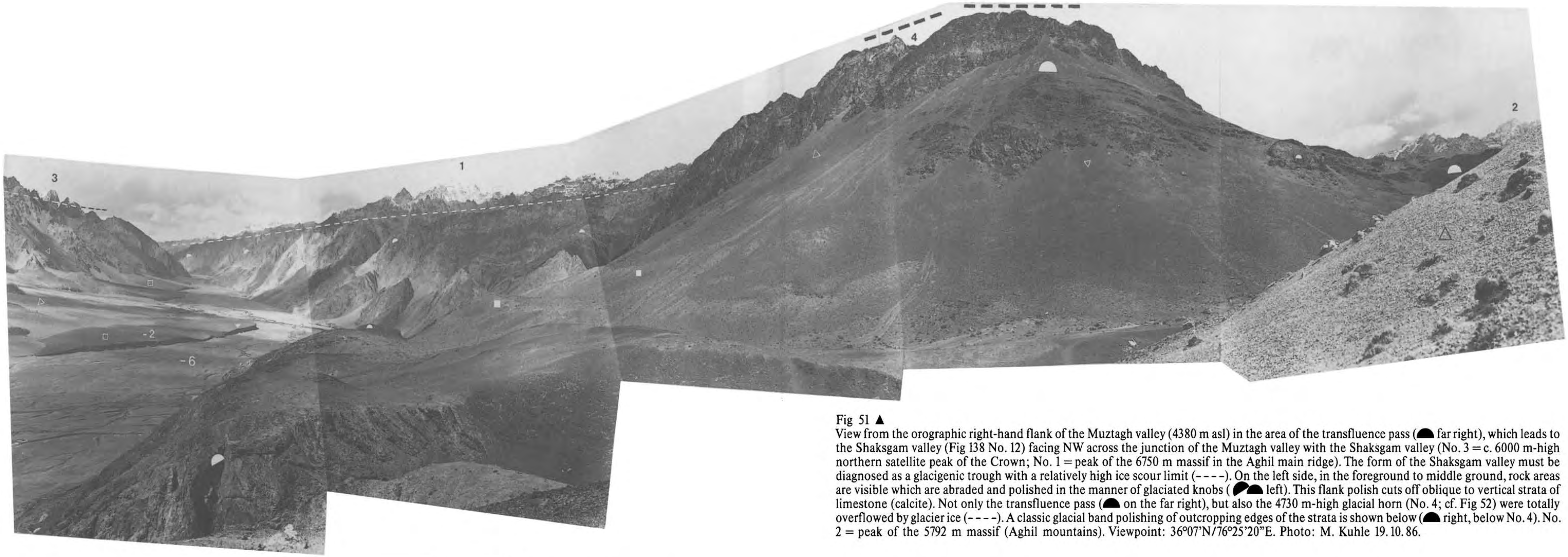
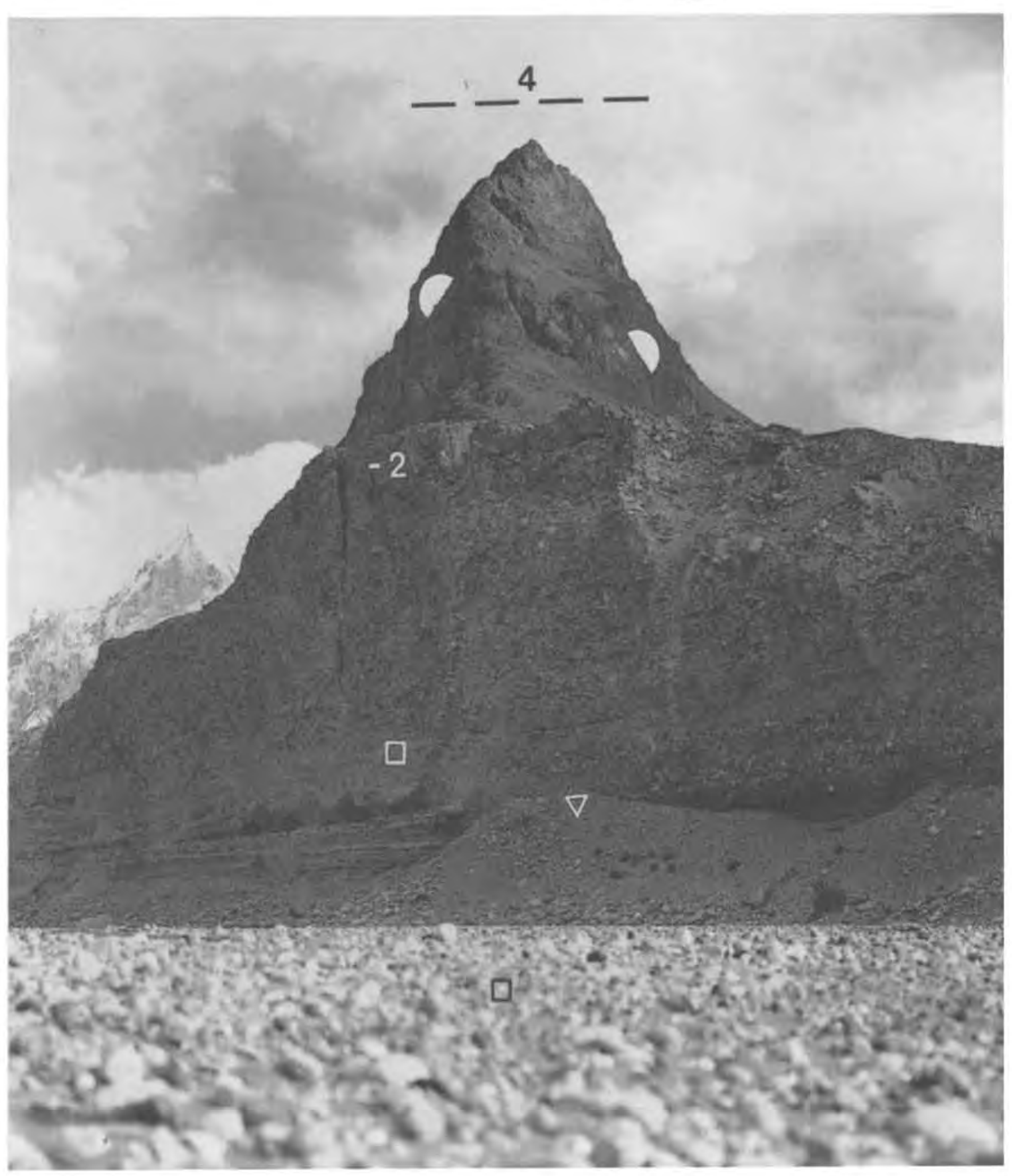


Fig 51 ▲
View from the orographic right-hand flank of the Muztagh valley (4380 m asl) in the area of the transfluence pass (◓ far right), which leads to the Shaksgam valley (Fig 138 No. 12) facing NW across the junction of the Muztagh valley with the Shaksgam valley (No. 3 = c. 6000 m-high northern satellite peak of the Crown; No. 1 = peak of the 6750 m massif in the Aghil main ridge). The form of the Shaksgam valley must be diagnosed as a glacigenic trough with a relatively high ice scour limit (- - - -). On the left side, in the foreground to middle ground, rock areas are visible which are abraded and polished in the manner of glaciated knobs (◓◓ left). This flank polish cuts off oblique to vertical strata of limestone (calcite). Not only the transfluence pass (◓ on the far right), but also the 4730 m-high glacial horn (No. 4; cf. Fig 52) were totally overflowed by glacier ice (- - - -). A classic glacial band polishing of outcropping edges of the strata is shown below (◓ right, below No. 4). No. 2 = peak of the 5792 m massif (Aghil mountains). Viewpoint: 36°07'N/76°25'20"E. Photo: M. Kuhle 19. 10. 86.



◀ Fig 52
View of the 4730 m-high glacial horn (No. 4) made of limestone in the exit of the Muztagh valley from the drift floor of the Shaksgam valley (□ bottom) at 3900 m asl. In front the historic drift floor terrace No. -2 (Middle Dhaulagiri Stage 'VII). Viewpoint: 36°08'15"N/ 76°25'E (Fig 138 No. 13). Photo: M. Kuhle 31. 8. 86.

Fig 52 a ▲
Glaciated knob (◓) in the middle of the Shaksgam valley. Situated in the confluence area of the Muztagh valley, it consists of calcitic limestones and has been shaped from a pre-glacial rock-bar mountain (Fig 138 No. 11). The rocks have undergone perfect glacial rounding. They are covered by a thin scattering of ground moraine. Glacifluvial drift and moraine ledges (■) have been deposited on the edges. The most recent drift floor surface (valley sander □), which forms the valley floor of the Shaksgam valley, is situated at 3900 m asl. It sediments the base of the glaciated knob. Viewpoint: 36°09'N/76°23'40"E. Photo: M. Kuhle 31. 8. 86.

◀ Fig 53
Downhill view of a representative glacigenic trough valley on the Kuenlun N-slope, seen from 4400 m asl (Fig 138 No. 15). It leads WNW, down to "Kudi Valley" as the main valley, which is reached at 3900 m asl (below - - - -, in the background). The valley is set out in granites. The valley bottom is filled with Late to Neo-Glacial moraines (III, IV, V ■). Cuspate areas and truncated rock spurs (◤◢) are preserved up to the ice scour limit (- - - -). Viewpoint: 36°33'N/77°15'E. Photo: M. Kuhle 28.10.86.

Fig 54 ▲
View from 5000 m asl from above the 4950 m-high "Mazar pass" (Fig 138 No. 16) towards WNW across a source basin of the "Mazar valley", which leads down to the Yarkand in the south (foreground to middle ground). No. 1 = 5796 m peak, a continuation of the glaciated Kuenlun main ridge - from the 6328 m massif following the strike of the mountain system towards the W. Beyond the source basin an orographic left-hand side valley of the "Kudi Valley" sets in on the right and, running down on the left, passes below Peak No. 1. At 3050 m asl it joins the main valley S of the Kudi settlement (Fig 138 No 40). Its source area had been filled with glacier ice up to (- - - -). On the valley slopes the post-glacial periglacial scree shows solifluidal block-band patterning (∇ background). Viewpoint: 36°35'10"N/76°00'E. Photo: M. Kuhle 27.10.86.

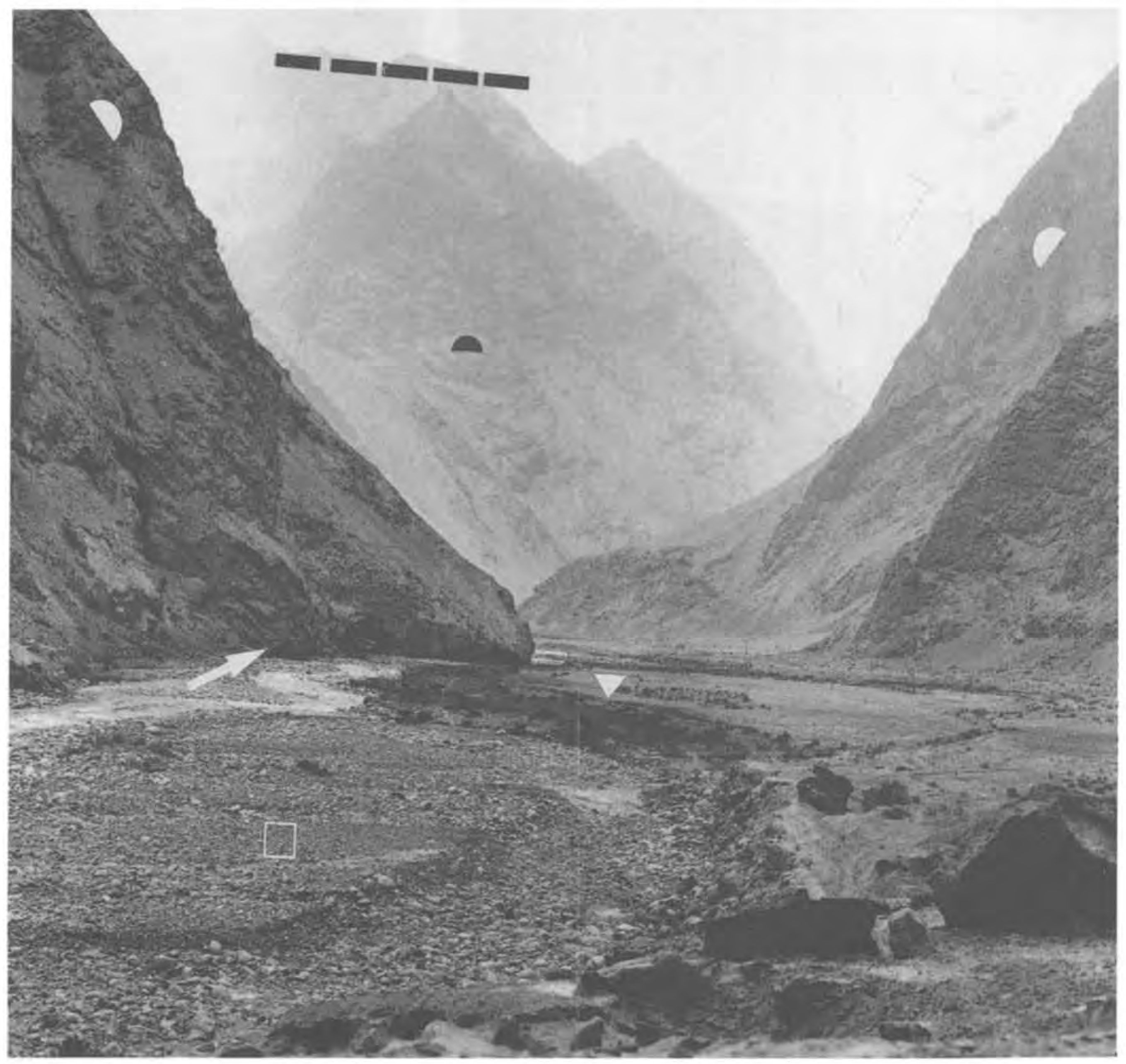
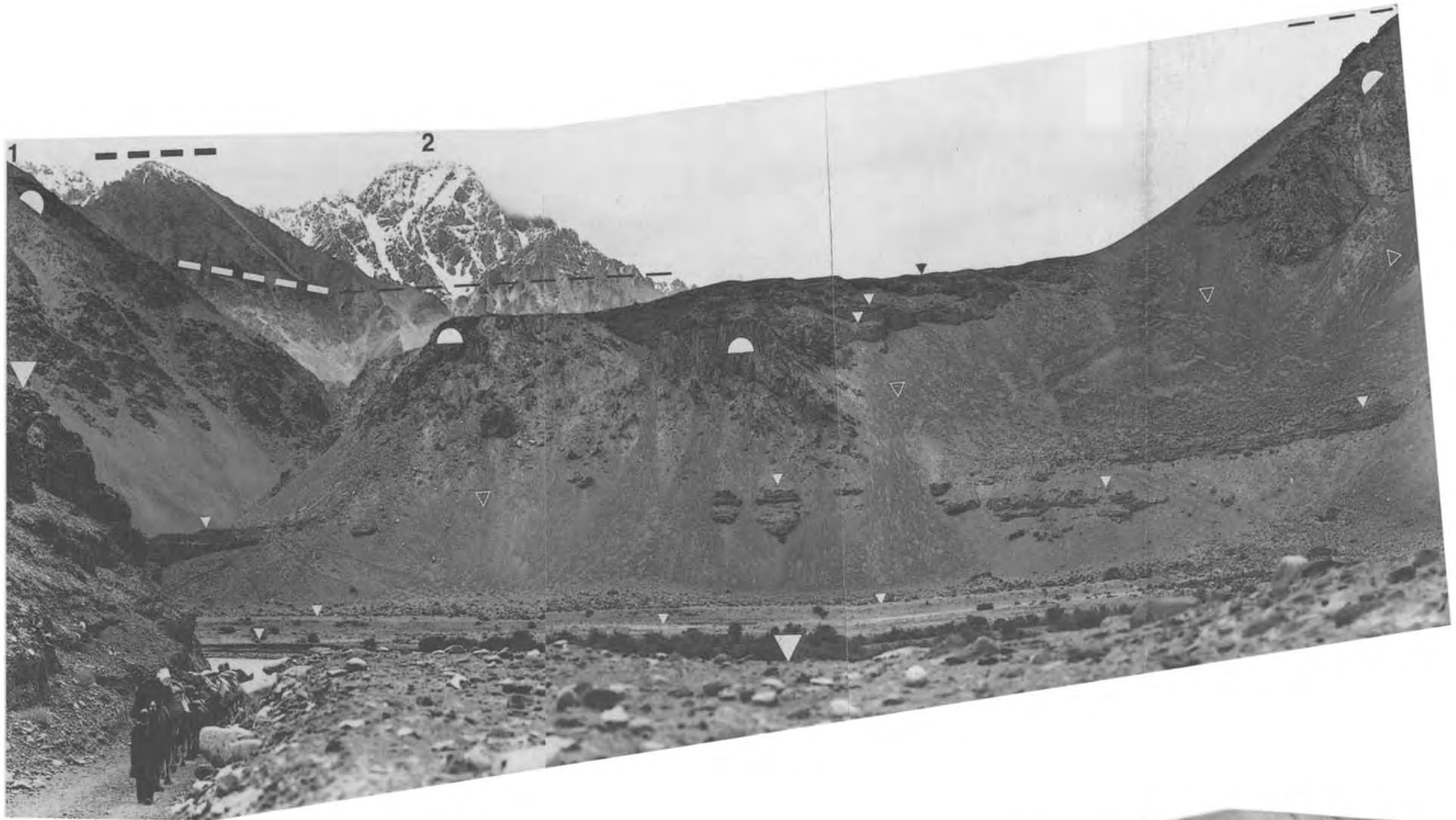


Fig 58 ▲
View from the bottom of the Kudi valley at c. 3100 m asl facing down-valley towards NW (Fig 138, right of No. 40). The features of a trough-shaped gorge are clearly visible; its relatively broad concave form (below ◤◢) has been planed down by flank abrasion and polishing from a substantial ice stream (- - - -). As a result of lateral erosion the post-glacial fluvial process led to undercutting (↗) of the glacigenic valley flanks in granite rock. Viewpoint: 36°46'20"N/77°01'15"E. Photo: M. Kuhle 19.8.86.

Fig 59 ▲
View of the orographic left-hand side valley of the Kudi valley from the confluence area (Fig 138 No. 40) somewhat S of the Kudi settlement at 3050 m asl facing upwards in a SSW direction. The valley leads straight down from the Kuen Lun main ridge (cf. Fig 54); thanks to its relatively steep gradient, it has the form of a narrow gorge. Ice Age glaciation (- - - - ice level) has given the valley the slightly concave appearance of a "trough-shaped gorge". Unequivocal flank abrasions and polishings (◤◢) in the local bedrock granites are only preserved in a few places. Viewpoint: 36°49'30"N/76°59'E. Photo: M. Kuhle 19.8.86.



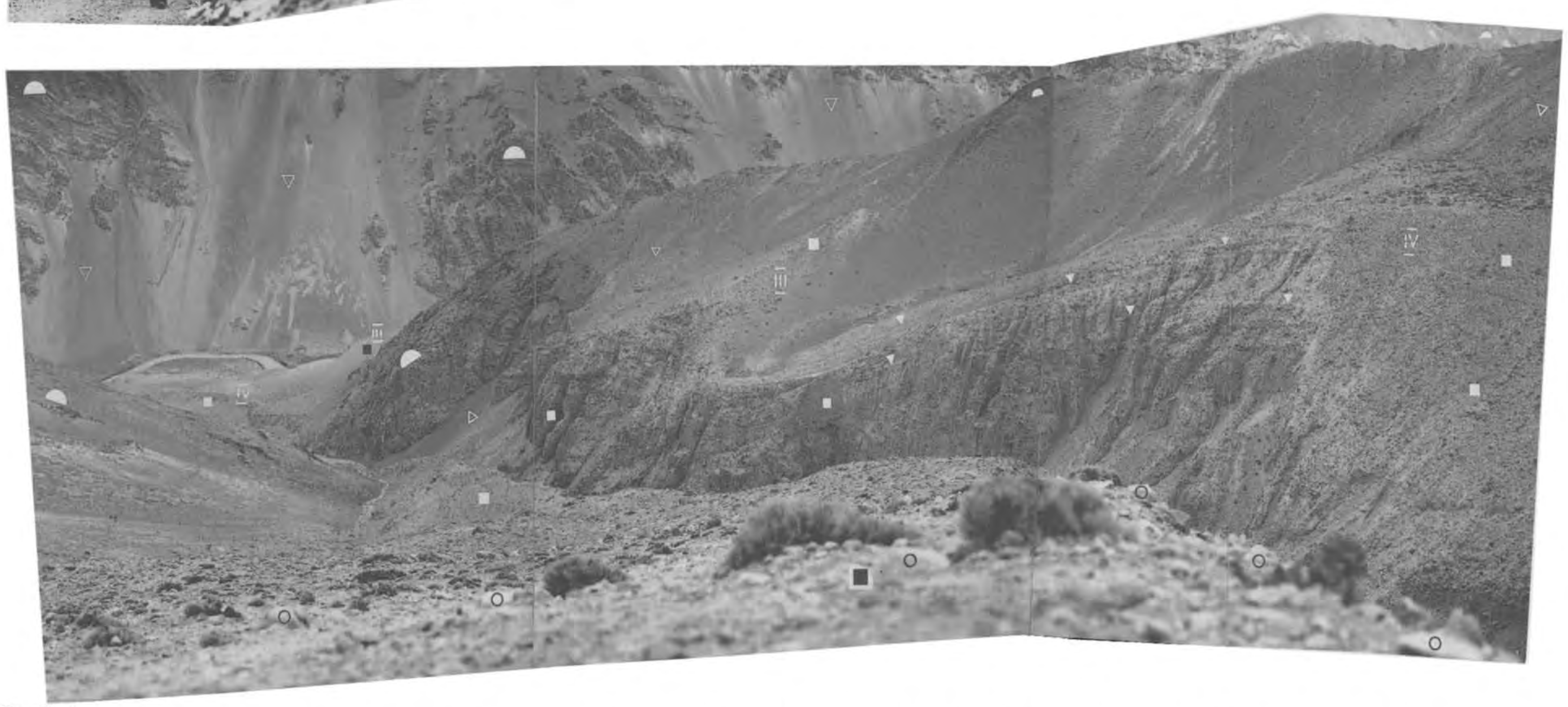


Fig 62 ▲
View from the orographic left-hand flank down the right-hand Yarkand side valley which drains the 6532 m-high massif (Fig 61; Fig 138 No. 18) facing S. At 4340 m asl the location of the exposure is in the area of the root of the left-hand Late Glacial lateral moraine of Stage IV (■■ foreground with moraine blocks ○). On the opposite side, the corresponding right-hand moraine terrace (IV right) is well exposed (■■, centre). Its internal construction shows banking and stratification (▼▼). This stage was the last one for the tributary glacier to reach the main valley (see end moraines ■ IV, far left; Fig 63). The main glacier had already melted down at this time. The higher moraines of Stage III provide credence for a last Late Glacial confluence with the main glacier. They terminate in an orographic right-hand main valley lateral moraine of the same age (■ III, far left). Viewpoint: 36°26'N/76°53'50"E. Photo: M. Kuhle 25. 8. 86.

◄ Fig 60
View from the bottom of the Yarkand valley at 3740 m asl, looking up-valley towards the ENE (Fig 138 above No. 51). No. 1 = peak on the S ridge of the 6532 m-high massif; No. 2 = another satellite of the 6532 m-high massif further S. Two ice stream levels must be differentiated (- - - - below = Late Glacial; - - - - top = Main Glacial period). Jutting out horizontally into the valley from right to left (◓◓ in the centre), the rock ridge represents the remnant of an older trough valley floor. Subglacial meltwaters of the prehistoric Yarkand glacier stream have cut a V-profile into it (second ▼ from the left). On the far left (▼ far left) a drift terrace is exposed (below the camel caravan of the expedition - to provide a comparison). The remaining (▼) mark further drift floor terraces (sander terraces). Viewpoint: 36°18'20"N/76°49'30"E. Photo: M. Kuhle 26. 8. 86.

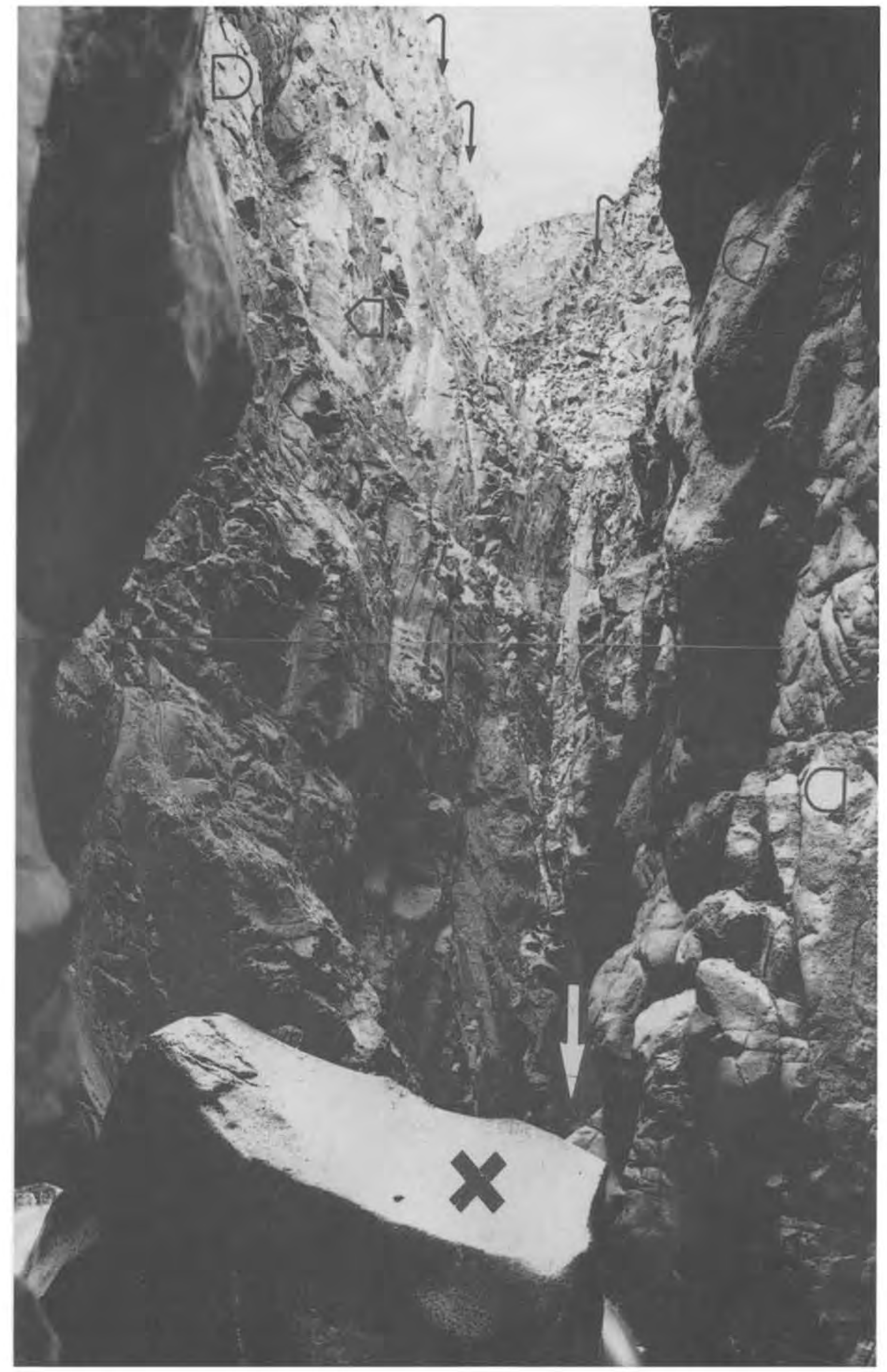


Fig 61 ▲
In the trough ground of an orographic right-hand side valley of the Yarkand, which had been heavily glaciated during the Ice Age, a sub-glacially cut gorge has been set out (Fig 138, left of No. 18). This is an up-valley view of the gorge at 4100 m asl, facing NNW. It is set out in hard granite, and drains the 6532 m-high massif (Kuenlun) to the S. X marks a gorge block above the talweg (↓). Heavy rain causes moraine blocks (basal till) to plunge from the upper edge of the gorge (↷). Viewpoint: 36°26'N/76°53'45"E. Photo: M. Kuhle 25. 8. 86.

