had been covered by an *ice cupola* rising well over 6500 m, 95% of this *subtropical radiation* income has been *reflected* as it were by a mirror, i.e. short-wave, back into space (Figure 50 right-hand columnar diagram). Therefore this energy was *no longer able* to heat the earth's atmosphere. It is on this association that the author's theory (Kuhle 1981, 1982e, 1987d, 1988b, 1989a, 1995, 1996) concerning the *onset of the Ice Ages* is based, the foundation of which is the *Tibetan ice sheet*. The *uplift* above the ELA, which probably took place for the first time in the Pleistocene, led to the glaciation of Tibet *despite* of its subtropical position. The resulting energy loss had a *cooling influence* on the globe to such an extent that the *nordic inland ices* were able to develop.

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