Fig 65 ▲
View from the floor of the "6008 m-high massif SSE-valley" at 3850 m asl, looking down towards the confluence with the Yarkand valley (↓) (Fig 138, between Nos. 19 and 38). This section of the territory, which shows the continuation of Figure 64 further down the valley, provides evidence for the existence of glacigenic V-shaped valleys. Though crumbling and weathering have roughened-up the valley flanks since deglaciation, as talus cones and talus slopes (◁▷) show, flank abrasion and polishing has been preserved in the granites in some places (◥◤). Flank polish and abrasion very high up the Yarkand valley provide information (▲) about the Main Ice Age thickness of the ice (- - - -). Viewpoint: 36°27'N/76°57'30"E. Photo: M. Kuhle 24. 8. 86.

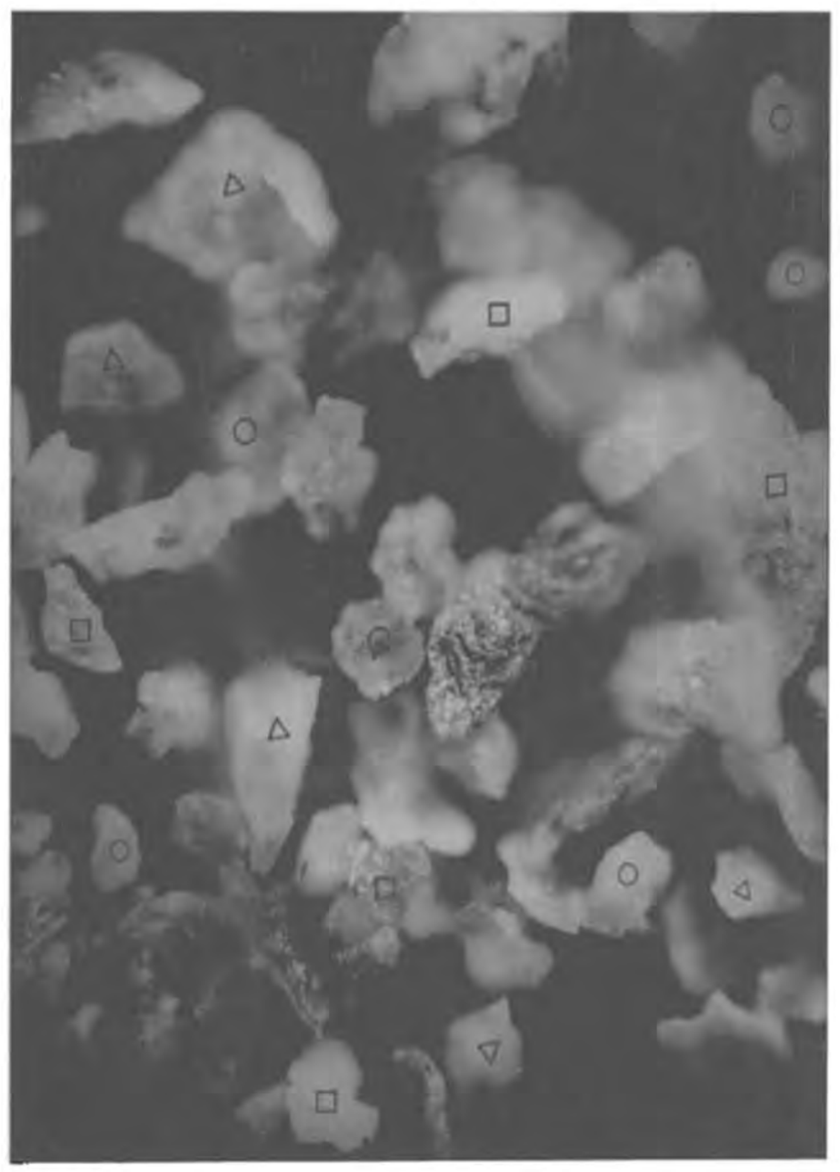


Fig 68 ▲
Microscopic photograph of representative grains > 200 μ of the 24. 8. 86/5 sample for morphoscopy (cf. Fig 56 and Fig 66 No. 7). This is a fluvial, or glacifluvial sediment of frost debris and moraines from metamorphite and granite parent rock, which has been transported < 10 km.
□○△ mark the three discernible grain surfaces (see running text). Viewpoint: 3770 m asl; 36°26'40"N/76°57'50"E; Fig 138, No. 38).

◀ Fig 63
Exposure of the right-hand end moraine (■ IV) in the exit of the orographic right-hand side valley of the Yarkand (Fig 138 below No. 18) at 3800 m asl. The diamictite material is relatively coarse-grained, a fact that is explained by the short distance it was transported by the at most 20 km-long tributary glacier. Intermittent bands of drift (→) are evidence of the considerable contribution the meltwaters made in this sedimentation process in the vicinity of the late Late Glacial glacier face. (□) mark talus cones from this dumped moraine material, (●) large erratic granite blocks which show dark brown crusts of iron manganese as a result of considerable insolation and potentially high evapotranspiration. Viewpoint: 36°25'N/76°54'20"E (Fig 62 IV, on the far left) Photo: M. Kuhle 25. 8. 86.

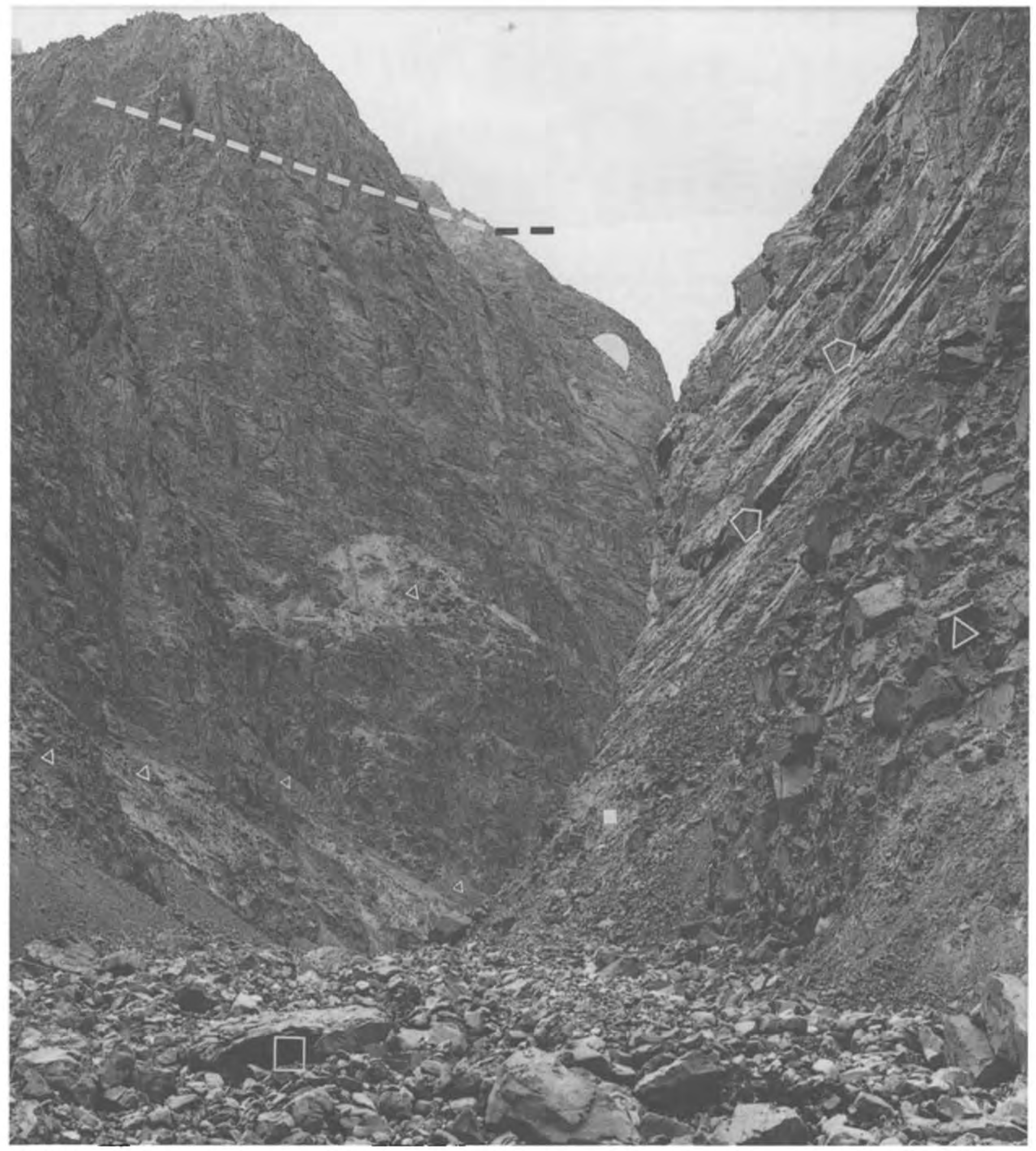


Fig 64 ▲
View from the drift floor at 3920 ml asl down a gorge to which flank polishing (◥) had given the form of a trough (Fig 138, right of No. 19). This orographic right-hand tributary valley of the Yarkand valley drains the 6008 m-high massif (Kuenlun) to the SSE. It is set down in granite, which tends to crumble widely (⬠) when affected by glacigenic undercutting and fluvial lateral erosion. (- - - -) marks a probable early Late Glacial ice scour limit. Viewpoint: 36°28'N/76°56'50"E. Photo: M. Kuhle 24. 8. 86.

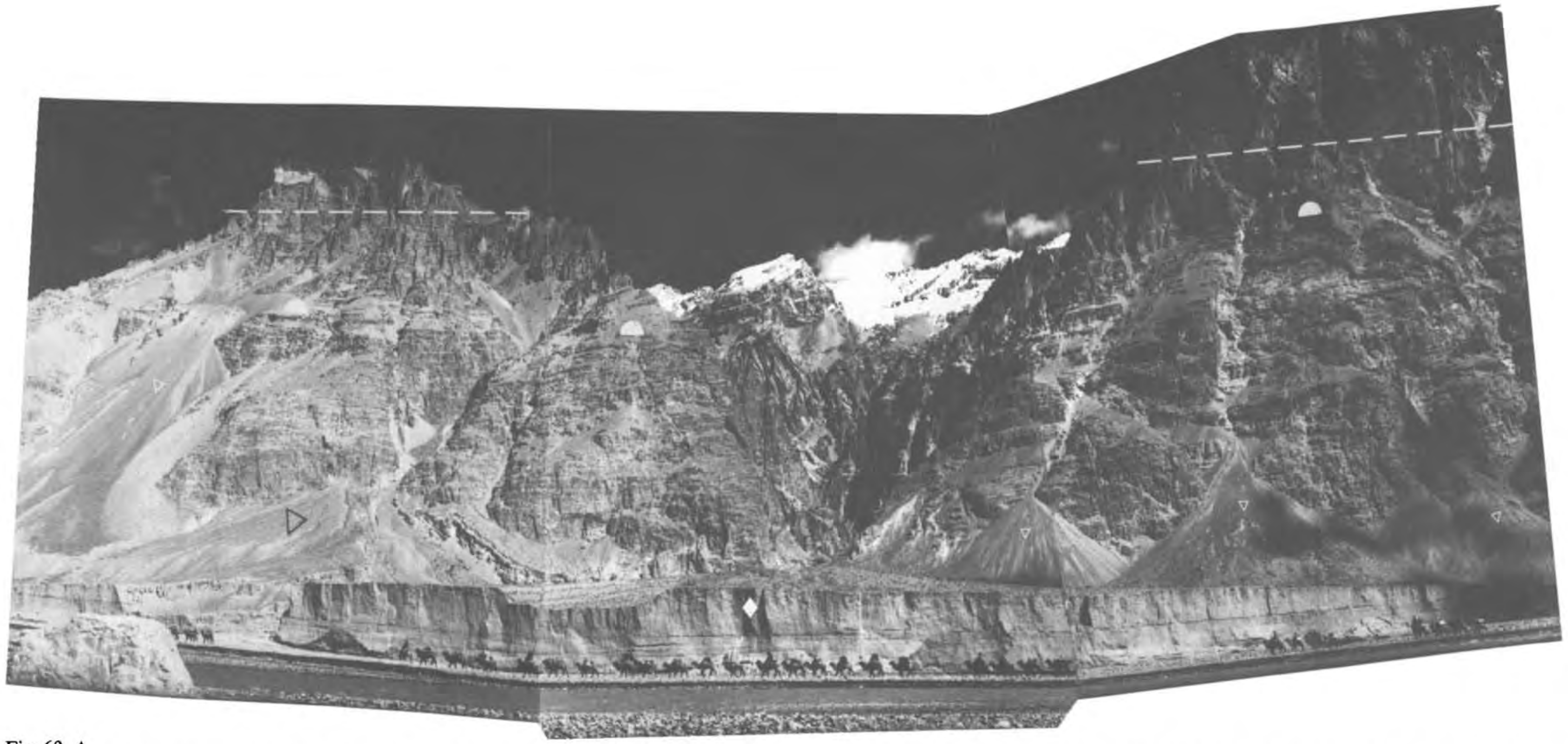


Fig 69 ▲
View from 4080 m asl across the Shaksgam valley to the orographic right-hand trough flank of the major longitudinal valley in the N (Fig 138, right of No. 21). The ice scour limit (- - - -) runs at 5000 m asl, and must be held to be from the early (old) Late Glacial period. It provides evidence of glacier thickness of more than 1000 m at that time; added to this is the thickness of loose material which has accumulated in the valley bottom (the caravan of camels is walking on this drift floor). The glacial band abrasion and polishing of the outcropping edges of the strata (▲) occur on the dolomites of the Aghil ridge. Their excellent state of preservation, in spite of arid continental conditions of free-thaw cycles, which have at any rate already built up more than 200 m-thick alluvial fans (◆), talus cones (▽) and mudflow cones (▷), is striking, given the considerable degree of dissolution and gullying of flanks immediately above the present glacier levels in the Karakorum. This tends to suggest a more recent age for these flank abrasions and polishings (▲), or a much higher glacier level during the main Ice Age. Viewpoint: 36°07'N/76°36'E. Photo: M. Kuhle 30.8.86.

Fig 71 ▲
View from the drift floor (□) of the Shaksgam valley at 4060 m asl (Fig 138 No. 23) in an ENE direction towards the orographic right-hand valley flank and the higher peaks of the Aghil mountains. No. 1 = 6500 m-high peak; No. 2 = 6500 m-high peak (both unnamed). (▲▲) marks the glacial band abrasion and polishing of the outcropping edges of the strata. (- - - -) marks the early Late Glacial polish level of the Shaksgam ice stream network at about 5000 m asl. The ice scour limit between Nos. 1 and 2 (- - above ▲) indicates a main Ice Age level at 5600 m asl. On the glacially abraded and polished trough flank Late Glacial ground moraine (basal till) positions are preserved up to several hundred metres high (◁). Over large areas they have been dissected into earth pyramids. Fig 122 shows the moraine material in detail. Hundreds of metres thick, the talus cones, alluvial fans and mudflow fans (▽▽) were built up in post-Late Glacial times. Every year when the Shaksgam river is in flood they are distally undercut (X). Viewpoint: 36°08'N/76°35'E. Photo: M. Kuhle 1.9.86.

Fig 70 ▲
View from 4200 m asl towards SSE up the Shaksgam valley to the high peaks of the more easterly Karakorum main ridge, which are part of the catchment area of this valley (Fig 138, between Nos 23 and 24). No. 6 = Apsarasas (7245 m); No. 5 = Teram Kangri (7462 m); No. 8 = Urdok (c. 7300 m); No. 3 = Sia Kangri (7422 m). In the foreground a current mudflow fan, which is being undercut by the present valley drift floor with the Shaksgam river (-6). -1 and -2 are the historic ice cave drift floor terraces of the older (VI) and middle Dhaulagiri Stage ('VII). (▲▲) mark the glacial flank abrasions and polishings of the main Ice Age ice stream network, which extend to more than 5500 m asl; (- - - -) marks its level. Viewpoint: 36°07'N/76°38'E. Photo: M. Kuhle 20.10.86.

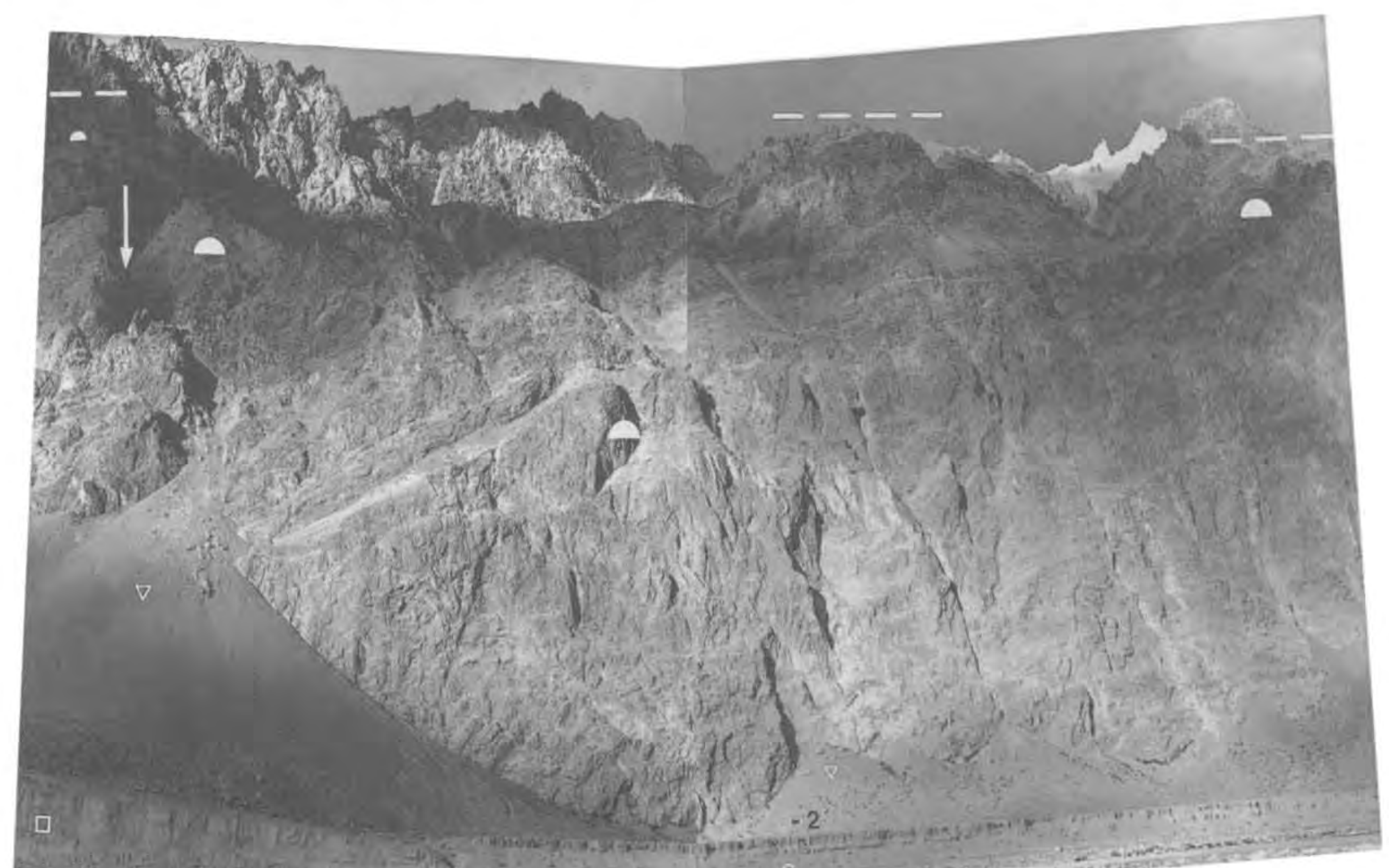


Fig 72 ▲
View from the drift floor of the Shaksgam valley (-6) at 4000 m asl (Fig 138 left of No. 21), facing NW towards the orographic right-hand flank of this trough valley. In respect of the state of their preservation, the quality of the (▲▲) glacigenic flank abrasion and polish decreases upwards towards the ice scour limit (- - - -). The cutting of the gorge in the wall (↓) and the piling up of the talus cone (▽ left) below its exit took place post-Late Glacial. Viewpoint: 36°06'25"N/76°33'E. Photo: M. Kuhle 1.9.86

◄ Fig 73
View from the drift floor of the Shaksgam valley (□) at 3980 m asl (Fig 138 between Nos. 21 and 20), facing NW down this large longitudinal valley towards the 4730 m peak (No. 4). Peak No. 4 is the glacial horn in Figures 51 and 52 from different perspectives. This peak divides the transfluence pass from the adjacent Muztagh valley towards the NW (Fig 138 No. 13); during the Main Ice Age it was totally covered by the Skaksgam ice stream network (- - - - left). The well preserved glacial flank abrasions and polishings (◖◗) belong to the Late Ice Age; talus fans and cones (□ left) belong to the post-Glacial (Holocene). Viewpoint: 36°06'30"N/76°29'E. Photo: M. Kuhle 1.9.86

Fig 75 ▼
Fluvial groove (◄) on the orographic left-hand rock-wall of the Shaksgam valley; on this scarp it is reached by the annual early-summer meltwater, and deepened further (Fig 138 between Nos 12 and 20; cf. Fig 76). (□) marks the body of drift material on the valley floor, regularly moved by the Shaksgam river. There are only a few meltwater arms at this season. Above a currently undercut rock mass (■) juts out, forming the approximately horizontal base for that rock groove (◄). In the background clearly visible rock abrasions and polishings reach up to great heights (◖). Viewpoint: 36°05'25"N/76°28'20"E, 3965 m asl. Photo: M. Kuhle 1.9.86.

Fig 76 ▼
Shows the upstream continuation of the scarp mentioned in Fig 75 with its rock groove (⇘) and the protruding rock base below (■). For the comparison of size there is a 182 cm-tall person (on the right of the right ⇘). (□) marks the actual Shaksgam drift valley; (◖◗) the orographic left-hand flank abrasion and polish; (- - - -) the Ice Age level of the glacier. Viewpoint: 36°06'25"N/76°28'21"E (Fig 138 between Nos. 12 and 20). Photo: M. Kuhle 1.9.86.

Fig 77 ▼
Mudflow cone at the foot of the orographic left-hand flank of the Shaksgam valley at 4060 m asl, facing up-valley towards the ENE (Fig 138, left of No. 23). ↓↓ mark the separate mudflow tracks which build up the cone; their lenticular cross-profiles (cf. Fig 78 X) also appear in the exposure. The mudflow cone is still in the process of construction. The very high exposure is kept steep by simultaneous, almost annual, undercutting (↘) from the Shaksgam river. Viewpoint: 36°08'N/76°35'E. Photo: M. Kuhle 1.9.86

Fig 78 ▲
Detail from the 65 m-high exposure wall of the mudflow cone (cf. Fig 77) on the orographic left-hand in the Shaksgam valley (Fig 138 left of No. 23) at 4060 m asl. Although this is a matter of perfectly chaotic, ie diamictite material of very different grain sizes with big blocks "floating" apart from one another in a matrix of fine material, a glacial-genesis of the sediment on the basis of the lenticular mudflow cross-profiles (X), ie macroscopically, must be excluded. These separate mudflow events and their sediments, which form the cone, are divided from one another by strata of rough scree and drift where the finer material has been washed out. This is evidence of the ever-present effect of the meltwaters from snow. Viewpoint: 36°08'N/76°35'E. Photo: M. Kuhle 1.9.86.

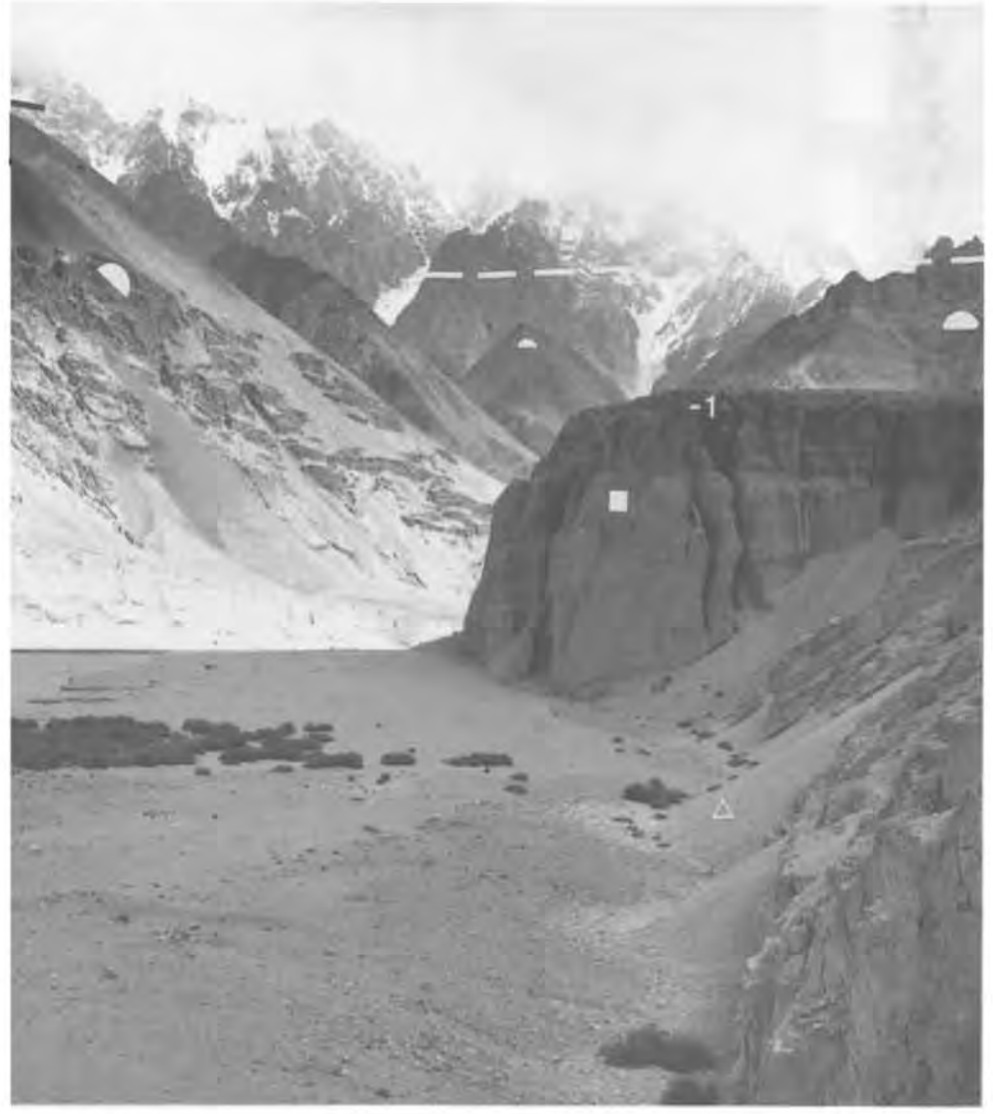
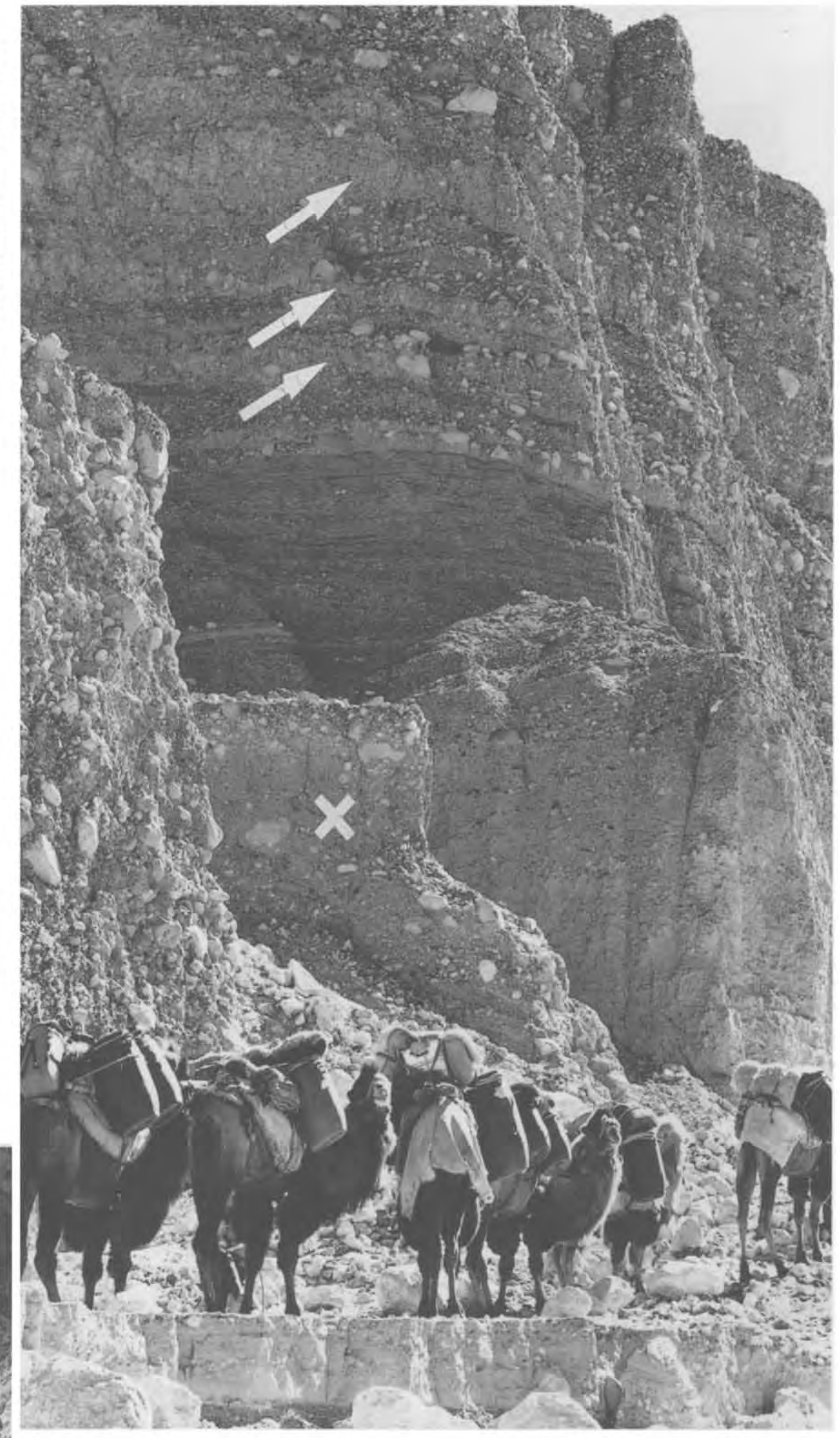
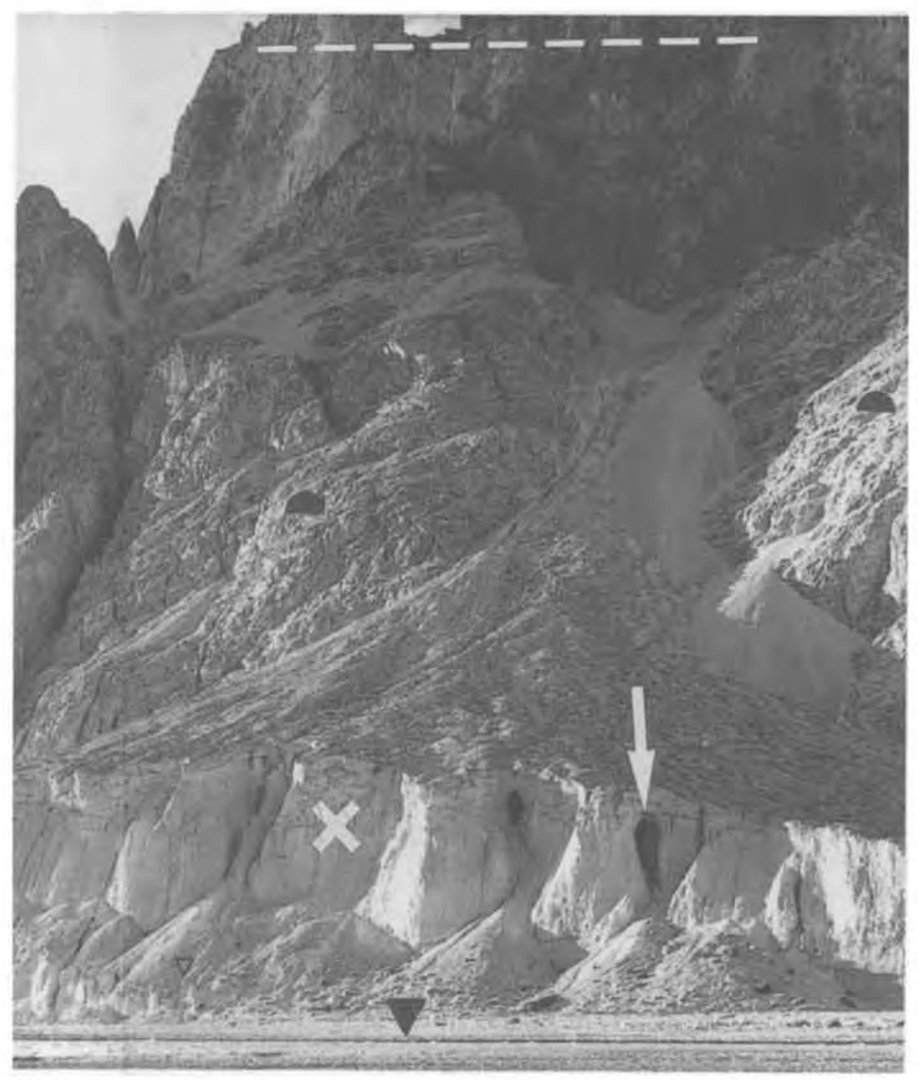


Fig 79 ▲
View from the left-hand flank of the Shaksgam valley (Fig 138 No. 23) at 4100 m asl, facing ENE valley upwards towards the remnant of a drift fan terrace (■ -1). This alluvial fan was deposited on the main valley floor as ice cave drift floor during the Neo-Glacial to historic glacier Stage VI (older Dhaulagiri Stage). It has meanwhile been distally undercut and eroded by the lateral erosion of the Shaksgam river. Figure 80 shows the still glaciated tributary valley, which forms the catchment area of this "indirect sander cone". (▷) marks this year's freshly deposited talus cones, which will be removed by the next floodwater. In the background, joined by the orographic right-hand tributary valley, are the c. 6500 m-high peaks of the Aghil ridge, together with the Ice Age flank abrasion and polish (◖▲) and ice scour limits (- - - -) on their slopes. Viewpoint: 36°07'35"N/76°36'30"E. Photo: M. Kuhle 31.8.86.

◀ Fig 80
View from the present drift floor of the Shaksgam valley at 4080 m asl looking SSW into a gorge-like, orographic left-hand tributary valley (Fig 138 No. 23), the head of which continues to be glaciated. During the older Dhaulagiri Stage VI an "indirect talus sander" (■-1) was tipped on the floor of the main valley from here, and during the 2050–2400 years of this Neo-Glacial stage, which have passed since, largely removed again by the lateral erosion of the Shaksgam river, so that steep terraces have formed (cf. Fig 79). The present sander cone (▽) penetrates these terraces. As the present drift floor, it belongs to the present glacier (background). No. 7 = N-satellite of the 6210 m peak; its top is c. 2000 m above the Shaksgam valley floor. (▲) marks flank abrasions and polishings, and (- - - -) points to the Ice Age upper limit of these glacial band abrasions and polishings. In spite of so substantial an ice thickness (- - - -), this glacigenic side valley beneath peak No. 7 is shaped like a gorge, or at most a "gorge-like" trough. This is the result of both the steepness of its talweg as well as the Late Ice Age subglacial meltwater erosion. Viewpoint: 36°07'40"N/76°36'32"E. Photo: M. Kuhle 31.8.86.

Fig 81 ▶
Outcrop of a mudflow fan in the Shaksgam-valley at 4080 m asl (Fig 138 between Nr. 23 and 22). It is built up of resedimented till, containing granite and limestone blocks (dolomite: Do 90%, Ca 10% and calcite: Ca 90%, Do 10%). The glacial diamicton (↗) was transported 4-6 km by mudflows (s. Fig 84 ▽). The grain-size distribution remained the same, however, in contrast to tills (primary till is exposed on the base of the mudflow layers X) the mudflow fan shows distinct bedding. Each mudflow event established a new layer (↗). Location (s. Fig 84 ◆): 36°06'30"N/76°38'45"E. Photo: M. Kuhle 20.10.86

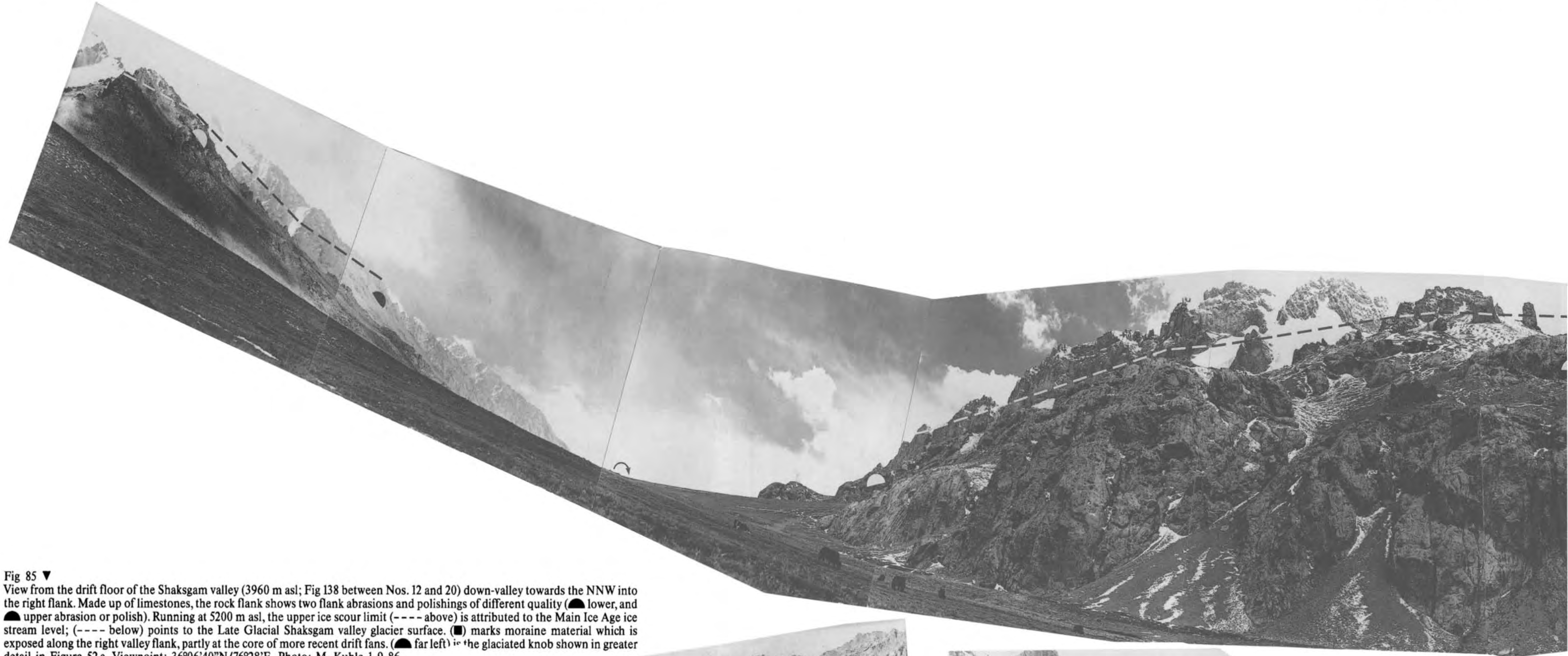




◀ Fig 82
View from the present drift floor of the Shaksgam valley at 4070 m asl, facing NW (Fig 138 right of No. 21) on to the right-hand trough flank with its glacial banded abrasion and polish (▲) in dolomite rock. (- - - -) marks the Late Glacial ice scour limit at 5000 m asl, c. 1000 m above the Shaksgam river (▼). The mudflow cone at the foot of the wall (X) has been built up within a few thousand years since the deglaciation of the Shaksgam valley. The driving force behind its formation is the annual meltwaters from snow in this S-facing mountain flank of the Aghil mountains, which rises to about 5500 m asl. Some of these meltwaters already seep into the surroundings near the cone and formed a wealth of subterranean karst forms with a cave system in the soluble loose rock (calcite and dolomite). Two of these karst caves have been exposed by the lateral erosion of the Shaksgam river (↓ and left of it). Viewpoint: 36°08'30"N/76°36'E. Photo: M. Kuhle 31.8.86.

Fig 83 ▼
View from the mudflow cone surface (♦) of the orographic right-hand side of the Shaksgam valley at 4250 m asl: panorama ranging from S via peak No. 7 (c. 6100 m-high satellite of the 6210 m massif, Karakorum) towards the W down the Shaksgam valley, into its orographic right-hand flank up to the exit of the "southern Aghil pass valley" towards the NW (No. 6 = c. 5300 m-high spur peak on the right-hand flank of the "southern Aghil pass valley") across the Shaksgam trough (Fig 138, right-hand above No. 23). During the Main Ice age the maximum glacier level must have been at least 5500 m asl (cf. main text), though there is no evidence of it in this middle chamber of the Shaksgam valley. The highest ice scour limits marked here (- - - -) run between c. 5000 and 5350 m asl. Formed in calcite and dolomite rock, the flank abrasion and polish (◥◢◤) gets better the further down it occurs. In parts, remnants of ground moraine (■ right) have been preserved on the valley flanks, which can be recognised by their gullies from afar. Viewpoint: 36°08'30"N/76°38'10"E; on the far right the camel caravan ascending the "southern Aghil pass valley". Photo: M. Kuhle 20.10.86.

Fig 84 ▼
View from a mudflow cone surface (♦; 4200 m asl) on the right-hand side of the valley (Fig 138, right side above No. 23), seen the Shaksgam valley upwards. Panorama from NE (No. 2 = c. 6500 m-high peak of the Aghil ridge), via E and ESE (No. 4 = 6755 m-high peak and No. 3 = "Shaksgam Horn" 5466 m), via SE (No. 1 = Sia Kangri 7422 m) and S as far as SSW (No. 7 = c. 6100 m-high satellite of the 6210 m massif, Karakorum) into the orographic left-hand flank of the Shaksgam valley. The "Shaksgam Horn" (No. 3) was at least covered by the Main Ice Age Shaksgam glacier (- -). (There is no evidence of the true thickness of the ice transfluence across this peak). This implies a glacier thickness of at least 1400 m from top to valley floor (□). Coming down from W Tibet, this substantial, Main Ice Age outlet glacier consequently had a thickness of 1400 m plus the thickness of the then vacant drift floor down to the bedrock rock base. (◢) marks the well preserved Ice Ace flank abrasions and polishings; (- - - -) marks the mostly Early to Late Glacial ice scour limits. (▼▼) (in the third of the photo on the left) shows the Late Glacial lateral moraine ledges on the orographic right-hand valley flank. Below (■) ground moraine (basal till) material covers the solid rock slope. The mudflow fan (♦) which had been constructed from ressorted moraine material in the orographic right-hand side valley (below No. 2) was transported away from it in a fan of numerous mudflow streams (▽↓). Viewpoint: 36°07'30"N/76°38'20"E. Photo: M. Kuhle 20.10.86.



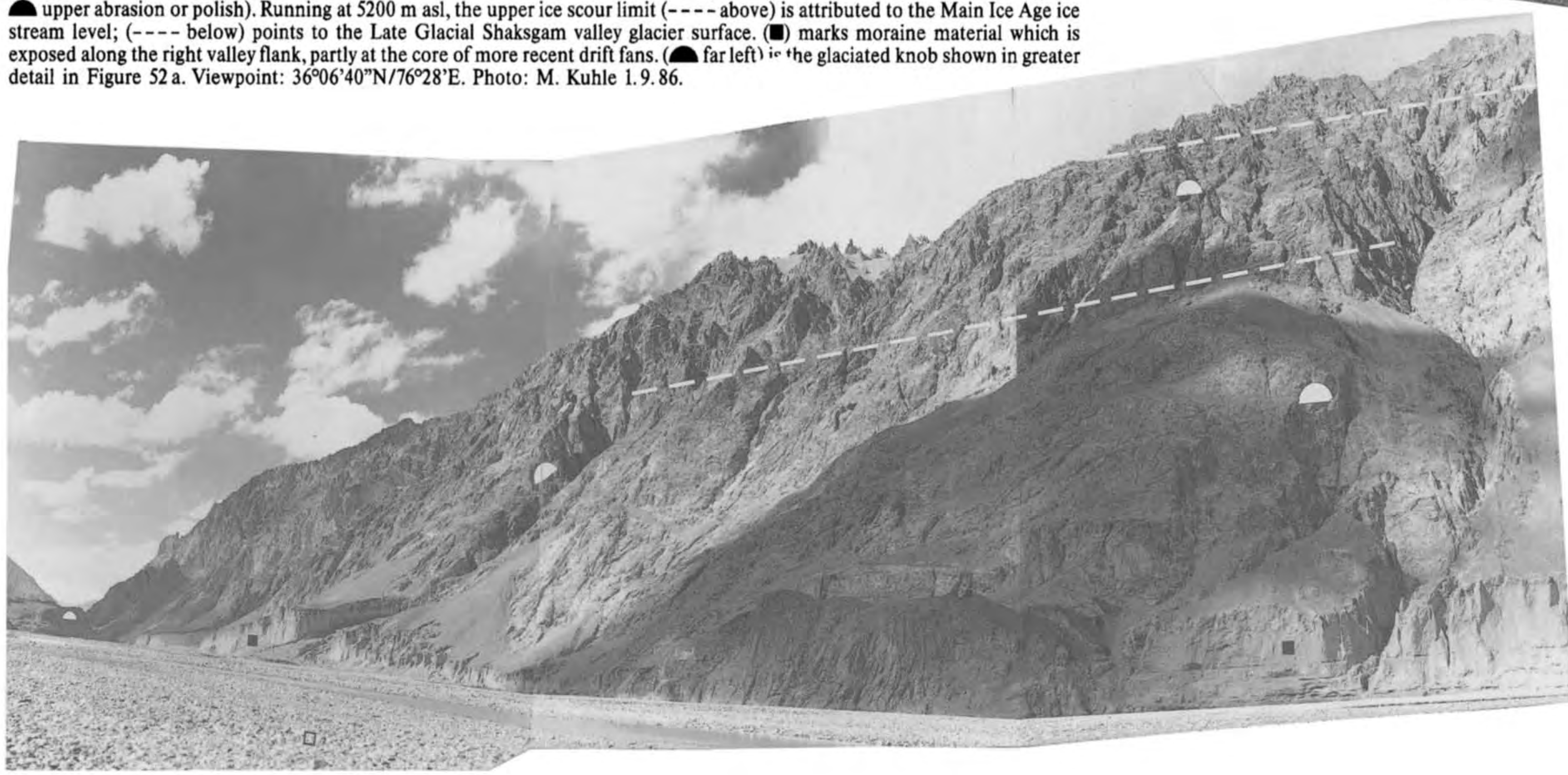


Fig 85 ▼
View from the drift floor of the Shaksgam valley (3960 m asl; Fig 138 between Nos. 12 and 20) down-valley towards the NNW into the right flank. Made up of limestones, the rock flank shows two flank abrasions and polishings of different quality (◓ lower, and ◓ upper abrasion or polish). Running at 5200 m asl, the upper ice scour limit (- - - - above) is attributed to the Main Ice Age ice stream level; (- - - - below) points to the Late Glacial Shaksgam valley glacier surface. (■) marks moraine material which is exposed along the right valley flank, partly at the core of more recent drift fans. (◓ far left) is the glaciated knob shown in greater detail in Figure 52 a. Viewpoint: 36°06'40"N/76°28'E. Photo: M. Kuhle 1. 9. 86.

Fig 87 ▼
View from the bottom of the "Northern Aghil pass valley" at c. 4740 m asl (Fig 138 No. 25) N of the 4863 m-high Aghil pass (/ˆ). Panorama from SE (far left) via SSE with the Aghil pass (/ˆ), via SW into the abraded and polished limestone flank (◓), via W to NW down-valley to the Surukwat-Yarkand valley system. On the far left, as also on the right of the photo, the orographic right-hand granite valley flank with flank abrasions and polishings (◓◓) and ice scour limits (- - - -) can be seen. The glacial flank abrasions and polishings on both sides of the valley (◓◓ in limestone and in granite) are evidence of the increase in the thickness of this Ice Age "transfluence glacier" from the Aghil pass, which came over from the Shaksgam valley and flowed down to the Surukwat valley. On the Aghil pass (/ˆ) it only reached a transfluence thickness of c. 600 m (cf. Fig 86). Only the heights are wet enough to support pasture for the - here - rare yaks (foreground, left). Viewpoint: 36°12'N/76°37'E. Photo: M. Kuhle 30. 8. 86.

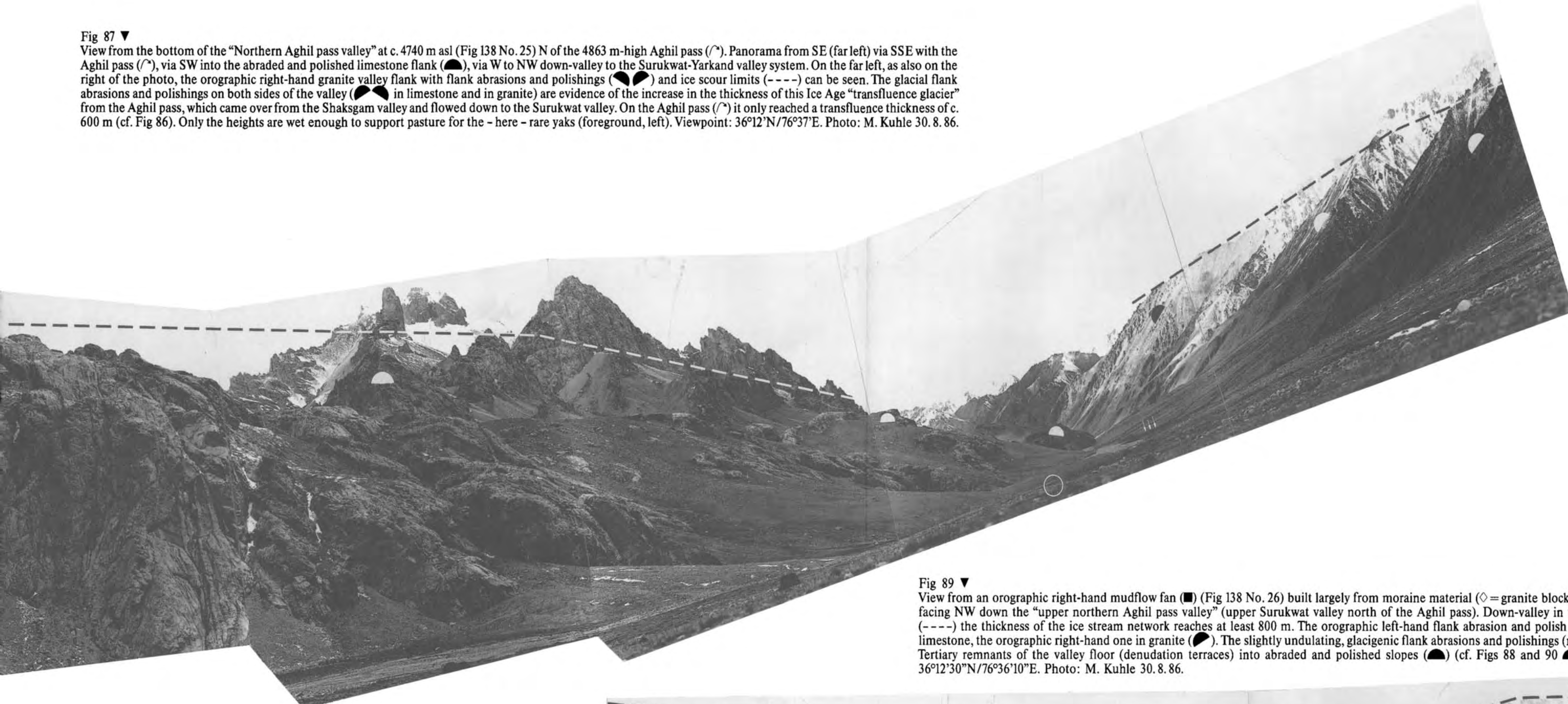


Fig 89 ▼
View from an orographic right-hand mudflow fan (■) (Fig 138 No. 26) built largely from moraine material (◇ = granite blocks) at 4670 m asl facing NW down the "upper northern Aghil pass valley" (upper Surukwat valley north of the Aghil pass). Down-valley in the background (- - - -) the thickness of the ice stream network reaches at least 800 m. The orographic left-hand flank abrasion and polish (◓) occurs in limestone, the orographic right-hand one in granite (◓). The slightly undulating, glacigenic flank abrasions and polishings (right) transform Tertiary remnants of the valley floor (denudation terraces) into abraded and polished slopes (◓) (cf. Figs 88 and 90 ◓). Viewpoint: 36°12'30"N/76°36'10"E. Photo: M. Kuhle 30. 8. 86.

Fig 86 ◄
View from 4880 m asl across the 4863 m-high Aghil pass (still free from snow in this particular October) (Fig 138 below No. 25) towards NW and on to the slopes of this transfluence pass (/ˆ). Still covered by glacier ice in some places, these rock slopes were abraded and polished by a c. 600 m-thick glacier that branched off from the Shaksgam ice stream towards the NW (◓), forming glaciated knobs in bedrock limestone. Probably a result of the Main Ice Age, the level of the glacier, which joined up with the Yarkand ice stream network, thus creating a surface contact with the Shaksgam ice stream network, ran at about 5500 m asl (- - - -). || mark large blocks of granite, which are suspended in a matrix of fine ground moraine. Viewpoint: 36°11'25"N/76°37'20"E. Photo: M. Kuhle

Fig 90 ▲
View from 4570 m asl towards the NE to the 6300 m-high massif (background) into the orographic right-hand flank of the "northern Aghil pass valley" (Fig 138 No. 26). The tributary valleys joining from the NE are glacigenic cuts. They divide the main valley flank into glacial cuspate areas and truncated spurs, which have undergone abrasion and polishing up to their highest points (- - - -). The side valleys release broad mudflow cones (O). The abraded and polished rock terraces (◓) preserve a Tertiary valley floor level (cf. Figs 88 ◓ left and 89 ◓ right). Weathered down to rough blocks, the granite only produced relatively insignificant scree slopes (▽) after deglaciation, but roughened up the glacier polish considerably. Viewpoint: 36°12'40"N/76°36'20"E. Photo: M. Kuhle 30. 8. 86.

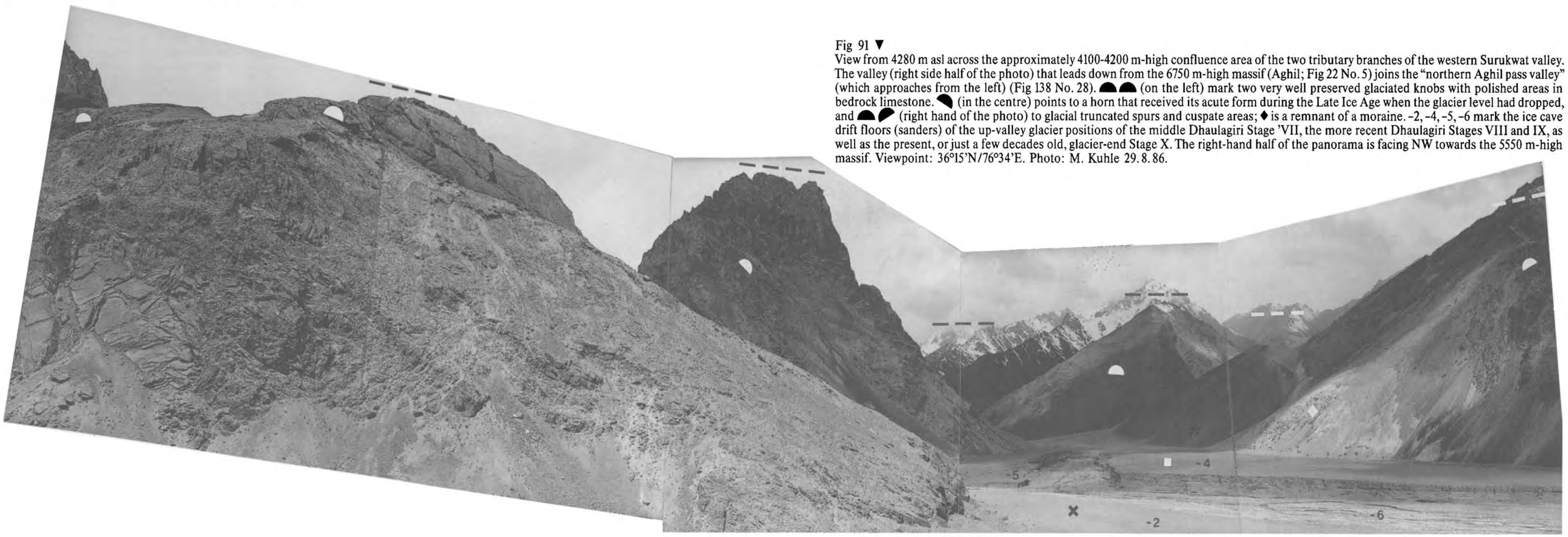
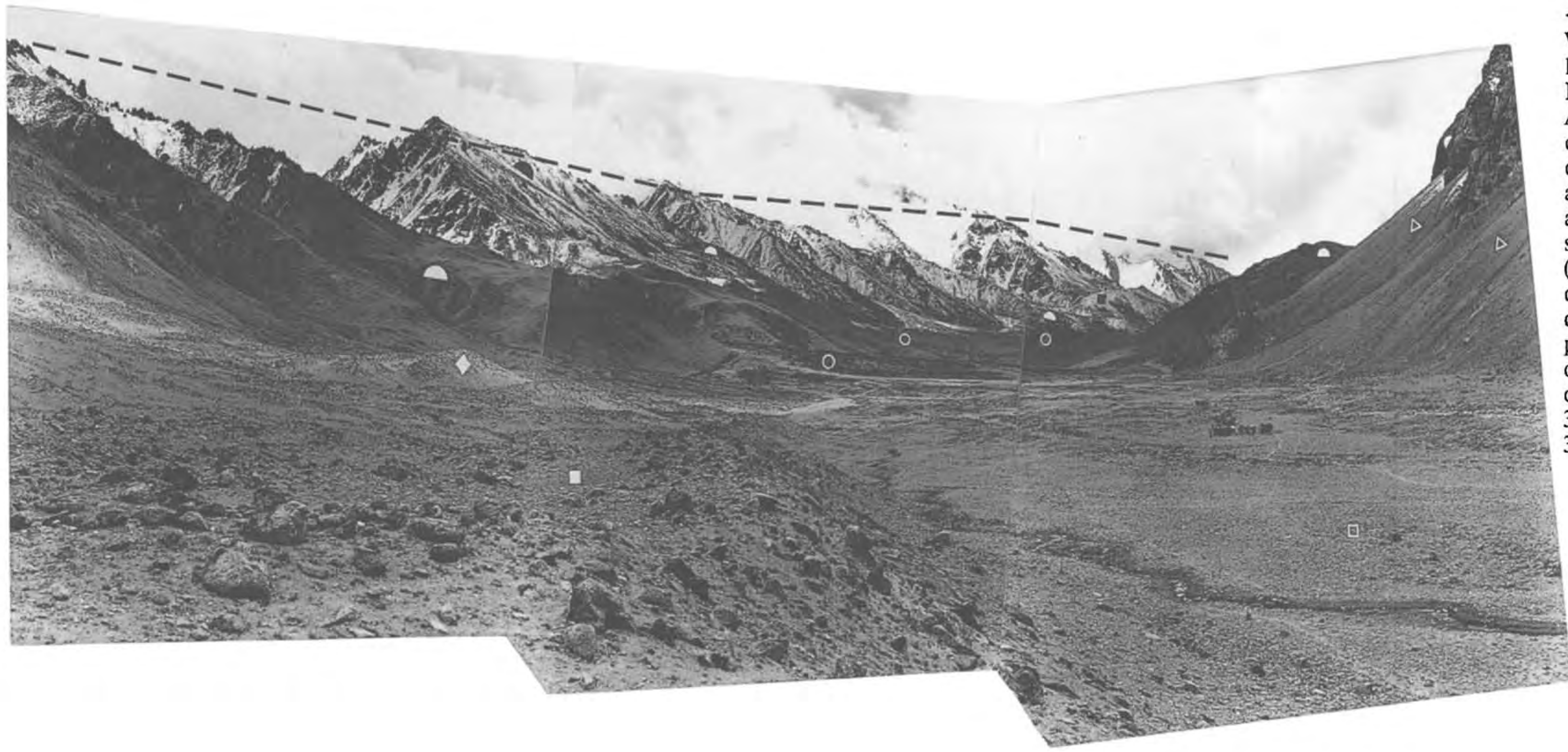
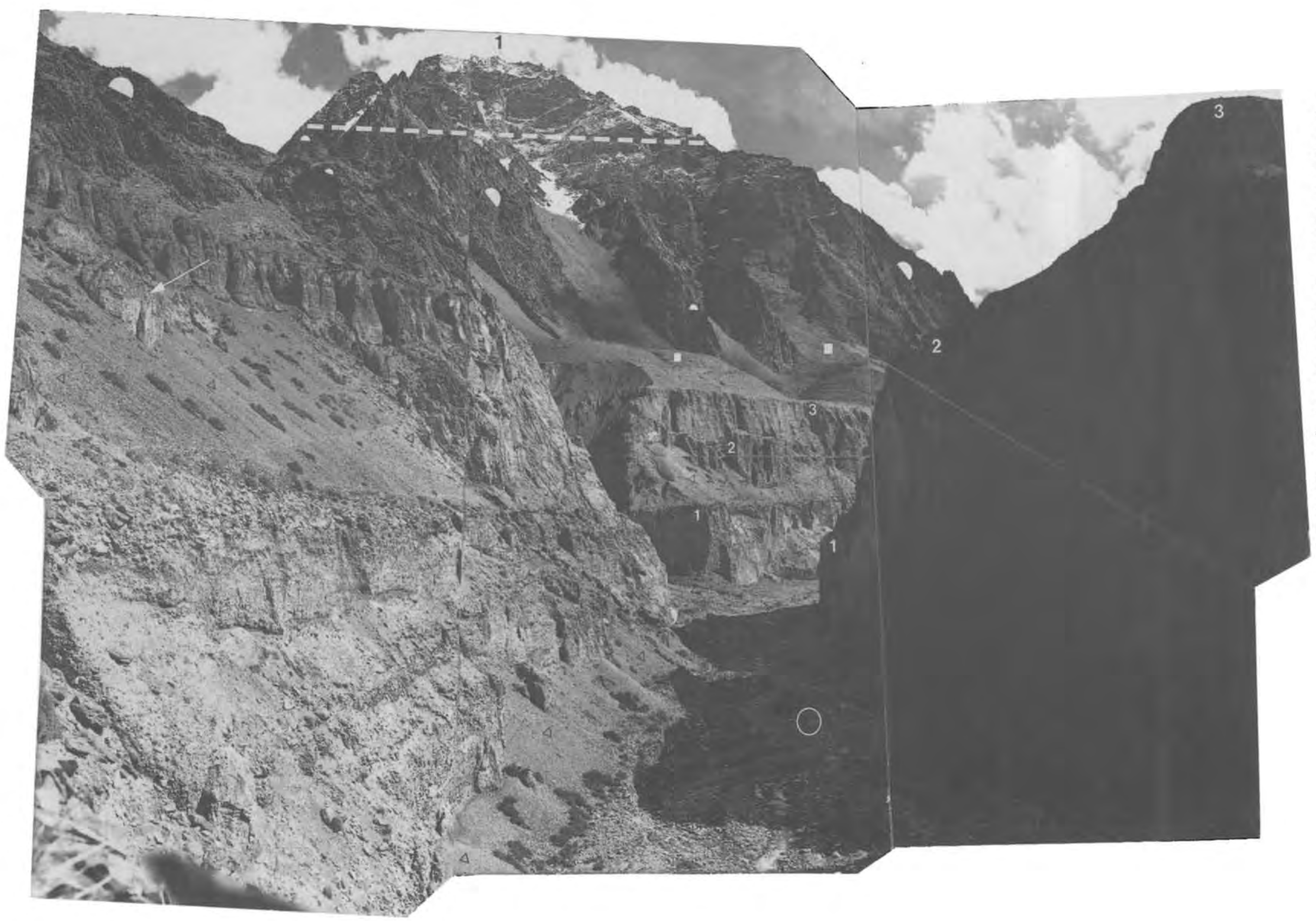


Fig 91 ▼
View from 4280 m asl across the approximately 4100-4200 m-high confluence area of the two tributary branches of the western Surukwat valley. The valley (right side half of the photo) that leads down from the 6750 m-high massif (Aghil; Fig 22 No. 5) joins the "northern Aghil pass valley" (which approaches from the left) (Fig 138 No. 28). ◓◓ (on the left) mark two very well preserved glaciated knobs with polished areas in bedrock limestone. ◓ (in the centre) points to a horn that received its acute form during the Late Ice Age when the glacier level had dropped, and ◓◓ (right hand of the photo) to glacial truncated spurs and cuspate areas; ♦ is a remnant of a moraine. -2, -4, -5, -6 mark the ice cave drift floors (sanders) of the up-valley glacier positions of the middle Dhaulagiri Stage 'VII, the more recent Dhaulagiri Stages VIII and IX, as well as the present, or just a few decades old, glacier-end Stage X. The right-hand half of the panorama is facing NW towards the 5550 m-high massif. Viewpoint: 36°15'N/76°34'E. Photo: M. Kuhle 29. 8. 86.



◄ Fig 88
View from a Late Glacial orographic right-hand lateral moraine terrace (■) at 4500 m asl (Fig 138 No. 27) in SE direction up into the "northern Aghil pass valley". The valley floor (□, camel caravan further behind) consists of glaci-fluvial drift sediments and some mudflow dykes. It lies at 4450 m asl. The orographic right-hand flank abrasion and polish (◓) occurs in granite and shows glacial truncated spurs and cuspate areas (◓) between the side valley exits. Since deglaciation substantial debris slopes (▷) have developed below the partly crumbled flank polishings along the limestone walls on the orographic left-hand. ○ mark the mudlow cones of tributary valleys on the right. Viewpoint: 36°13'50"N/76°34'50"E. Photo: M. Kuhle 30. 8. 86.



◄ Fig 92
View from the orographic right-hand flank of the gorge section of the western Surukwat valley at 3840 m asl (Fig 138 No. 29) facing up-valley towards the S. Below the peak No. 1 (= a NW, c. 5430 m-high satellite of the 6300 m-high peak in the Aghil main ridge) a currently still glaciated orographic right-hand side valley joins. Its talweg reaches that of the Surukwat valley to the left of the two figures 1 in the valley bottom. In the very high parts of the steep walls especially (below No. 1), the glacigenic flank abrasions and polishings (◓◓) have been greatly affected and dissolved by denudation and rock-fall gully formation. Polished and abraded by Main Glacial glaciers up to its highest levels (till ----), the valley profile was filled with Late Glacial drift material (1, 2, 3), before its subsequent step-wise dissection into gravel terraces down to the present valley floor (○). Viewpoint: 36°17'20"N/76°35'E. Photo: M. Kuhle 29. 8. 86.

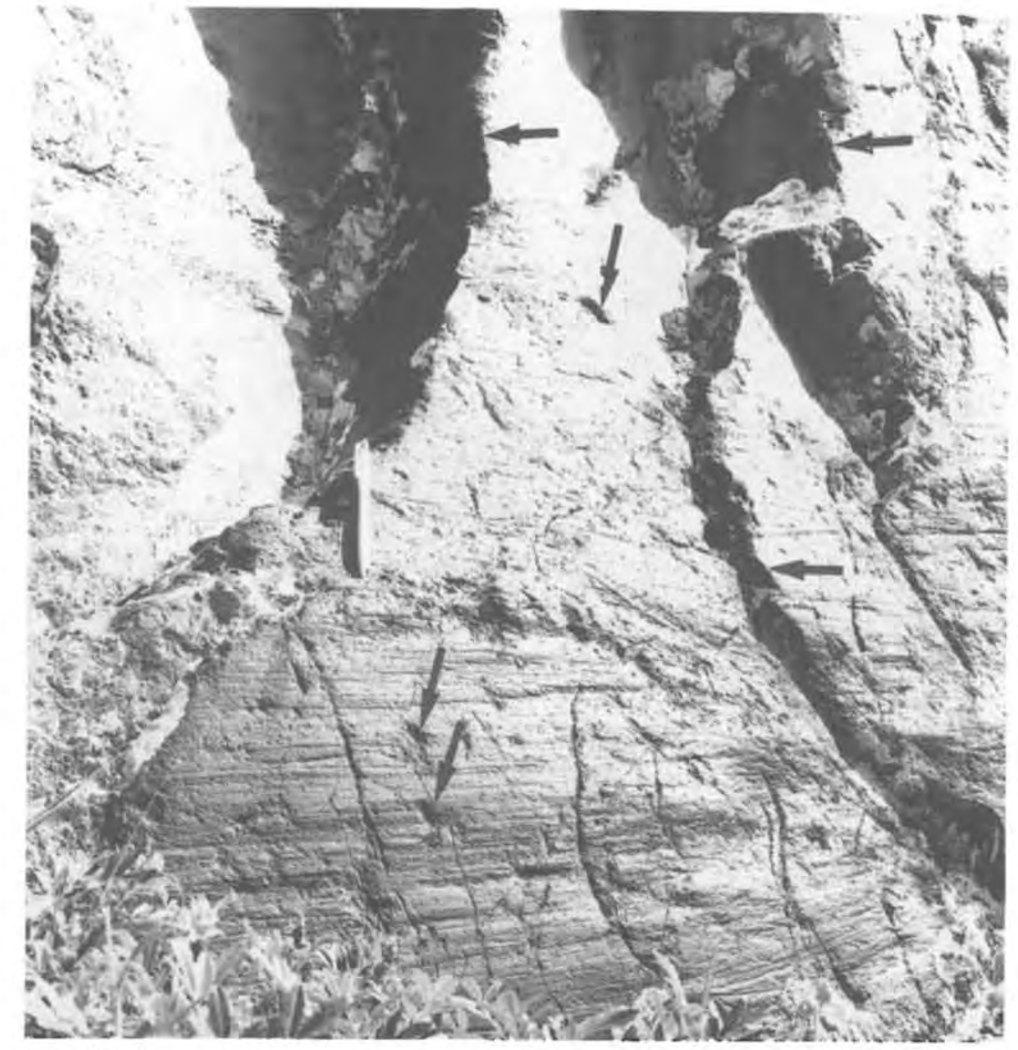


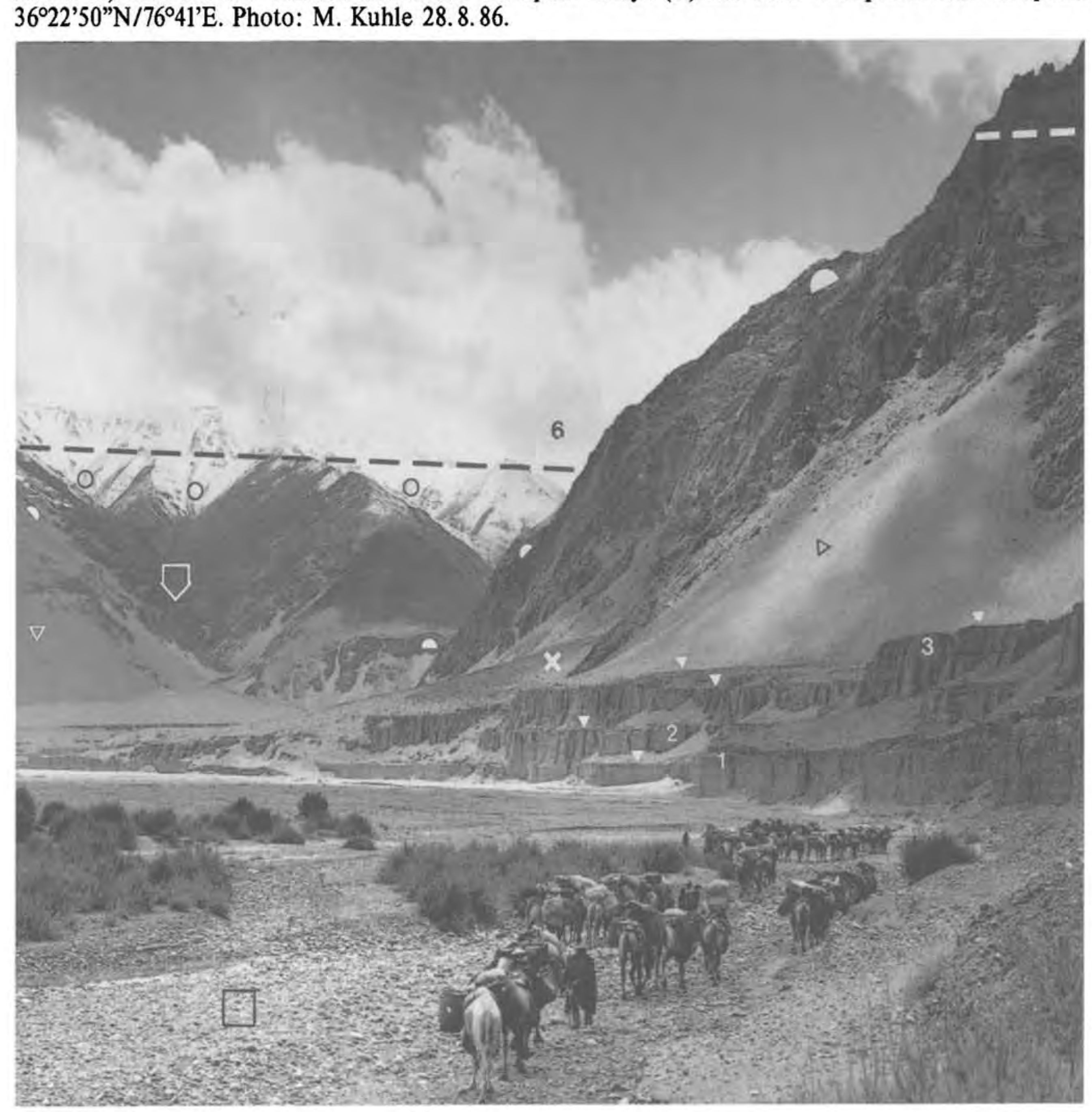
Fig 93 ▲
Detail of a quarzite rock face on the orographic right-hand flank of the western Surukwat valley at 3700 m asl, with striae from a prehistoric glacier (Fig 138 No. 46). The size of the striations (which are horizontally arranged) can be estimated by comparing them with a ball-pen (which is vertically arranged). ↙ mark the somewhat larger, more extensive injuries to the rock, like "chattermarks"; ← mark much more significant sickel-shaped rock outbursts in the direction of the ice movement (from right to left), which are to be attributed to detraction with the aid of regelation processes. The quarzite areas show iron manganese crusts, which point to considerable potential evaporation of this semi-arid to arid N-slope of the Aghil mountains. Viewpoint: 36°20'N/76°36'E. Photo: M. Kuhle 28. 8. 86.

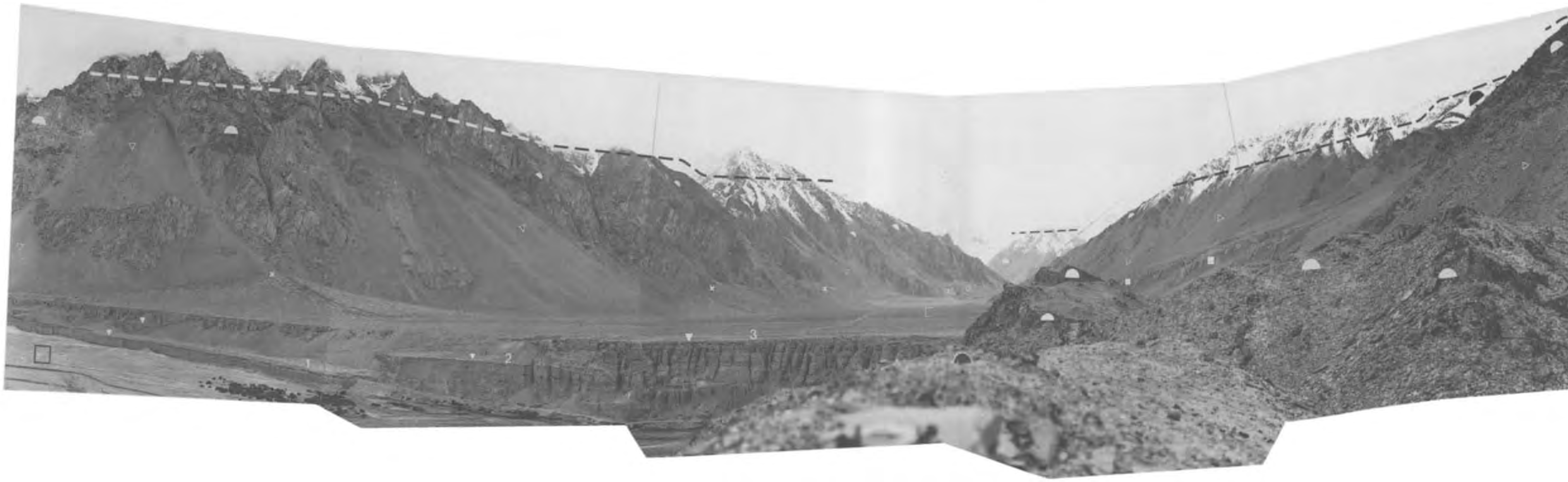
Fig 94 ▲
View from the lower western Surukwat valley at 3500 m asl (X) towards the orographic right-hand valley flank in the SE (Fig 138 No. 48). At its base five ice cave drift floor terraces (outwash terraces ▼▼) pile up as far as the outwash level 3 (middle Late Glacial period: Taglung Stage II). Further up they are followed by abrasions and polishings in the form of glaciated knobs (◓). They occur in the outcropping edges of the strata of reddish-brown sandstone. When seen from the perspective of Figure 95 (◓◓ far right) these flank polishings can be recognised as part of a glacigenic cuspate area (Fig 138 left of No. 48). Between the abraded and polished rocks early-Late Glacial ground moraine covers (■■) are deposited on the slopes. Viewpoint: 36°25'N/76°40'40"E. Photo: M. Kuhle 29. 8. 86.

Fig 95 ▲
View from the confluence of the eastern (left) and western Surukwat valley (Fig 138 between Nos 33 and 48) at 3490 m asl (X), showing a panorama from E (left side edge of the photo) by way of S (No. 6 = 5100 m-high ridge-back on the NE spurs of the 6300 m massif in the Aghil) to SSW (right side edge of the photo). Between the cuspate areas the Ice Age glacial flank abrasion and polish has caused (◓ right side of the photo) glacigenic V-shaped valleys (⩒) to terminate. They are now unglaciated up to the source basin of the valley (terminal facettes of the valley) (○). Above the present valley floor (X) the Late Glacial (3, 2, and 1) to Neo-Glacial and historic glacifluvial drift terraces rise like stairs (▼▼). Some of their areas are the recipients of alluvial fans from adjacent valleys (for instance, 3 on the left and 2 on the right). On the left side of the photo a granite mountain spur has been abraded to a great height (- - - -) by the eastern tributary of the Surukwat glacier (◓◓).
Viewpoint: 36°20'15"N/76°41'20"E. Photo: M. Kuhle 28.8.86.

Fig 96 ▼
View from the area of terrace 3 ▼ (talus cones △ on the far left and mudflows are set in upon them) of the orographic right-hand side of the lower Surukwat valley at 3590 m asl down-valley towards NNE (middle of the panorama), to the confluence with the Yarkand valley (left below No. 1) (Fig 138, right of No. 33). Above the wide valley drift floor (□) and the drift floor terrace (▼) glacially abraded and polished trough flanks (◓◓) extend as far as the ice scour limits (- - - -) at 4400 m asl. In places Late Glacial embankments with cores of lateral moraine (bank formations) are deposited against these trough flanks (■). No. 1 marks up to 5250 m-high mountain ridges SE of the 5994 m-high peak (Kuenlun mountains). ◓◓ (above ↑) are the glaciated knobs in the confluence area, which are shown in detail in Fig 98. Viewpoint: 36°22'N/76°41'E. Photo: M. Kuhle 28.8.86.

Fig 97 ▲
View from a location near "Ilik" in the confluence area of the Yarkand and Surukwat valley at 3455 m asl (Fig 138 right-hand side above No. 33), facing S towards the Surukwat valley and up to the Aghil mountains (No. 6). The camel caravan is standing on the present drift floor among myricariae bushes. The highest, orographic left-hand, Late Glacial drift terrace (▼ 3 = drift floor of the Taglung Stage II) has received talus slopes (▷) as well as mudflow cones (X), ie they have formed after the middle Late Glacial period. The ice scour limits (- - - -) entered above the Main Glacial flank abrasions and polishings (◓◓) and run up to 1000 m above the drift floor (□). The polish of the glacial cuspate areas (right and left of ⩒) between the confluences of the V-shaped valleys (⩒) has been well preserved. Viewpoint: 36°22'50"N/76°41'E. Photo: M. Kuhle 28.8.86.





◄ Fig 98
View from the confluence area of the Surukwat valley (left edge of the photo) and Yarkand valley (right half of the photo) (Fig 138, approximately between Nos. 33 and 34) at 3580 m asl, looking down the Yarkand valley towards the WNW (□ right). Polished or abraded out up to an altitude of 4400 m asl (----) during the Main Ice Age, the bottom of this trough consists of a fresh drift floor (□ left) and the Late Glacial drift terraces 1, 2 and 3 of the Sirkung Stage (IV), the Dhampu Stage (III), and the Taglung Stage (II) glacier stands. After deglaciation the flank polishings and abrasions (▲) were transformed or covered by talus cones and slopes (▽), by mudlow fans (X), and by Late Ice Age kames with moraine cores (■). In the foreground and middle ground on the right glaciated knobs occur in vertical phyllites (▲▲) (cf. Fig 42). Below ▼ No. 2 the expedition camp with tents and grazing camels can be seen in the "Ilik" locality. Viewpoint: 36°23'30"N/76°41'35"E. Photo: M. Kuhle 27. 8. 86.

Fig 99 ▲
View from the present drift floor of the lower Surukwat valley at 3450 m asl in the confluence area with the Yarkand valley (Fig 138, right of No. 33) facing NE, up the glacial Yarkand trough. Above the glacigenic drift terraces (▼) 2 and 3 a glaciated knob (▲) can be seen, which was created by the glacial abrasions and polishings of the early Late Glacial period (Ghasa Stage I) and of the Main Glacial period. During the post-Main Glacial period this glaciated knob (cf. Fig 128 ▲ in the background) was undercut by the Surukwat river on the side shown here. This caused steep crumbling (cf. Fig 101 right of the left ▲). Even the terrace levels break - due to the effect of the undercutting (○). (----) marks the Ice Age glacier level in the Yarkand trough throughout the valley with its sinusoidal flank polish profiles (▲). Rubble production (▷) after deglaciation has profited from bedrock slate, which is prone to frost weathering along the line of crevices. (■■) point to Late Ice Age lateral moraine terraces (bank formations). Viewpoint: 36°23'N/76°41'E. Photo: M. Kuhle 28. 8. 86.

Fig 100 ▲
View from the drift floor of the lower Surukwat valley near "Ilik" in the confluence area with the main valley (Yarkand valley) at 3450 m asl (Fig 138 between Nos. 33 and 49), facing N into the right flank of the Yarkand valley. Built up from phyllites, this valley slope is glacigenically abraded and smoothed (▲) well above its outcrops up to an ice scour limit (----) at c. 4400 m. Since deglaciation semi-arid, and moreover high continental, frost weathering has been particularly productive in these phyllosilicates (▷). Below the valley flank there are glaciated knobs (▲) at 3580 m asl (see Figs 42 and 98 ▲ in the detail); these glaciated knob rocks, in turn, have drift floor terraces deposited below them (3 ▼▼). These glaciated knobs have "drowned" in the Late Glacial drift floors No. 3 (Taglung Stage II). Viewpoint: 36°23'N/76°41'10"E. Photo: M. Kuhle 28. 8. 86.

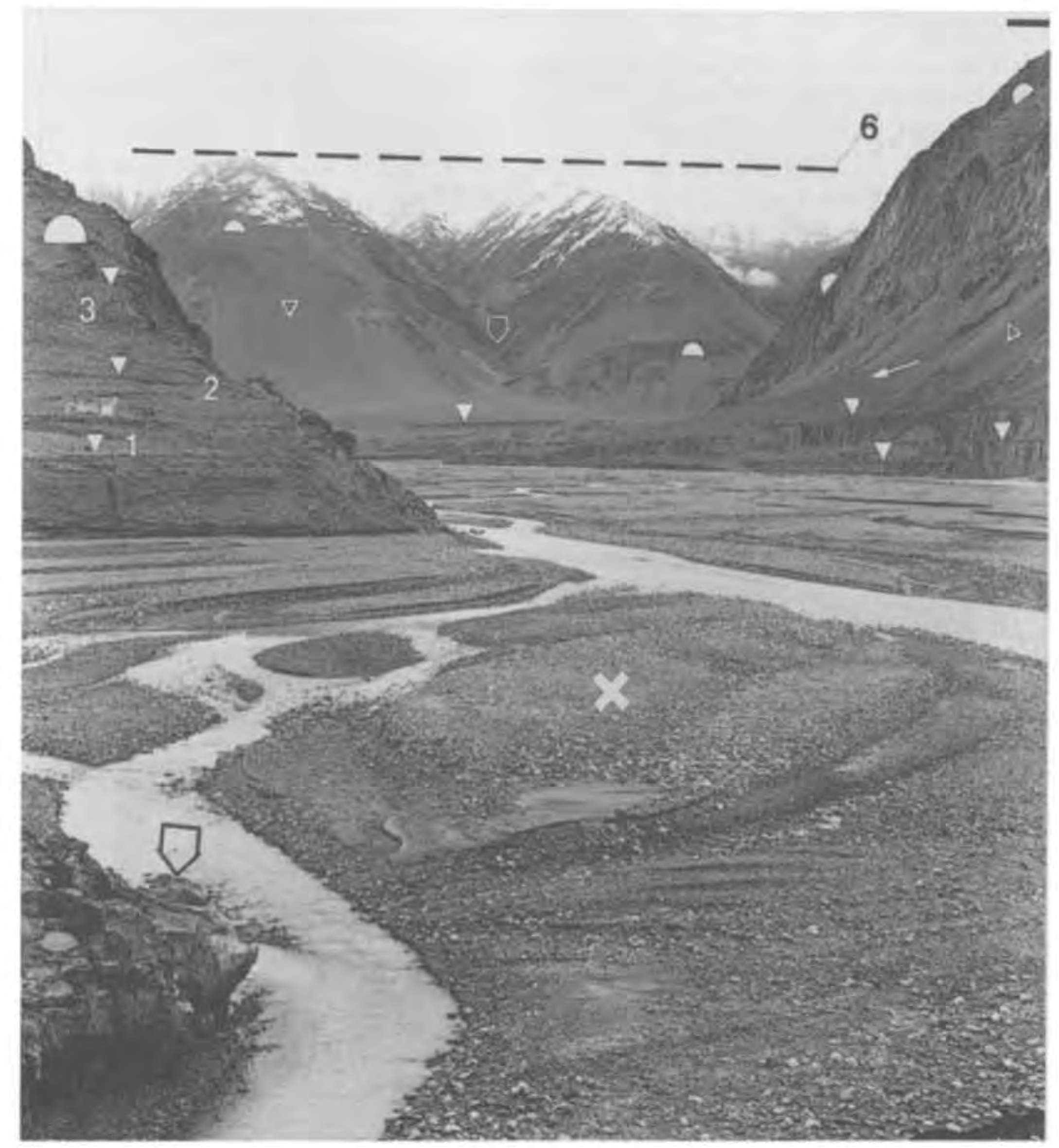


Fig 101 ▲
View from the locality where the Surukwat meltwater run- off (X) joins the Yarkand (Fig 138, somewhat higher to the right of No. 33) at 3460 m asl, facing S and up the Surukwat valley. ▽ (foreground) marks churn-like or pothole-like rock forms due to the activity of Late Ice Age subglacial meltwater run-off (locality see Fig 96 ↓). In the background glacigenic cuspate areas and truncated spurs (▲▲) between the V-shaped side valley exits (▽); in the middle ground on the left Late Glacial drift floor terraces (▼) 1, 2 and 3, and above a post-glacial fluvially undercut glaciated knob (▲) (locality see Fig 96 ▲, left above □). Viewpoint: 36°23'N/76°41'20"E. Photo: M. Kuhle 27. 8. 86.

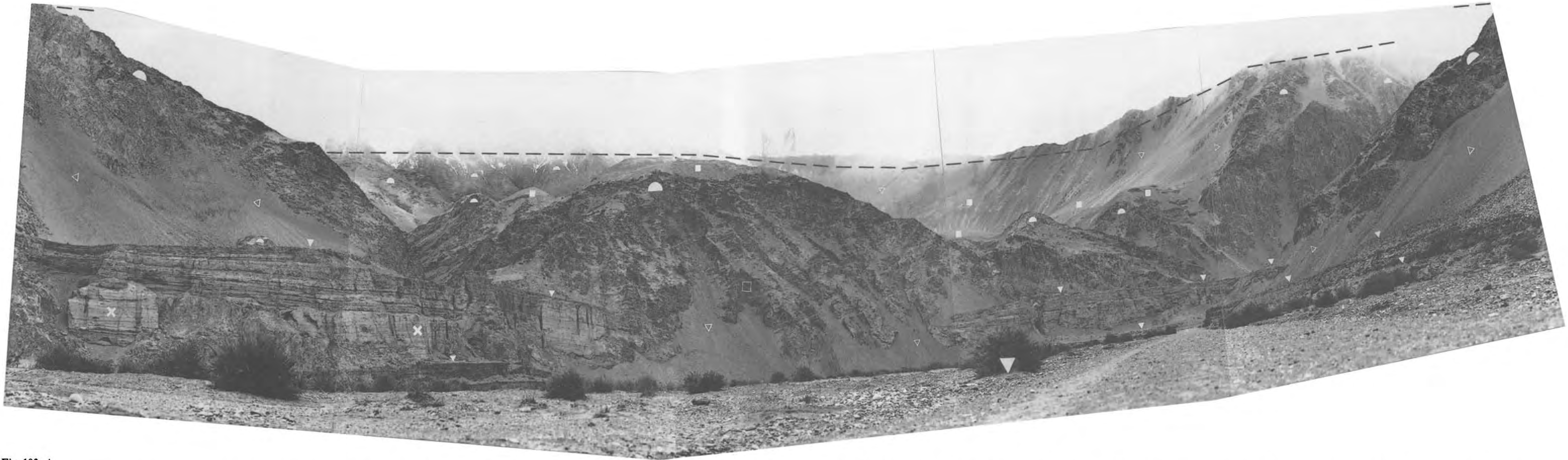
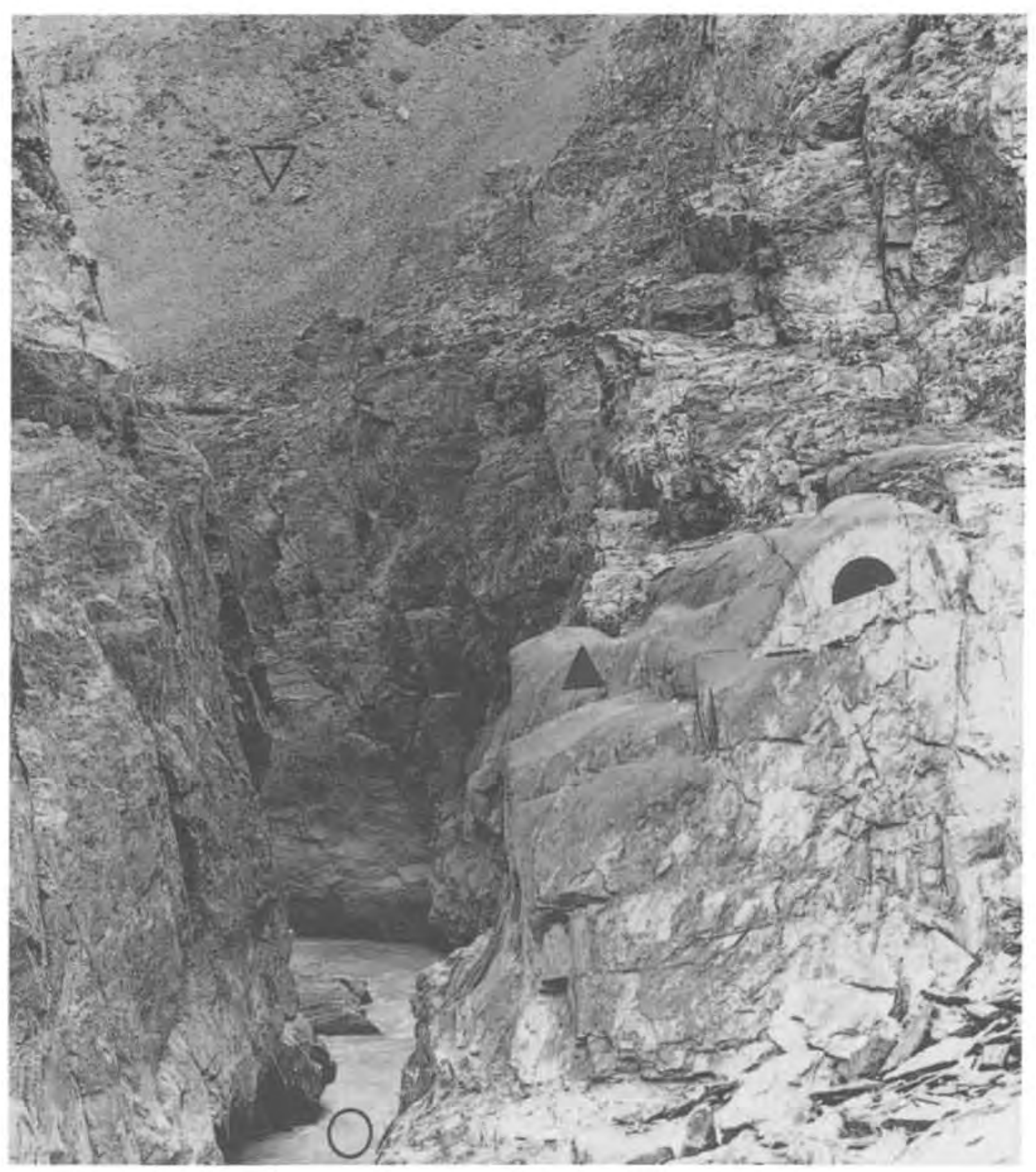


Fig 103 ▲
View from one of the lowest drift floor terraces (▼) on the valley bottom of the Yarkand valley (Fig 138 between Nos 49 and 34) at 3680 m asl, looking into the orographic right-hand side valley. The panorama from N (left edge of the photo) to E (right-hand edge) shows a hanging valley, which is connected by a kilometre-wide exit step that is set in rock (□). This exit step, and simultaneously glacigenic confluence level, is divided up into separate glaciated knobs (◖◗ middle ground in the centre). These glacigenic polish forms of the bottom, which are formed in bedrock slate (phyllite) are covered by Late Glacial moraine material (■ middle ground in the centre). Below the ice scour limit (- - - - in the background) polished slopes, occuring on outcropping edges of the stratum, are preserved (◖◗) and further down even Late Glacial lateral moraines and Main Ice Age remnants of ground moraine (■ in the background on the right) (cf. Fig 99 ◥■ in the background). After deglaciation frost-weathering has covered the steep relief with talus cones and talus slopes (▽). In parts the older (higher) glacifluvial pebble terraces (▼▼) contain rhythmic limnites (varve clays) (X) which point to the damming back of a glacier lake in the lower Yarkand valley by the Late Glacial Surukwat glacier. Viewpoint: 36°25'N/76°43'30"E. Photo: M. Kuhle 27. 8. 86.

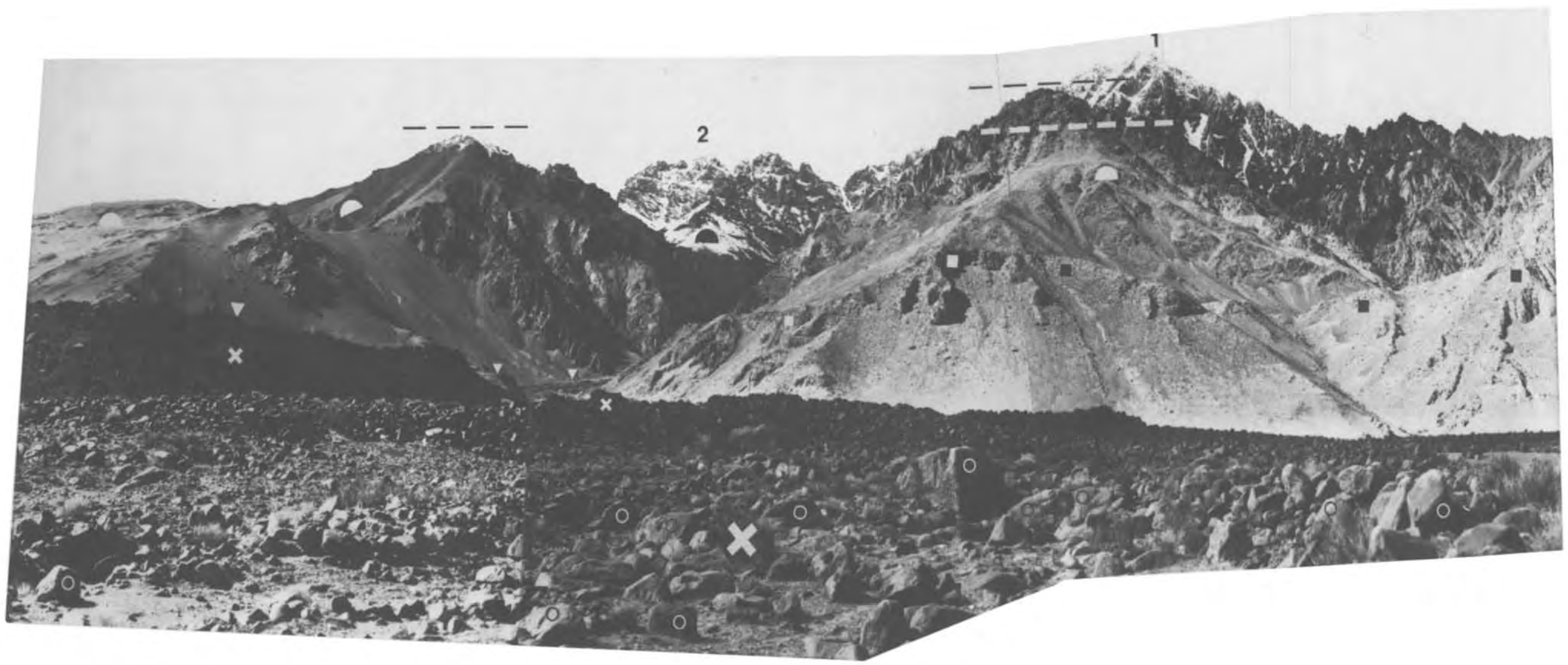


◄ Fig 102
At the point where the Surukwat joins the Yarkand (locality see Fig 96 †) it cuts (○) with a gorge through a bedrock slate threshold (3445 m asl; Fig 138 between Nos 33 and 49). A few metres above the river the fine reliefs of Late Glacial glacier polishings are preserved (▲◗). Likely to have been set down already in sub-glacial times, the gorge cut through the latter. Viewpoint: 36°23'N/76°41'20"E. Photo: M. Kuhle 27. 8. 96

Fig 104 ▼
View from the orographic right-hand drift terrace edge near the "Mazar" military station, a few metres above the Yarkand river at 3800 m asl facing SE (Fig 138 between Nos 38 and 39). The glacigenically V-shaped valley (right-hand edge of the photo) leads down from the 5880 m-high peak in the Aghil mountains, now displaying only minor glaciation, or firn shield trimmings (○) on the slopes of its source basins. The orographic right-hand flank of this side valley (◥), as well as the left flank of the main valley (Yarkand valley) experienced glacigenic flank abrasion and polishing (◗) on the bedrock metamorphites. Exposed since deglaciation, and weathering fast under freeze-thaw cycle conditions, the sedimentary rock bears near-surface frost debris covers, which merge with talus slopes (♦) further down. Five different levels of glacifluvial and fluvial terraces must be discerned here (▼▼). (- - - -) marks the highest established ice scour limit of the prehistoric Yarkand glacier at c. 4900–5000 m asl (cf. Fig 105). It ran c. 1000 m above the accompanying ELA. The forms, which have taken shape in the valley flank in the area of this ice scour limit (- - - -) belong to the Late Ice Age in respect of their formation. Viewpoint: 36°26'40"N/77°00'E. Photo: M. Kuhle 21. 8. 86.

Fig. 105 ▲
View from the transfluence pass (◆) on the orographic right-hand flank of the Yarkand valley 600 m above the valley floor (□) at 4420 m asl, looking W down the valley (Fig 138, left next to No. 53). Largely polished by glacigenic flank abrasion and polishing (◆◆) up to the ice scour limit (- - - -) at 5000–5100 m, the outcropping edges of the strata of bedrock metamorphites are more or less steeply cut by the slopes, mountain ridges and transfluence pass areas (cf. Fig 104). The cross-profile of the Yarkand valley shown here is that of a classic trough, the bottom of which was infilled by a braided river to form a canyon (□). Periglacial debris formation which cause slopes of frost compensation, concordantly transforms its flanks (▷). Late Glacial bank formations and moraines have been locally preserved (■). ○ and ▼ mark alluvial fans from side valleys, as well as terrace levels from glacifluvial drift floors. Viewpoint: 36°28'30"N/77°05'15"E. Photo: M. Kuhle 24. 8. 86.

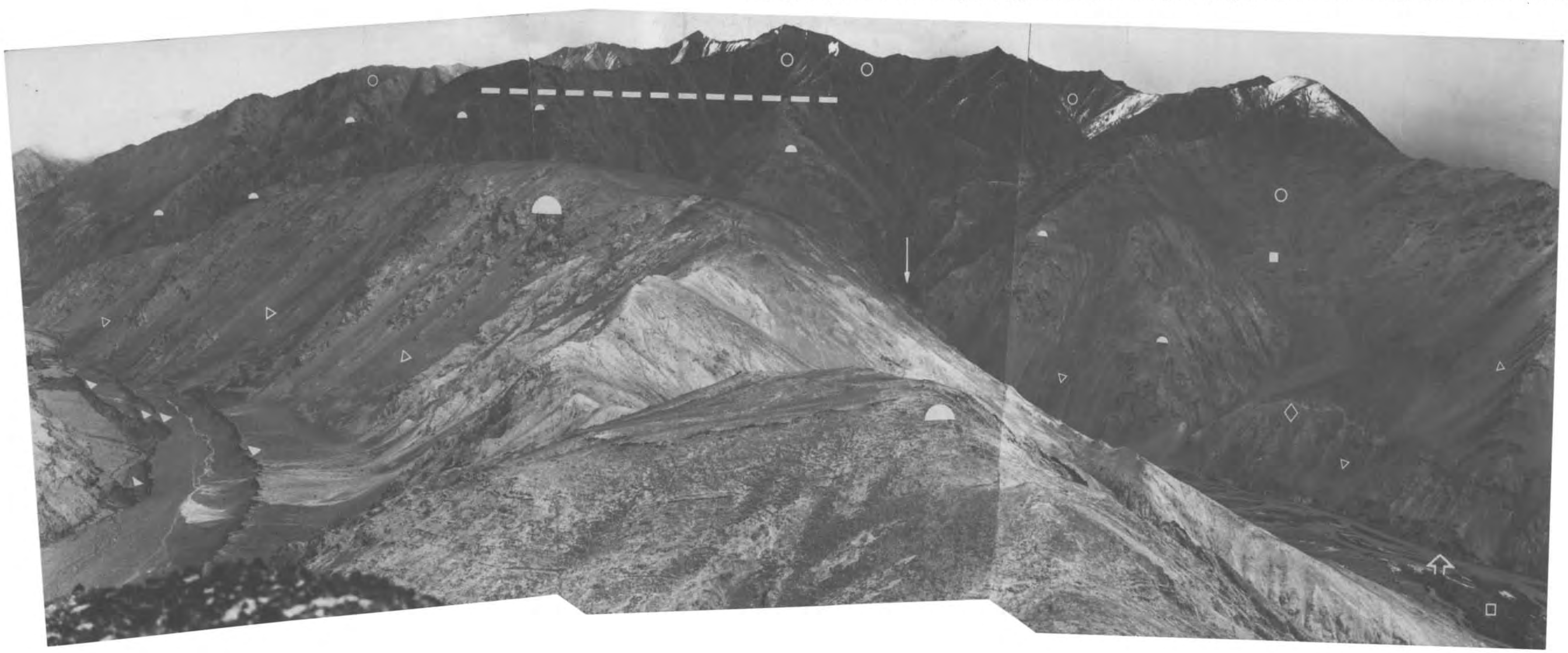
Fig 108 ▲
Exposure at 3760 m asl on the orographic right-hand bank of the Yarkand river, a few decimetres above the level of the fore-flood level (Fig 138 No. 37, cf. Tab 2 samples 24. 10. 86/ 4/1b/1c/1d). There is river sand and gravel (◇ at the base of the exposure, and above a stratum of peat (□) (the ice axe is 55 cm long), which being between 0.60 and 1.0 m below the surface of the exposure (▼) has been radio-carbon dated to be 110 ±60 YBP, 4580 ±65 YBP and 5935 ±85 YBP. They are covered (X) by more recent alluvial fan material. The most recent (first) date is explained by the fresh, recent root network. The two older dates are evidence of the time of origin of glacifluvial valley drift floors (sanders) of Neo-Glacial glacial locations. This contains evidence of a totally ice-free main valley floor in this valley chamber in the Neo-Glacial period, which is significant in this context. The Yarkand glacier had already left here during the Late Ice Age. Viewpoint: 36°24'N/76°52'E. Photo: M. Kuhle 24. 10. 86.



◄ Fig 106
View from the edge of a mudflow fan (X) near the talweg of the Yarkand valley at 3780 m asl into the orographic right-hand valley flank (Fig 138 No. 37). The exposure is facing N into the 6532 m massif of the Kuenlun main ridge, with the satellite peaks Nos. 2 and 1, which are visible here. The 6532 m-high main peak lies a little outside the angle of vision where the ridges of the peaks No. 2 and 1 meet (left, behind and above No. 1). The mudflow fan (Xx) consists of dislocated granite moraine material with rough blocks (○), which has been transported out of the orographic right-hand side valley (below No. 2). On the lower parts of the slopes of the orographic right-hand main valley flank a lower (■ left) and a higher lateral moraine terrace, with kame sediments, have been deposited (■ right). They belong to the last Late Glacial glacier stages to have had a main valley glacier. At that time the glacier surface was already far below the ELA. The very different state of preservation of the glacigenic flank abrasions and polishings (◆◆) permits a differentiation of two ice scour limits (- - - - below and above) or glacier levels. The lower limit belongs to the earliest Late Ice Age, to Ghasa Stage (I); the upper one to the Main Ice Age. In both cases the upper surface of the ice stream network was above the snow line. Viewpoint: 36°23'50"N/76°51'10"E. Photo: M. Kuhle 26. 8. 86.

◀ Fig 109
View from 4200 m asl down the "southern Mazar pass valley" towards the Yarkand valley in the SSE (background) (Fig 138 left above No. 39). In this glacial trough valley with rock abrasion reaching far up the flanks (◗◖) of crystalline slates (phyllites) a drift floor (□) was laid down, which in turn received at least five levels of drift terraces (▼), thus creating a canyon-shaped cross-profile of the valley. Frost weathering after deglaciation created decimetre- to metre-thick debris covers, as well as talus slopes (△▷) that rise up many hundreds of metres. Steep wall gorges or large gullies produce mixed forms of mudflow/alluvial fans (○). In places where the river undercuts these tall slopes on precipices, dry avalanches cause successively rising cracks (↗). Viewpoint: 36°29'35"N/76°59'35"E. Photo: M. Kuhle 20.8.86.

Fig 110 ▼
View from 4000 m asl towards the SE across a ridge and up the Yarkland valley (right) into an orographic right-hand side valley (left) (Fig 138 No. 53). Composed of metamorphosed sedimentary rock of varying hardness (phyllites with quarzite strata), the ridge has been abraded by Main Ice Age glacier filling of the valley system (◗). - - - - marks the accompanying glacier level on the basis of glacigenically abraded and polished areas of the valley slopes and valley slope spurs (◗). The rough gorge flanks of the most recent Post-Glacial fluviatile linear erosion (↓) present a contrast to their soft forms. (■) indicates a block glacier and the presence of permafrost in this valley landscape above 3800 m asl. (○○) label valley-head basins suitable for Ice Age and Late Ice Age cirque formation; (▼▼) mark the edges of Late to Post-Glacial drift floor terraces, some of which must be regarded as glacifluvial sander formations. Viewpoint: 36°28'10"N/77°05'20"E. Photo: M. Kuhle 23.8.86.



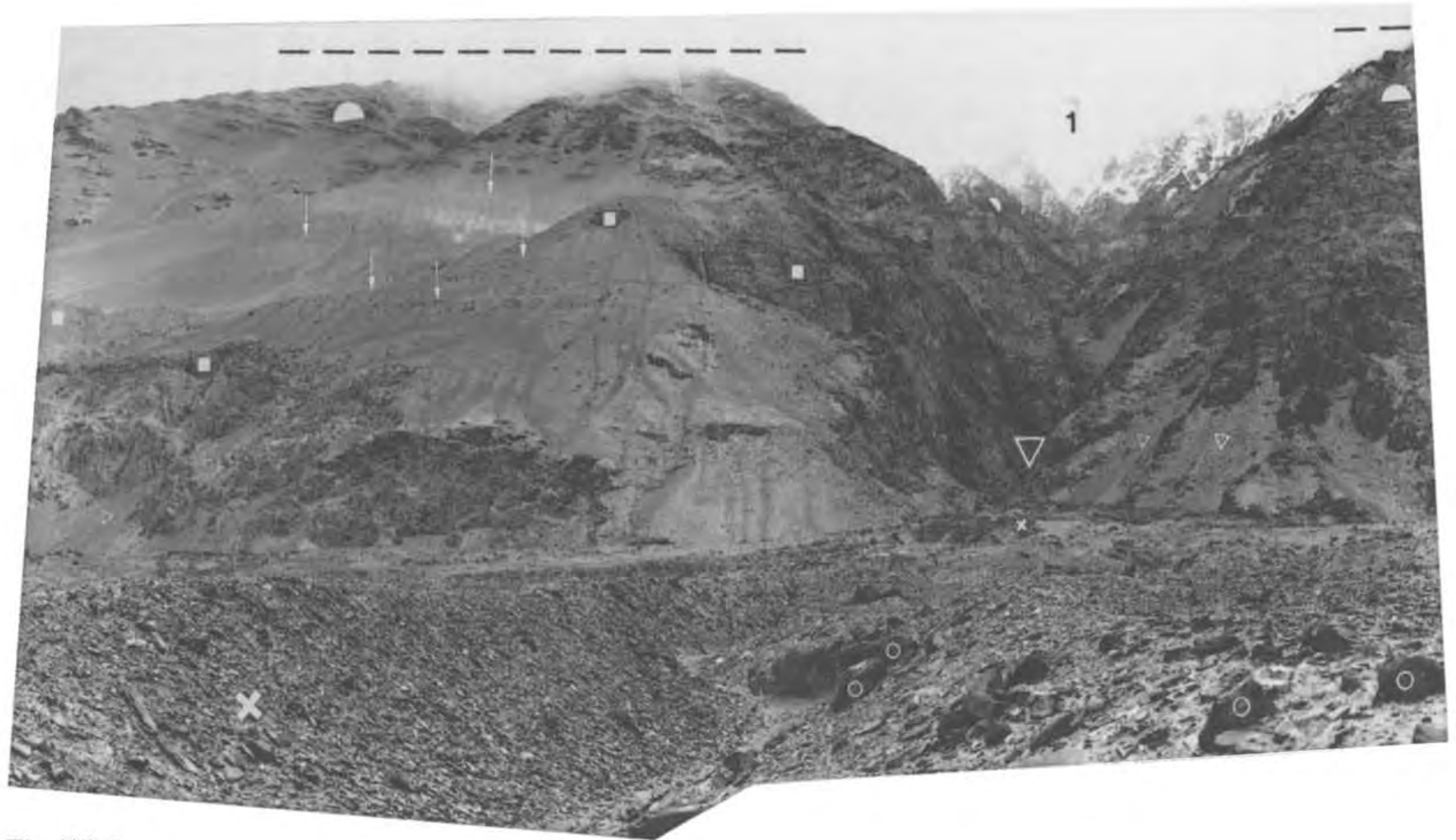


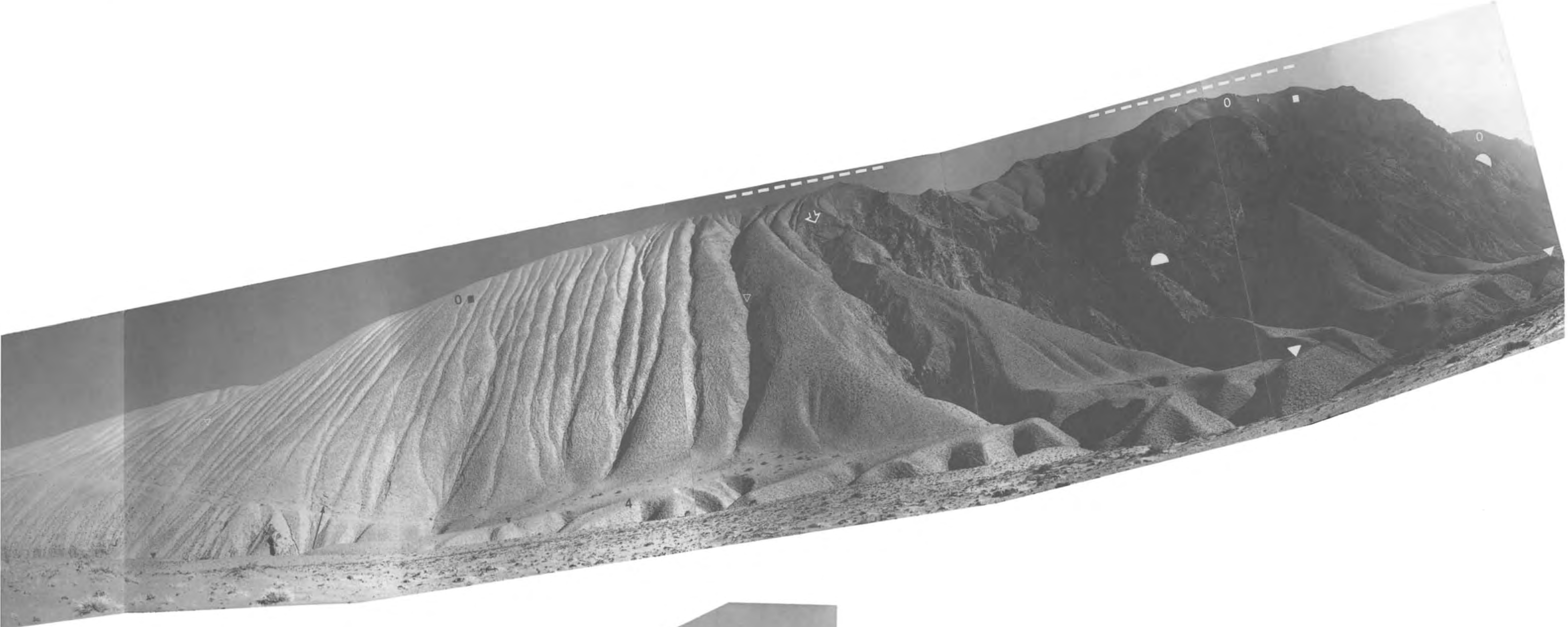
Fig 107 ▲
View from 3700 m asl across a mudflow fan (X) facing S into the orographic left-hand flank of the Yarkand valley and into a steeply descending side valley (Fig 138 above No. 49). No. 1 = c. 5300 m-high peak in the highest catchment area of this V-shaped side valley. It is set in phyllites, with the upper slope sections shaped by glacigenic flank polishing (◀▶). Running along a gully-like narrow gorge, the talweg (▽ large) is the result of subglacial cutting. While passing over its outcropping edges of the stratum, the main glacier (▲) has abraded and polished the main valley flank to an altitude of c. 4700–4800 asl (- - - -). Below it is connected to a ground moraine cover (■■ left), with exaration furrows and lineaments of rough blocks (↓↓), which lies on top of the bedrock rock flank. In the side valley exit there is an orographic right-hand lateral moraine of the tributary glacier (■■ right), which has pushed across the Late Glacial main glacier or fitted themselves to its side. Here, too, the major part of the mudflow cone consists of dislocated Late Glacial moraine material with rough blocks (OO). Viewpoint: 36°24'50"N/ 76°43'20"E. Photo: M. Kuhle 27. 8. 86.

◀ Fig 111
View of an orographic right-hand side valley of the "Kudi valley" at c. 3000 m asl, facing E and up-valley (Fig 138 below No. 54), which must be considered a representative glacigenic, V-shaped gorge valley of the Kuenlun N-slope. There are glacial flank abrasions and polishings in the bedrock granites (◀▶), which result in a slightly concave broadening of the gorge profile. At the base of this "gorge-shaped trough profile" there is a sharply incised cut profile which stands out against the flatter upper slope areas with a rocky ledge on each side (↘). Set into the present talweg (⇓), this cut was created by sub-glacial meltwater erosion during the Last Ice Age, and subaerially worked upon since deglaciation. Its drift filling is evidence of a currently weak state of erosion, and the fact that V-shaped profile at the bottom of the valley could not have been formed without sub-glacial metlwater erosion. Viewpoint: 36°50'50"N/ 76°58'40"W. Photo: M. Kuhle 18. 8. 86.

Fig 113 ▼
View from the orographic right-hand flank of the "moraine valley of Pusha" in the northern mountain foreland of the Kuenlun at 2550 m asl (Fig 138, above No. 43; as for the viewpoint cf. Fig 112 in the right-hand valley flank) across this moraine valley and other corresponding parallel moraine valleys. The panorama extends from SW (0 on the left side edge of the photo) to W (right-hand edge of the photo). All the ridges marked 0 are moraine walls from the Main Ice Age. Those shown in this photo attain relative heights of 500 m to more than 700 m above the valley floor, or tongue basin floors, which hold the very substantial outlet glacier tongues. The photograph was taken from 550 m above the glacifluvial drift floor (No. 4 - drift floor of Ghasa Stage I) in the "valley of Pusha". The formation of this end moraine landscape of parallel stripes is polyglacial. It took place in the course of the Pleistocene Ice Age era when the outlet glaciers from W-Tibet and the Kuenlun N-slope repeatedly reached the Tarim basin. On the moraine ridge (foreground) 25–30 cm long erratic blocks of green, massive crystalline rock were dug up from a decimetre-thick loess cover at 100 m above this viewpoint (at 2650 m asl). Further S, at the edge of the next mountain range, limestone occurs as bedrock. ● mark small alluvial fans which serve as depositories for alluvial loess and dislocated moraine material from the gullies. Viewpoint: 37°16'40"N/77°09'20"E. Photo: M. Kuhle 30. 10. 86.

Fig 112 ▼
Panoramic view from one of the major moraine valleys on the Kuenlun N-slope at 2550 m asl. It is the "moraine valley of Pusha" (or "Posseh", Fig 138 No. 43; cf. Fig 113), looking down-valley from WNW (0 on the left edge of the photo) via NNW (■0 centre of the photo) to SE (◥0 on the right-hand edge). The photo was taken from the glacifluvial drift terrace 4 (▼) which had been put down during the Late Ice Age glacier advance (Ghasa Stage I) after the first post-Main Ice Age glacier retreat. The moraine walls reach heights of 800–900 m above the valley bottom (- - - -) and were last deposited during the Würm Main Ice Age. Sedimented out into the foreland, these lateral moraines simultaneously present lateral moraines of the adjacent moraine valleys on the left and right, which makes them medial moraines. The moraine walls extend the glacially polished and abraded limestone rock flanks (▲◥) of the Kuenlun valleys which end here by about 15 km, and out into the Tarim basin (mountain foreland) (■0). In the Main Ice Age the moraine walls were syngenetically covered, and in the Post-Glacial period also by aeolian primary loess. The latter was dissected by gully washing (▽) and deposited as alluvial loess at the foot of the slope. Viewpoint: 37°11'30"N/77°02'50"E. Photo: M. Kuhle 29.10.86.

◀ Fig 114
View from 2680 m asl on to a Main Ice Age glacier tongue basin in the northern (NNE) Kuenlun foreland 15 km E of the "valley of Pusha" and 6 km W of the "valley of Tess" (Fig 138 left side, somewhat below No. 55). Exposure facing W, taken from the orographic right-hand 500–550 m high wall of lateral or medial moraines (0 X) across the talus sander 4 of the Ghasa Stage (I) which covers the floor of the tongue basin, to the orographic left-hand wall of lateral or medial moraines (0 background). The saddle in the latter points to a Main Ice Age transfluence (↷↶). (↓↓) mark exaration rills and furrows in the ground moraine material (horizontally arranged) on the flow direction of the glacier tongue. The ground moraine is undercut and exposed by the present meltwater stream (▽△). Two low gravel terraces (▼) were formed. Run-off precipitation water has dissected the loess-covered moraine surface into gullies (▽). In the area where the photo was taken large dark green quartzite pebbles were found on the moraine culmination. They are erratic, ie. they travelled here over a distance of tens of kilometres. They present evidence of the intensive involvement of meltwater in the sedimentation process of this large end moraines, the base of which lies between 2100–2200 m asl (4). Viewpoint: 37°20'20"N/77°23'20"E. Photo: M. Kuhle 31.10.86.



◀ Fig 116
Panoramic view across the middle Shaksgam valley, taken at 4880 m asl a little above the Aghil pass (4863 m asl; Fig 138 right-hand below No. 25) and ranging from SE (left edge of the photo) to SSW (right-hand edge); No. 6 = Apsarasas, 7245 m; Nos 5 and 8 = Teram Kangri group, 7462 m; No. 3 = Sia Kangri, 7422 m; No. 4= Urdok c. 7300 m; No. 1 = Gasherbrum I (Hidden Peak), 8068 m; No. 2 = Gasherbrum II, 8035 m or Broad Peak group, 8047 m; No. 7 = 6210 m peak, N-satellite of the Skyang-Kangri group. □ marks the Shaksgam valley floor at 4100 m asl. The glacial flank abrasions have polished the valley shoulders and glaciated knob-like rock heads in the bedrock limestone up to at least 5500 m asl (- - - - left and right). - - - - (in the centre) marks the early Late Glacial glacier level at 5000–5200 m asl. The Aghil pass (where the photo was taken) was consequently overflowed by a 600 m-thick Main Ice Age glacier arm which moved NW towards the Yarkand ice stream. The high peaks of the Karakorum towered 2000–2500 m above the Shaksgam ice stream network which had the Tibetan inland ice flow-off towards the NW. Viewpoint: 36°11'N/76°37'E. Photo: M. Kuhle 20.10.86.

Fig 115 ▲
View from 1480 m asl towards W across the varied talus sanders (drift floors) of the last (Würm; 5) and the last but one (Riß; 6) Ice Age (○) (Fig 138 above No. 45). Laid down by an anastomosing system of channels in the form of a fan extending of many tens of kilometres (1–2° inclination) during the cold periods (cf. Fig 55 Nos 2 and 8; Fig 56 [17.8.86/2]; Fig 134), these drifts are now dissected by "microfluviatile channels" (▽) in the wake of heavy rains. This almost barren pebble desert (Serir) in the Tarim basin is part of the Takla Makan desert, and shows the formation of deflation pavement and ventifacts on the larger stones. In the background offset, neogenic sediments from the area of the Tarim basin boundary fault are visible. Burdened by the loose sediments of the surrounding high mountains, isostatic down-warping of the basin begins here. Viewpoint: 37°46'N/77°26'E. Photo: M. Kuhle 17.8.86.

◄ Fig 118
Erratic block of glimmerite granite or gneiss originating from the transfluence pass of the Shaksgam-Muztagh valleys at 4450–4500 m asl, c. 550–600 m above the present valley floor (Fig 138 No. 12) (cf. Fig 37 ■ on the right). Facetted by glacier transport, the smaller block, which was found in otherwise dolomitic moraine material together with other, up to 1.5 m-long blocks of this kind, shows a gneiss-like banding of the light feldspar crystals on the opened-up side, as one finds in the bedrock of the main Karakorum ridge. These are blocks which have been subject to long-distance transport by the Late Glacial Shaksgam glacier. The immediate slope catchment area of the site where this block was found consists solely of calcite rock. Sample locality: 36°05'N/76°28'E.

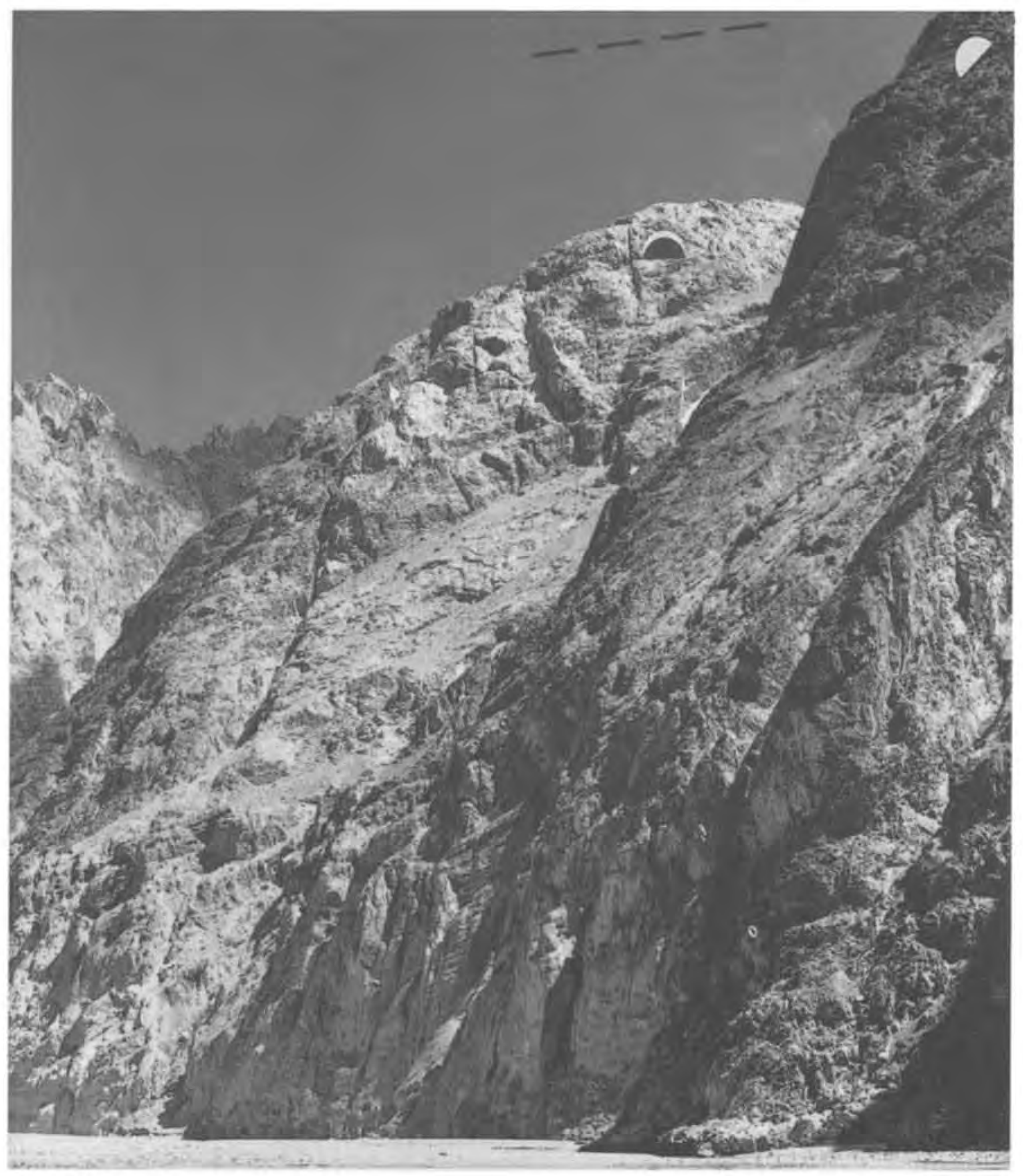


Fig 119 ▲
View from the drift-floor of the Shaksgam valley from c. 3950 m asl towards the SSE into the orographic left-hand limestone flank and up-valley (Fig 138, to the right of No. 12). This steep valley wall shows the features of a trough flank, as the glacigenically abraded and polished (◗) wall first becomes steeper from top to bottom, and subsequently changes from a convex polished profile above the drift floor to a concave one below the drift floor. The abraded and polished areas (◗) show little splintering or crumbling. The drift floor of the Shaksgam valley in its entire width is activated by seasonal floods, evidence of this being shown in its uniformly light colouring extending to the very edge of the rock flank. Viewpoint: 36°06'20"N/76°28'E. Photo: M. Kuhle 1.9.86.

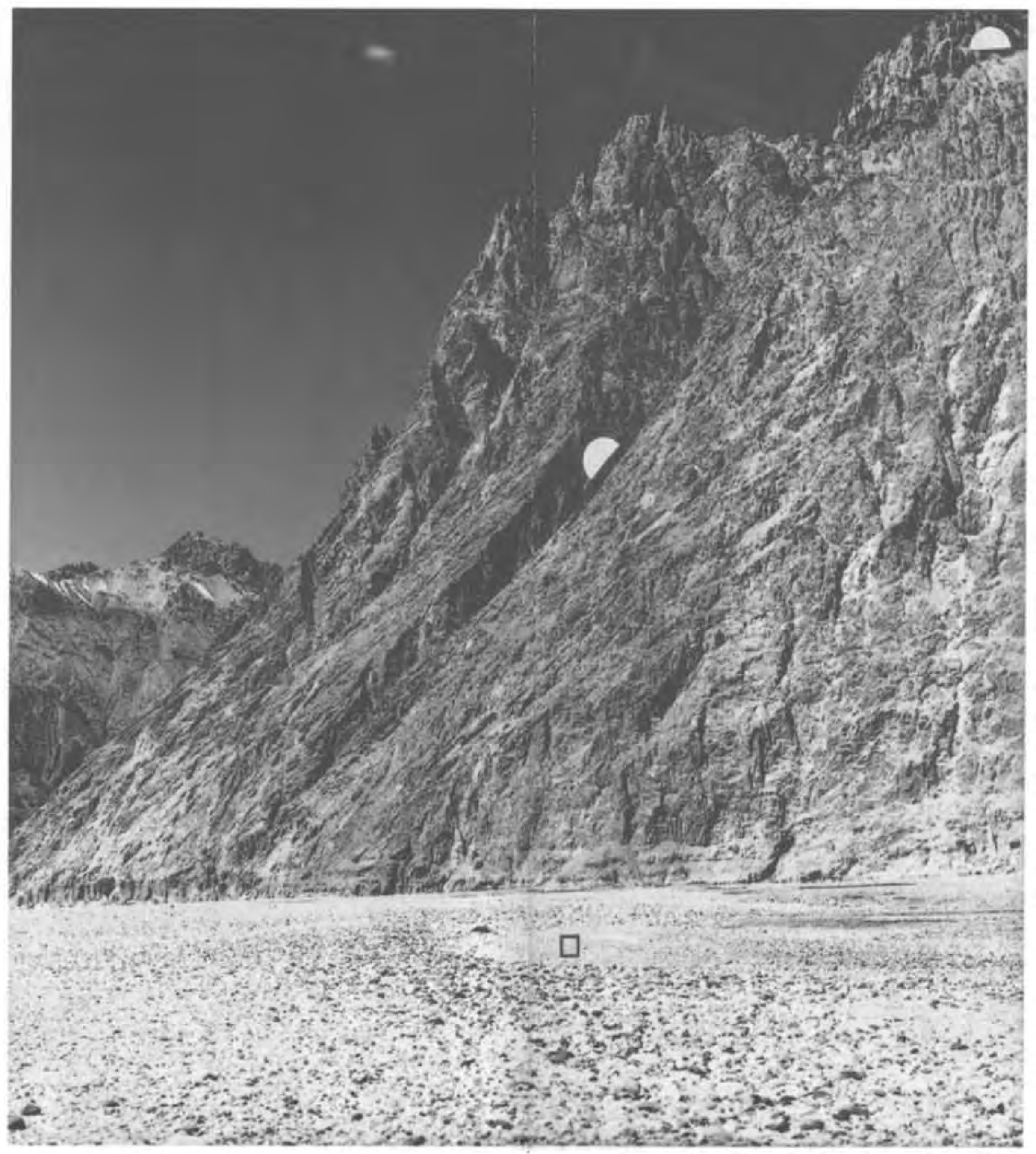


Fig 120 ▲
View from the drift floor (□) of the Shaksgam valley at 3990 m asl into the orographic right-hand trough flank down-valley towards the W (Fig 138, left below No. 21). This photo shows a Main- to Late Glacial glacier scarp, which follows a marked bend of the valley to the left. Hitting this bend at an obtuse angle, the glacier ice, thus diverted, has scoured out a groove-like concave bow into the rock which reaches high up the wall (◗). Viewpoint: 36°07'N/76°32'E. Photo: M. Kuhle 1.9.86.

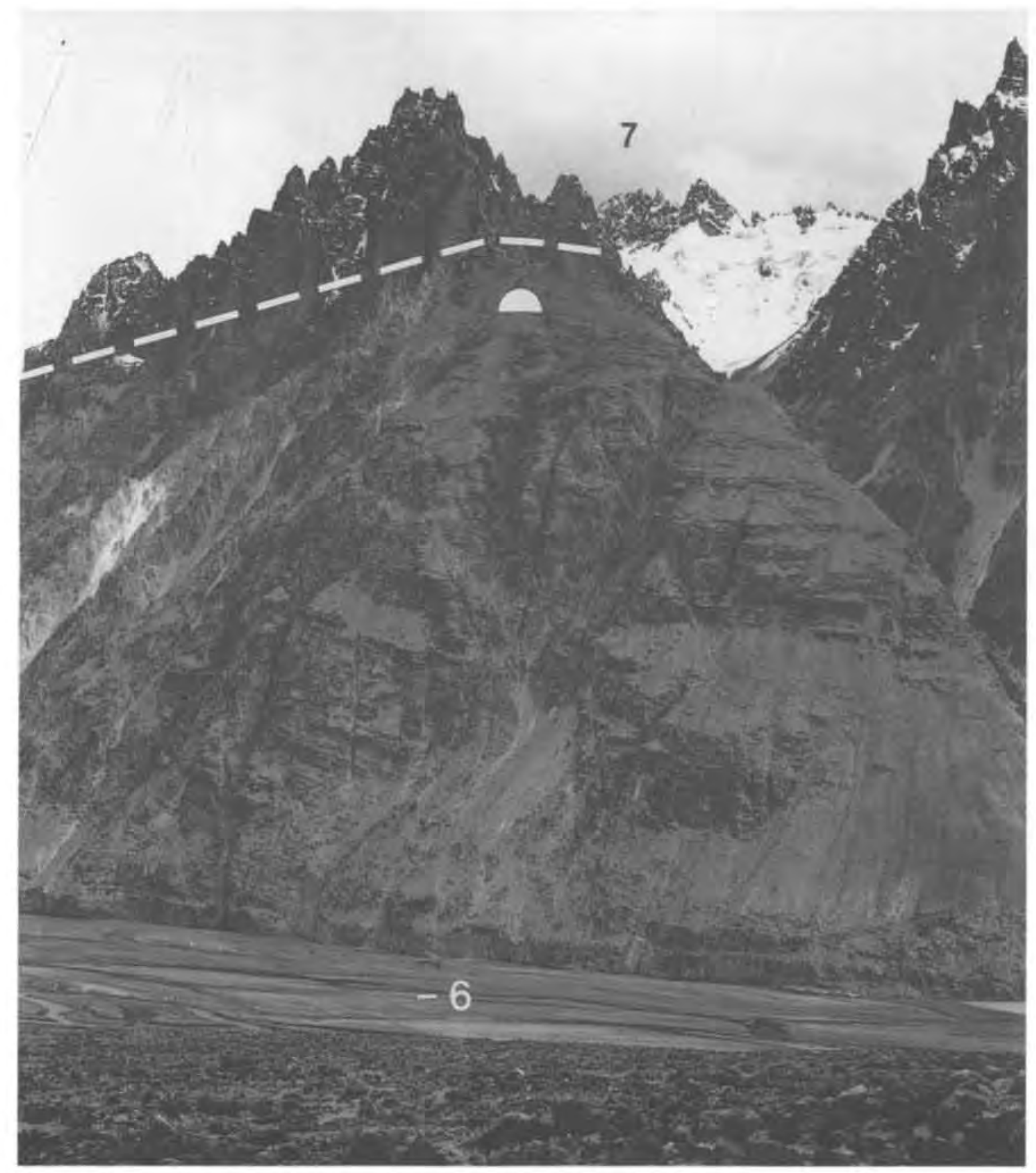


Fig 121 ▲
View from a mudflow cone (with granite blocks in the foreground) at 4180 m asl into the orographic left-hand flank of the Shaksgam valley towards the SSW (Fig 138, right of No. 23). No. 7 = summit superstructure on the 6210 m massif; –6 present drift floor of the valley. From a genetic point of view it must be regarded as a current ice cave drift floor (ie. a sander which the valley canalizes). It was deposited by glaciers (Staghar-, Urdok-, N-Gasherbrum- and S-Skyang-Lungpa glaciers) which reached the floor of the Shaksgam valley. Late Glacial flank abrasion and polishing (◓) on these outcropping edges of limestone extends to a polish line (----) at an altitude of 5000–5100 m, ie. to 1000 m above the drift floor. Viewpoint: 36°08'N/76°37'45"E. Photo: M. Kuhle 29.8.86.

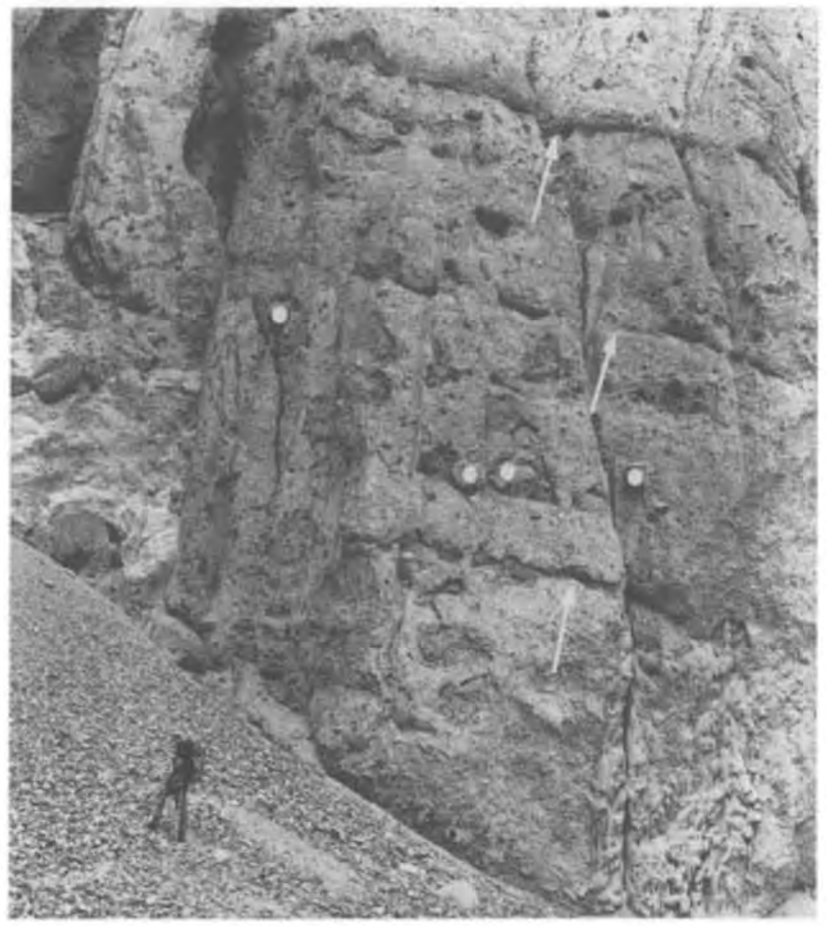


Fig 122 ▲
View from 4270 m asl into the orographic right-hand flank of the Shaksgam valley in the exit of the "southern Aghil pass-valley" on to Late Glacial ground moraine material (●). In this place it has been preserved over several hundred metres up the valley slope (see Fig 71 ◀; cf. Fig 83 ■; Fig 138 on the right above No. 23). (●●) mark large polymict blocks. They are rough-edged, rounded and facetted; isolated from one another, they "swim" in a pelite-rich matrix. Their wealth of fine material is an indication of the intense grinding by the heavy pressure exerted by a very thick and fast-flowing ice stream burden. Banding of crumbled holes and grooves in the exposed wall (↗) is indicative of banking of the ground moraine, pointing to typical strata sedimentation. For a comparison of size see the 1.80 m-tall person. Viewpoint: 36°08'20"N/76°37'43"E. Photo: M. Kuhle 20.10.86.

Fig 123 ▲
View from 4100 m asl down the middle section of the western Surukwat valley ("lower northern Aghil pass-valley") towards the N (Fig 138 left, above No. 27). No. 1 = 6094 m peak in the northern Aghil mountains; a hanging glacier tongue which, from a thermal viewpoint, belongs to the "cold" type, emanates from this glaciated mountain and flows down south (right of ----, background). It ends in a rough, steep drop which is characteristic for this type. (----) marks the Ice Age glacier surface in the area of the orographic left-hand flank of the valley. The orographic right-hand flank abrasions (◗) have left a concavely scoured, glacigenic trough valley profile in the bedrock granite. (▽) mark present talus cones, (□) a talus and mudflow fan, and (■) a rough block moraine of granite scree rock, which has been transported by an orographic right-hand side valley glacier. Viewpoint: 36°16'20"N/76°34'45"E. Photo: M. Kuhle 21.10.86.

Fig 125 ▲
View from the orographic left-hand side valley at 3550 m asl towards the SSE up the lower Surukwat valley (Fig 138, right of No. 33). In the foreground is the mudflow-fan surface (X), which is shown in the right-hand third of Fig 126. It is covered by blocks which have been transported over short distances from the immediately adjacent valley flank (●). Their forms are accordingly rough. Below the crest ridges (No. 6) of the Aghil mountains which rise to c. 5600 m here, truncated spurs and glacial cuspate slopes (◓) set in. The polishing of their inclines and the rounded ridges above mark an Ice Age minimum glacier level (----) about 1000 m above the valley floor in the confluence area of the eastern (left) and western (right) branches of the Surukwat valley. The tributary valleys (○▽) which, now free from glaciation, divide the main valley flank into these cuspate slopes, are the source of alluvial fans in the Late Glacial drift floor terrace (sander terrace ▼, 3, Taglung Stage II). Viewpoint: 36°22'N/76°40'50"E. Photo: M. Kuhle 28.8.86.

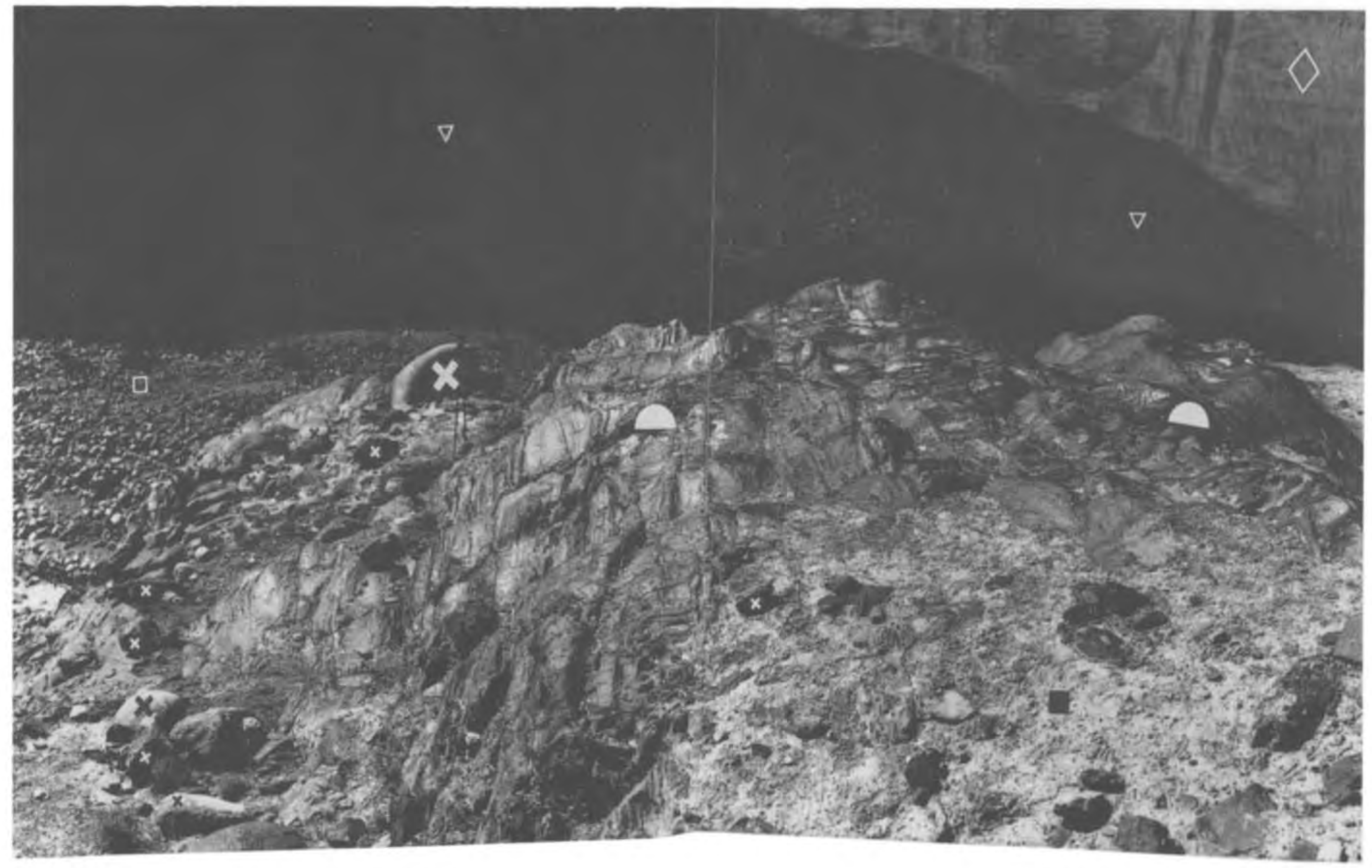


Fig 124 ▲
Glacially abraded, polished and rounded bedrock quarzite rocks (◓) in the orographic right-hand flank of the western Surukwat valley at 3700 m asl (Fig 138, No. 46). Affected by polishing and also by sub-glacial meltwater, the rock surfaces bear a ferro-manganese crust. In parts they continue to be covered by boulder clay (■) and more or less rounded polymict blocks (X). (□) marks the high-water bed of the present Surukwat river; (▽) shows fresh talus slopes, which have accumulated from material crumbling down the walls of glacifluvial drift terraces (♦). Viewpoint: 36°18'N/76°35'15"E. Photo: M. Kuhle 29.8.86.

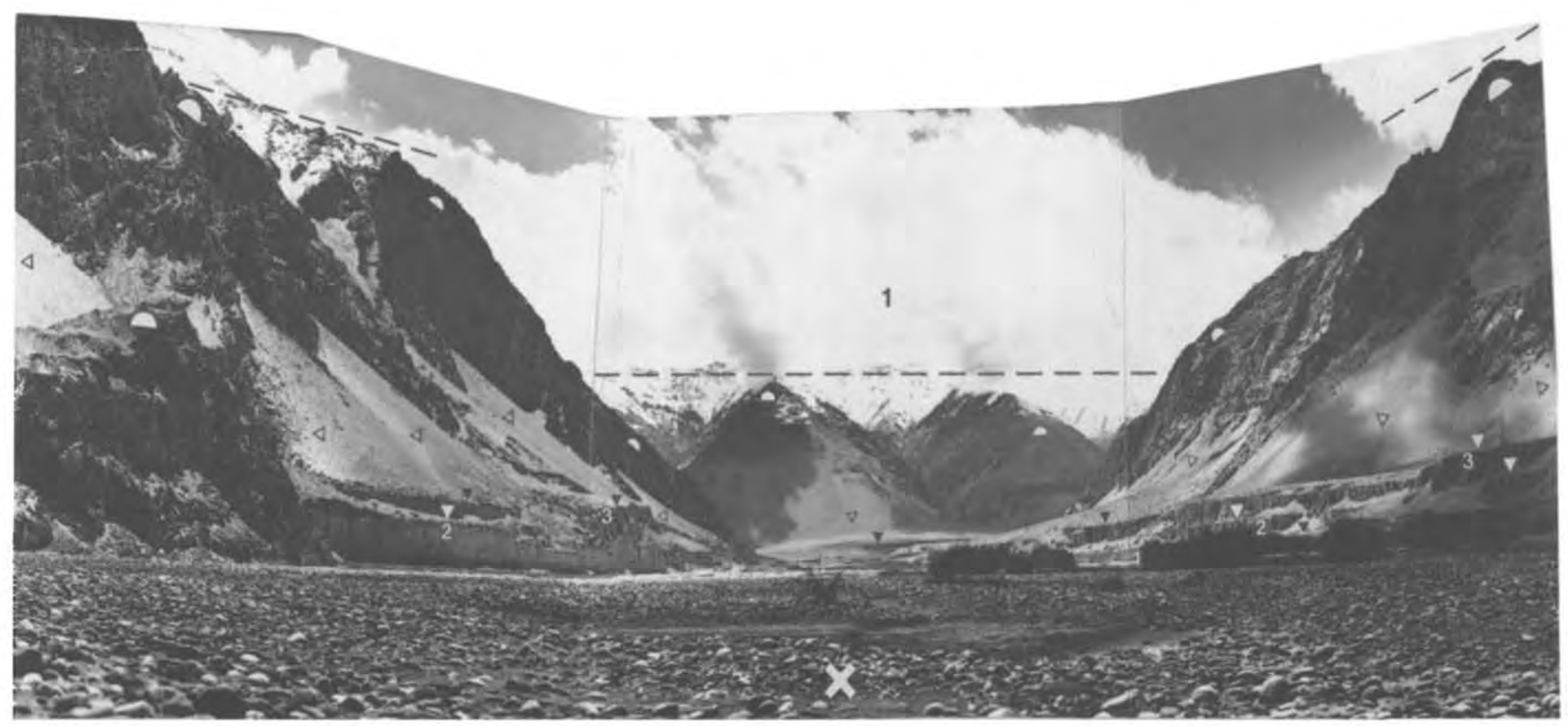


Fig 126 ▲
View from the present drift floor of the lower Surukwat valley (X) at 3450 m asl (Fig 138, between Nos. 33 and 49), facing S towards the Aghil mountains (near No. 1 = 5250 m-high crest ridge). ---- mark the surface of the prehistoric ice stream network. Glacially abraded up to more than 1000 m above the valley floor, the valley flanks (◖◗) of bedrock metamorphic rocks (phyllites) have been roughened by crumbling since deglaciation, and frost-induced talus slopes (▷▷) as well as detrital embankment, followed by terrace formation (▼ 2,3) have flattened and stepped its cross-profile. Viewpoint: 36°23'10"N/76°41'E. Photo: M. Kuhle 28.8.86.

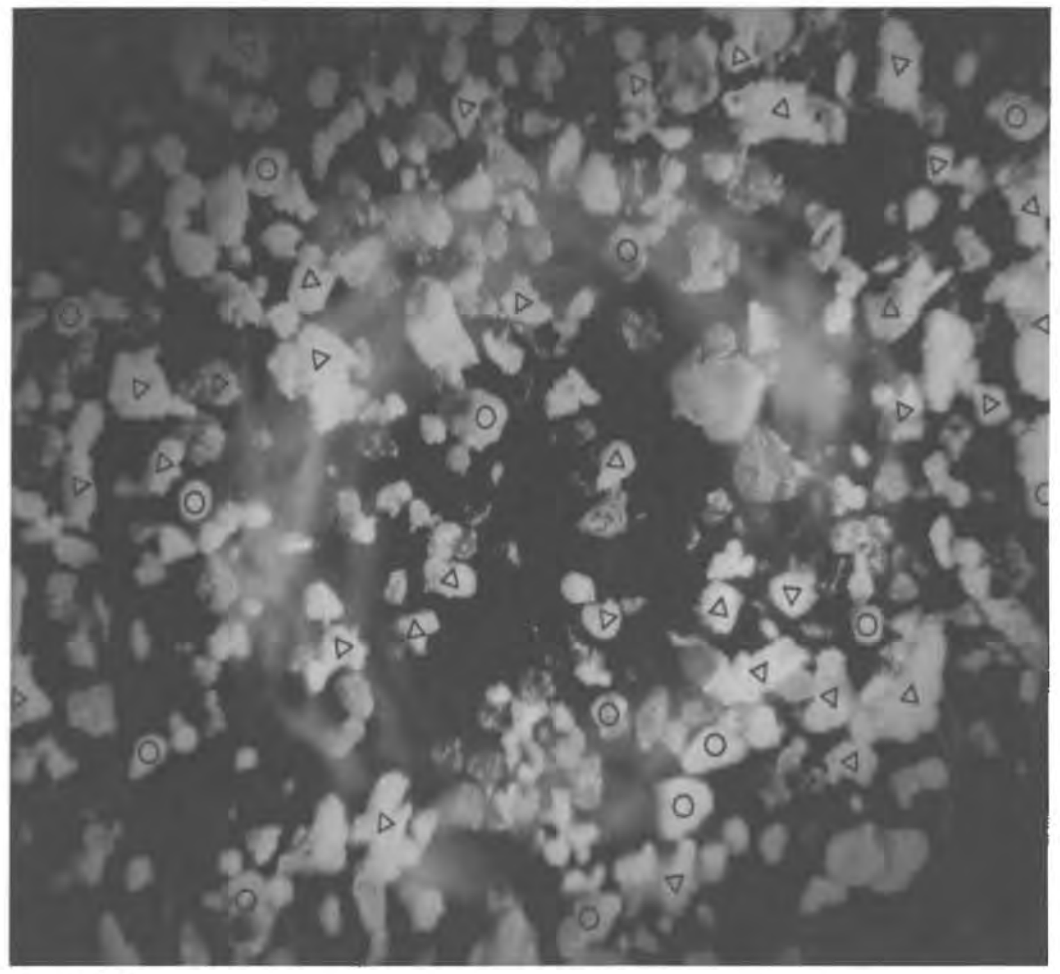
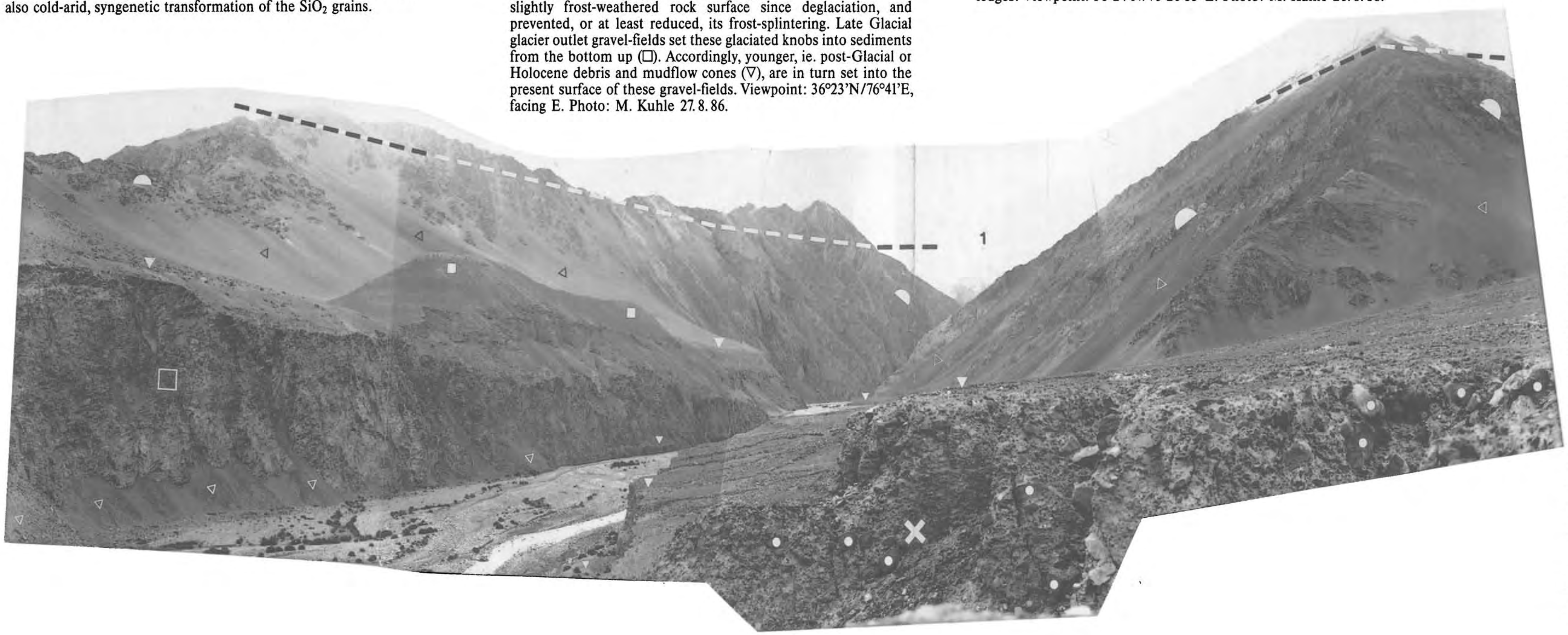


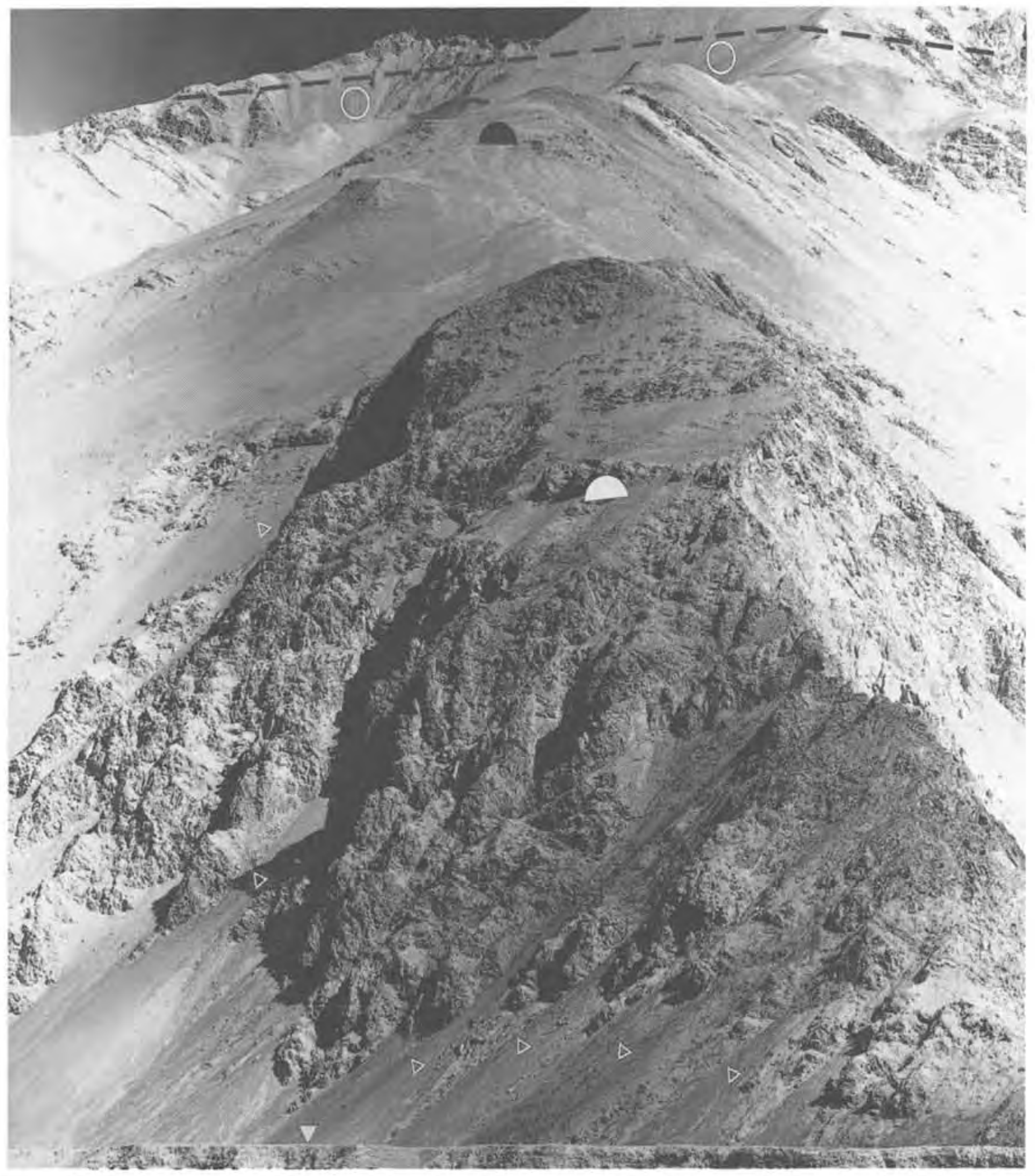
Fig 127 ▲
Microscope picture of the grains >63 μm from sample 17.8.86/1. The sample was taken from the major cone sander in the northern foreland of the Kuenlun mountains at 1480 m asl (Fig 138 ⌑ right-hand above No. 45). Cf. further analysis information in Fig 55 (curves 2 and 8), Fig 66 (curves 5 and 8), Fig 56 (17.8.86/2) and Fig 115 (○, 5 and 6). The morphoscopic analysis (Fig 56) (surface texture) of the quartz grain surfaces shows 75% dull aeolian grains (▽). The fact that, in spite of a glacifluvial distance of many tens of kilometres, the grains had to be transported, only about 15% of them appear to be fluvially lustrous (○) is evidence of the substantial aeolian, ie. here also cold-arid, syngenetic transformation of the SiO_2 grains.

Fig 128 ▲
Main to Late Ice Age glaciated knobs (▲) with preserved polishing (↓) in vertical pelitic metamorphites (phyllites). These glaciated knobs are in the confluence area of the Surukwat valley and the Yarkand valley (Fig 138, No. 33). Their surface is about 3580 m asl, approximately 100 m above the present gravel floor of the two valley bottoms (cf. Figs 99 and 42). Though shallow, the fluvially-formed plunge pools constitute evidence of the contribution to the rock surface formation made by sub-glacial meltwater (↓). The surface of the glaciated knobs continues to be partially covered by ground moraine (ꞌ). It has conserved the slightly frost-weathered rock surface since deglaciation, and prevented, or at least reduced, its frost-splintering. Late Glacial glacier outlet gravel-fields set these glaciated knobs into sediments from the bottom up (□). Accordingly, younger, ie. post-Glacial or Holocene debris and mudflow cones (▽), are in turn set into the present surface of these gravel-fields. Viewpoint: 36°23'N/76°41'E, facing E. Photo: M. Kuhle 27.8.86.

Fig 130 ▲
View from a rock wall fan (X) above the valley floor at 3800 m asl, looking SW into the orographic left-hand flank of the Yarkand valley (Fig 138, No. 37). Late Glacial moraines (■) lie on the exposed rock base of more or less horizontally-bedded sedimentary rocks up to 700 m above the valley bottom. They are topped by rock heads (◥) with abraded flanks, which have been formed above the snow line during the Main Ice Age. At that time the level of the ice stream network (- - - -) was at 5000 m asl, ie. 1200 m above the valley floor. Compare the levels of moraine and polish lines on the opposite (right) valley flanks shown in Figs 60 and 106. A snow-cut gorge (▽) dissects the confluence step, which forms the junction with an orographic left-hand side valley (hanging valley) from the 5880 m massif (Aghil). ▼▼ mark Late Glacial glacifluvial drift ledges. Viewpoint. 36°24'N/76°20'35"E. Photo: M. Kuhle 26.8.86.



◄ Fig 129
View from the area of the mouth of this orographic right-hand side valley of the Yarkand (Fig 138 left-hand, below No. 50) facing NNW up this side valley. No. 1 = 6136 m peak in the valley catchment area (Kuenlun). The valley floor is situated at 3750 m asl. Above it on the right there are two terrace levels (▼▼ centre of the photo), which are the work of two generations (X) of mur fans. Their substratum contains large, rough-edged, smooth-edged, and also rounded blocks (●●), which point to a formation from dislocated local moraine from the immediately adjacent small, second-order side valley (its junction may be found on the right-hand edge of the photo). (□) marks a rock base topped by glacifluvial drift material (▼) and kame-like moraine material (■). Above the talus slopes (▷▷), which mask the foot of the slopes, and are part of the present development of periglacial slopes of frost compensation, remnants of Ice Age flank abrasions and polishings (◥◤) are preserved in the crystalline bedrock slates (phyllites). (▲) on the left is a transfluence pass, leading over from the main (Yarkand) valley. (- - - -) marks an early Late Glacial polish line at 4750 m asl. Viewpoint: 36°24'25"N/76°48'E near Bazar Dara. Photo: M. Kuhle 27.8.86.



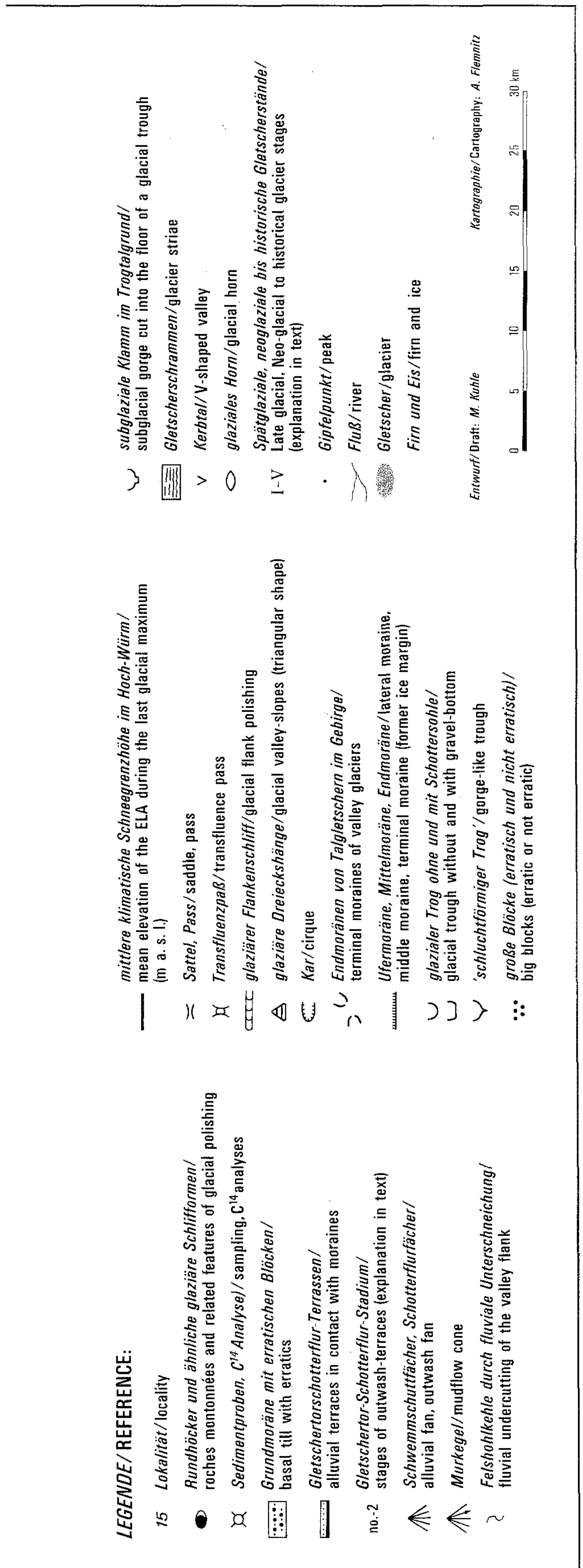
◄ Fig 131
View from the Mazar military station at 3800 m asl into the orographic left-hand flank of the Yarkand valley, towards the SE (Fig 138, below No. 39). At the bottom the terrace edge (▼) of a Late Glacial, glacifluvial drift floor (of a valley sander) can be seen. Formation and preservation of Ice Age flank abrasions and polishings (◓) varies according to the rock fabric: softer strata higher up experienced much more rigorous back-abrasion and back-polishing (below the upper ◓) than the layer edges of relatively resistent metamorphites at the base (◓ ■ below). Only at the harder strata associations do the slopes become steeper again (◓ above). ○○ mark Late Glacial corrie forms. Viewpoint: 36°26'10"N/77°01'E. Photo: M. Kuhle 21.8.86.

◄ Fig 133
For locality see Fig 132. View of the orographic right-hand end moraine of the "Pusha moraine valley" in the northern Kuenlun foreland, facing S up-valley (Fig 138, centre, between Nos. 43 and 44). The moraine ridges (■) reach relative heights of 400–700 m. The time of their formation must be described as polyglacial, since outlet glacier tongues, which repeatedly reached the Tarim basin in the course of several Pleistocene ice ages, contributed to it. The moraines consist of polymict, partly rounded and facetted blocks (of limestone, phyllite, crystalline slates), in part of significant dimensions (○). Isolated from one another, these blocks "swim" in a fine matrix. The moraine ridges carry a primary layer of loess, which is dissected by gully washings (▽). On particularly steep gully slopes the loess slips off in the form of more than one metre-thick "loess boards" (↑). At the gully exits at the foot of the slope, the down-washed secondary loess from higher up is sedimented in the form of shallow cones (●). Viewpoint: 37°18'N/77°07'E. Photo: M. Kuhle 30.10.86.

Fig 132 ▲
View from the floor of the "Pusha moraine valley" (cf. Figs 112 and 113) at 2000 m asl, facing S up-valley to the orographic right-hand lateral moraine (or median moraine, which is also the end moraine here) (Fig 138, centre, between Nos. 43 and 44). The point where the photograph was taken is on the glacifluvial ice cave drift floor terrace No. 4 of the Late Ice Age (Ghasa Stage I) (terrace of a sander which became canalized in the moraine valley). (■) marks the moraine of the Late Ice Age (Main Ice Age) (No. 0), which has been cut into by arid gully washing (▽▽). (For details see Fig 133). The sedimentation of these end moarines from the far-reaching W-Tibetan outlet glaciers, and those from the Kuenlun which advanced as far as the Tarim basin, took place with significant involvement of glacier meltwater, so that in many places kames from glacifluvial drift are incorporated into the moraine (↙) (see Fig 134). Viewpoint: 37°17'N/77°08'10"E. Photo: M. Kuhle 30.10.86.

Fig 134 ►
View from c. 2000 m asl into the orographic right-hand flank of the "Pusha moraine valley" in the northern foreland of the Kuenlun, facing SSW (Fig 138, between Nos. 43 and 44). Late to Post-glacial backward erosion during and since deglaciation has cut small and very steeply flanked side valleys (small gorges) into this moraine valley flank (■) which had been formed by moraine material. They allow the diamictite glacial material to be analysed (macroscopically) in the exposure detail. Several hundred metres high, the moraines are built up of polymict blocks, which had been deposited in a matrix of fine materials (○) (cf. Fig 133 ○ and ongoing text). In some places conditions for deposits result in a banking. Even interspersed glacifluvial (kame-like) material of drift and sand, which is sorted and stratified (↓), has been exposed. (↑) marks a typical break in the loess cover on top of the moraine, which allows a morphological insight into the thickness of particular primary loess strata. Viewpoint: 37°17'N/77°08'10"E. Photo: M. Kuhle 30.10.86.

Fig 138 Glacio-geomorphological indicators for the reconstruction of the maximum prehistoric glacier cover in the area under investigation by the 1986 expedition between the main Karakorum ridge and the Tarim basin. Design: M. Kuhle.



Tab 2, 20.8.86/2), also at 3740 m asl. The "Vale of Kudi", though a petrographically comparable granite catchment area, also shows a *predominance of coarse silt* of about 46%, which is similar to that in other deposits (cf. above), and due to the coarse-grained granite parent material. The essential difference consists, however, in the proportion of 20% of clay, indicating *still water sedimentation.* This sediment was deposited more than 1610 ±90 YBP ago (Tab 2, 20.8.86/2) - this being the age of the fluvial valley floor. Thanks to the presence of glaciers in the former and the present catchment areas, it is possible to interpret these gravel deposits as prehistoric "direct" and contemporary "indirect" *outwash gravel fields* (Kuhle 1983, pp. 336–339) (cf. Fig 58 □; 59 □).

4.4 Observations on the "6532 m-Massif" with Regard to Categorical Late Glacial Glacier Traces and Moraine Deposits in the Kuenlun S-Slope (Fig 138 No. 18; Main Peak: 36°27'N/76°52'E).

Fig 60 shows the 5610 m mountain spur (No. 2) south of the 6532 m main peak. The main peak is approached by the icy rock ridge further north (No. 1). Behind the ridge the most significant glacier flows down S from the glaciated mountain group, which currently covers a glaciated area of c. 8 x 8 km^2. Nourished by two small source branches, this 6 km-long glacier (measured along the main branch) now ends at about 5000 m asl. Three of the six more than 6000 m-high peaks of this massif are among its on average 5900-high catchment area. These figures allow an orographic snow line at 5450 m asl to be calculated for the Kuenlun S-slope. About 2 km down-valley from the 1986 glacier end a more than 150 m-deep, about 1 km-long, *glaciofluvial gorge* in monolithic granite sets in (Fig 61). Its talweg contour terminates down-valley at 4100 m asl. Above the glaciofluvial gorge there is a hanging valley bottom, which has been widened by glacigenic scouring; on its rocky floor coarse boulders are deposited almost to the gorge edge. The valley flanks rising from this floor beyond the glaciofluvial gorge incision have been smoothed and shaped in the way of glacigenically polished and abraded surfaces up to the crest at 4700 m. The valley bottom, into which the gorge has been cut by sub-glacial meltwaters, terminates at c. 4250 m asl, thus forming a 150 to 170 m-high *confluence step* to the main valley, namely the Yarkand. Adjacent to this steep step there are two *Late Glacial lateral moraine generations* (Fig 62 ■ IV, III; 138, No. 18) both 3.1 km away from the recent glacier tongue. The highest lateral moraine deposits occurring on both valley flanks reach up to 4340 m (Sirkung Stage IV). The older lateral moraine (Dhampu Stage III) sets in at 500 m down valley. Its glacier attained the *confluence* with the *main Yarkand valley glacier,* which continued to exist at that time as documented by terraces of lateral moraine on the orographic right at the corresponding level of the Yarkand valley (Fig 62 III, left). The moraines of tributary valley exits, moreover, show that the *late Late Glacial* glacier of the Sirkung Stage (IV)

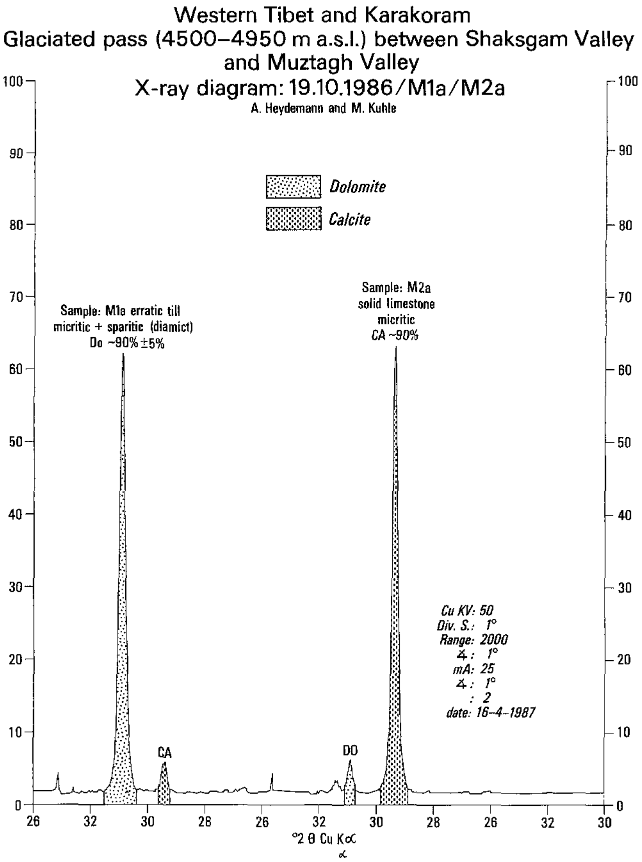


Fig 117 The erratic dolomite blocks and the dolomite scree (left peak) are mixed with up to 1.5 m-long mica-granite blocks (Fig 118) from the upper catchment area of the Shaksgam valley. The erratic dolomites lie on top of bedrock calcites (right-hand peak). The calcite rocks have glacigenically polished surfaces and the form of glaciated knobs (Fig 38 ▲). They are on the 4500 m-high Shaksgam-Muztagh valley transfluence pass (Fig 37 ▲ right, and Fig 51 ▲ right). Locality of samples: 36°05'N/76°28'E; Fig 138, No. 12).

extended down to 3750 m in the main valley floor (Fig 62 IV, left; 63 IV). The position of the ice margin, which had met with an already *glacier-free* main valley, is evidence of a *snow line depression* of c. 625 m (present glacier tongue end at 5000 m asl, the prehistoric one at 3750 m asl; difference 1250 m. 1250 : 2 = 625 m). This is an orographic ELA depression to c. 4800 m asl, and almost *half* the amount that can be proved for the *Main Ice Age* snow line depression (cf. Chapt. 6). The almost 200 m-high outcrop shown in Fig 62 (IV, on the right) presents the characteristic *banking structure* (■) of the *lateral moraine,* with a coarse layering in the upper parts, indicating the increasing *influence of meltwater* (▼). There is reason to believe that a *sub-glacial* incision of the gorge (Fig 61) coincided with the building of these Late Glacial moraines, since both gorge and moraines were situated more than 400 m *below* the snow line of the time. The lowest moraine section of the ice margin of Stage IV (Fig 63) shows the compact coarse boulder packing *without* layering or even banking; this is typical of *end moraine sedimentation,* ie of a deposit *without* any remaining major *glacier movement impulse.* Fig 63 (●) depicts large moraine boulders lying close to, or just a little above, the stream bed. The granite blocks are slightly *weathered* and are coated with *iron-manganese crusts,* with decimetre-deep finely weathered, yellowish-loam detritus in between. The incrustation with iron-manganese takes several hundred to several thousand years to develop. This is an indication that during the Holocene, re-depositing of material near the stream bed, or alternatively, by mud flows, must have been of *minimal importance.*

Another valley to be presented as belonging to the "6532 m massif", and draining S into the Yarkand valley, is the parallel valley to the E (Fig 138 No. 19). It has the form of a "gorge-shaped trough" (cf. Kuhle 1983, p. 155; 1991 b, pp. 1–8). Fig 64, taken at a distance of 3–4 km from the present glacier end, depicts the upper section of this increasingly - upward - narrowing gorge through which the Late Ice Age glacier had flowed. In 1986 the tongue was at 4850 m asl. Remnants of *neo-Glacial to late Late Glacial* moraines are found down to that level where the gorge passage begins at 4200 m asl. In the gorge passage itself *remnants of ground moraine* are preserved in situ in some cornices in the walls and in wall gorges (Fig 64 ■ and ∇ (right)). They consist largely of local granitic, coarse angular boulder debris. Glacigenic and slightly concave scouring of the gorge walls appears up to many hundreds of metres above the valley floor; this is the main feature of the *"gorge-shaped trough form".* Fig 65 shows the lower part of the gorge reaching down to c. 3800 m asl. Here, too, the valley is too *narrow* to be able to preserve end moraines indicating Late Glacial ice margin positions. There are none down to the trough bottom of the Yarkand valley (Fig 65, background), although in the W-parallel valley such moraines are preserved almost intact (cf. above). The ground floor within the gorge passage is some metres to decametres wide (Fig 64 □; 65 ●). It shows a representative mixture of present and Holocene *gravel floor (outwash) deposits.* During their passage through the narrow gorge they become channelized and receive fresh detritus from the autochthonous talus slopes (Fig 64 ◁ left; 65 ◁). Fig 66 Nos. 2 and 7, both show the cumulative grain size graph of the glacio-fluvial sediments with large *quantities of moraine.* The considerable proportions of fine sand and silt are attributable to the properties of the granite parent material. These samples, together with those from Fig 67/a and /b were taken from *glacio-fluvial* terrace formations 1.3 to 3 m above the present stream (Fig 138 No. 38), which are already showing more or less developed reddish-brown traces of weathering. The clay peak of sample 25.10.86/3 (Fig 67/b) is evidence of a proportion of a *fine moraine material matrix* purely fluvial material does *not* have. The datings listed in Tab 2 (25.10.86/1 and /3) are evidence of the recent age of this body of glacier mouth outwash plain of the "indirect outwash" (sander) type. The characteristic morphometry of fine grains can be gathered from Fig 56

(24.8.86/5) and 68: the considerable proportion (37%) of fresh and glacigenic transformed material with fractures and chattermarks on the grain surfaces indicates *glacier transport* and the supply of *fresh debris* in the gorge, whereas the dominant influence (63%) of *aeolian* processes confirms the aridity and absence of a meadow vegetation cover: the lower proportion of merely 2% of fluvial rounded and polished fine grains demonstrates the short distance they are transported (less than 10 km in this instance), which is typical of glacier mouth outwash plains (for sample localities see Fig 65 ↓ and 105 ↓).

4.5 The Post-Main Ice Age (Late Glacial and Holocene) Glaciofluvial Gravels and their Terrace Forms in the Skaksgam Valley, in the Yarkand Valley and in the Vale of Kudi (Fig 138, Nos 20–24, 30–32, 36, 40, 41 and 43).

The presentation of the following findings and data resulting from observations have *not* been drawn up as an end in themselves, but for the purpose of directing the attention to the *post-Main Ice Age* formation of outwash gravel fields. Following the presentation of the historic to Late Glacial inventory of glacial forms, this sub-chapter in a final section sets out to prepare the concluding introduction of the *maximal glacier infilling* of the mountain relief up to the northern forelands of the Kuenlun.

4.5.1 Loose rocks in the Shaksgam valley

The gravel floor of the Muztagh valley has already been described (Chapter 4.2). Four sediment samples from the level of historic to Late Glacial outwash gravel floor (Fig 36 X; 138 No. 10) on the orographic right between the junction of the Sarpo Laggo valley and the K2 valley are radiometrically dated (Tab 2, 15.10.86/1, 2, 4, 5). The samples were taken from altitudes between 3900 and 3950 m asl, and are evidence that no glacier can have been in this valley cross-profile between 730 ±100 and 12870 ±180 YBP any more. Any intermediate or subsequent overrun is *excluded,* since all the datable materials (peat and peaty-clays; Fig 74/c) are *soft loose rocks* which have been taken from *near the surface,* from a depth of only 0.2 to 1.2 m. In view of the *intensive exaration processes* (cf. Fig 43 and 50 ↓↓) set in train by the ground polishing of an ice stream several hundred metres-thick the loose rock could *not* have been *preserved.* The important conclusion to be drawn from this is that the Late Ice Age (and in any case the Main Ice Age) Muztagh glacier must already have *melted down* by 12870 YBP (cf. Chapt. 4.2). As has been mentioned above, the Muztagh glacier of Stage IV or III must have been the last one to pass this locality. This data basis *also shows* that, lying at roughly the same altitude above sea-level and drawing on glacier catchment areas at comparable altitudes, or even feeding on the prehistoric Muztagh glacier, the Shaksgam valley floor (Fig 138, No. 11) was *freed from* ice at approximately the *same time.* This is conclusive evidence that all the undisturbed loose rock material in this steep-flanked trough of the Shaksgam valley, in so far as they are not morainic but of glaciofluvial origin, must have been deposited after about 12870 YBP, and are thus *very young* (cf. Fig 27 □; 37 □ -6, 38 □; 39 ■ -6; 51 □ -6; 52 □; 52 a □; 69 ◆; 70 -6; 71 □ X ∇; 72 -2-6; 73 □; 75 □; 76 □; 77; 78 X; 79 ■; 80 ■; 81 X; 82 X; 83 ◆ -6; 84 □ ◆; 85 □; 116 □; 120 □; 121 -6). The present valley gravel floor has been laid down by the Shaksgam river. Every summer the floodwater arms resulting from the enormous *discharge of glacier meltwater* sweep across the present valley gravel floor over its entire width of c. 1 km (Fig 37 -6). Evidence of this exists in the form of an orographic left-hand *undercutting caveto* in the bedrock, about 2–4 m above the fresh gravel bed (Fig 75 ◀; 138 No. 20). This is a matter of lateral erosion on the *outer bank,* which is caused by the rise in the water level of c. 2m. Nearby Fig 76 shows the formation of a *basal rock socle* (■) below the cavetto (↶), thus indicating a development in three phases.

Phase one: the *gravel level* occurred c. 2 m higher than now, overlay the rock base (■), and the rock cavetto (↶) was subject to regular undercutting; Phase two: increased lateral erosion on the escarpment slope (undercut slope) led to denudation of the gravel floor, huts lowering the gravel level by c. 1 m and exposing the bare rock floor (■); Phase three: further lowering of the gravel level by another metre and undercutting of the rock floor, thus creating a small *rock terrace* or rock socle (Fig 76 ■). From now on, the upper caveto is only reached by *exceptionally* high floods; however, regarding the fresh smoothing of the rock, such floods are not *rare* (Fig 76 ◀) – these *seasonal* peaks of meltwater run-off from snow and ice occur between May and the beginning of August. During our 1986 expedition the hydrological data of the Shaksgam and the Yarkand valley were collated and examined by Professor Feng Qinghua (Feng Qinghua 1991, pp. 255–263). The lateral erosion diagnosed above in the bedrock of the Shaksgam valley had at the same time also been undercutting all the *talus fans* and *mudflow cones.* This led to steep terrace steps and rock slide faces, both tens to hundreds of metres high (Fig 27 □ above; 37 □; 39 ■; 52 □; 69 ◆; 71 X; 72 □; 73 □; 77 ➘; 78 X; 79 ■; 80 ■; 81 X; 82 X; 83 ■; 85 ■). *Besides* the meltwater discharge within the normal seasonal cycle, there are occasions when substantial *glacier lake outbursts* lead to movements on the gravel floor of the Shaksgam valley over its entire breadth, and to such *undercutting* of adjacent loose rock material.

4.5.1.1 An excursus concerning the hydrology: the Shaksgam floods induced by meltwaters and glacier lake-outbursts

The cause of these outbreaks are the 21 km- and 28 km-long glacier tongues of the Kyagar- and Teram Kangri glacier, which advance as far as the Shaksgam valley. Both act as *glacier lake dams* (Fig 138 right below No. 47; Fig 70 below Nos. 6, 5, 8, 3). The Kyagar glacier lake sends regular discharges through a *sub-glacial* meltwater tunnel, the Teram Kangri glacier lake chiefly discharges on its margins but also has a subsidiary, sub-glacial escape route in an ice tunnel (cf. the studies concerning hydrology carried out by Feng Qinghua 1991, pp. 258–263 in the course of the 1986 expedition: "These glacier outburst floods in the Shaksgam valley [Yarkand river system] are characterized by high peak discharge, big rising rate, relatively small total volume and short duration" [as above p. 263]). The nearest hydrographic measuring station is situated at Kagun, far below the junction of the Shaksgam with the Yarkand (1420 m asl; 37°59'N/76°54'E in the northern Kuenlun foreland, leading down to the Tarim basin. The *great distance* (520 km) from the positions of these episodically-discharging glacier lakes is the reason for some of the actual run-off being lost for measurement. Sixteen floods due to *glacier lake outbursts* were observed over the period 1954–1984. They regularly took place from summer to early autumn (June to October). The floods tended to reach run-off peaks of 2000–3000 m^3/sec. On three occasions, lastly in 1984, it rose to 4500–4700 m^3/sec. The highest run-off peak, recorded in 1961, was 6270 m^3/sec. Normal summer *meltwater peaks* registered during the same period varied between 1000 and a maximum of 2220 m^3/sec, with the year of the 1986 expedition seeing the second highest discharge ever measured during the 32-year period of observations standing at 2000 m^3/sec. The *glacier lake outbreaks* produce *flood volumes* of 0.19×10^8 m^3 to 1.5×10^8 m^3, which is about 1/10 of the comparatively continuous annual run-off. In order to give an idea of the *morphodynamic potential* for the Shaksgam valley floor, or the undercutting of its edges, the mean "rate of flood travel" of 11.1 to 16.6 km/h is also significant, although the highest flood discharge peak did *not always* coincide with the greatest velocity. Nonetheless, it is possible to note a general *increase in speed, together with water quantity.* The mean water volume of the Shaksgam river throughout the year is calculated to be around 130–150 m^3/sec. The erosion module for the entire area eroded by the Yarkand system is stated by Feng Quinghua (1991, p. 262 Tab 8) to be 1260 t/km^2/year. As far as *glacier lake outbursts* are concerned, one must imagine the discharge of two lakes with a maximum of 3.23×10^8 m^3 (Kyagar dammed glacier lake on the Shaksgam valley floor at 4760 m asl) and 1.92×10^8 m^3 (Teram Kangri dammed glacier lake on the Shaksgam valley floor at 4520 m asl). The lakes were dammed back by respectively 60- and 90 m-high and 0.3- and 1.5 km-long ice dams, which the glacier tongues had formed. These lakes drain within a few hours, so that the actual passage of the flood wave through the valley takes about 18 to 22.5 hours.

4.5.1.2 Large young mud fans, debris slopes, alluvial fans and terrace remnants in the Shaksgam valley and their mutilation: an example of diametric, syngenetic morphodynamics in the Karakorum

It has not been possible to provide unequivocal evidence of the maximum level of run-off reached during a dammed glacier lake outburst, but 4 metres above the normal flow level per 1 km of valley width are *probable; considerably more* is to be expected in areas of narrow, *bottleneck-like,* parts of valleys. This is, however, the place to draw attention to the Myricariae bushes in the foreground of Fig39. Only 1-2 m above the receiving stream (though in the recess of an inner bank), they were nevertheless not swept away entirely with roots and all, but were able to recover after the flood on August 30th, 1984. The problem remains unsolved. The question of the *water-level* does not really affect the effectiveness of the process of *undercutting* these large cones and fans (Fig 27 □; 37 □; 39 ■; 52 □; 69 ♦; 71 X; 77 ➘; 79 ■; 82 X; 85 ■). In every case it amounts to a retreat, which, starting at the *distal base,* continues right to the top in the form of these crumblings on the edges of cones and fans (Fig 77 ➘; 78 X). The importance of undercutting can be *directly* assessed from these crumbling masses: metre-high and very fresh (one year old) *debris piles* of material from the steep cliffs above have accumulated at the foot of gravel- or debris-cliffs. They are removed by summer floods or glacier lake outbursts (Fig 27 ▽; 52 ▽; 78 ▽; 79 ▷; 82 ▽). At times the steep gullies and "organs" in these escarpments produce small special debris cones or fans, which are only a few months (Fig 81, below X) or a few years old (Fig 80 below ■; 27 between □▽□). Corresponding special cones also emerge from gravel and debris caves (Fig 82 ↓) in karstic dolomite debris. In any case *all* these *tributary* debris infillings, from steep tributary valley gorges or wall gullies, are characterized by substantial *distal* transformation (Fig 37 □; 73 □; 78 X; 80 ▽). The *height* of the debris- and gravel cliffs present a measure (Fig 69 ♦; 77) of their considerable intensity, as this is the *equivalent* of the degree of *mutiliation* of these accumulations in their *ground plan,* and at the same time for the considerable removal of *masses or cubatures.* In the face of such *denudation dimensions,* the observation becomes more important that these cones and fans are nonetheless actively *engaged in formation.* In early summer the snow melt causes mudflows and sediments from mountain torrents to be deposited on the floor of the Shaksgam valley, from which they are *syngenetically* removed. These accumulations consequently present *stable* forms at the *peak of their development.* Supposing that such ruins of cones and fans are stable, the processes of *synchronous* aggradation and degradation become the direct expression of *extreme morphodynamics* in this longitudinal valley of the Karakorum (Fig 84, right-hand side of the photo). In extreme cases the fresh escarpments of cones and fans reach heights of 100 to 120 m (Fig 27; 39; 69; 77; 82; localities: Fig 138 Nos. 20–23), though having been deposited against the Shaksgam glacier (cf. below) many began their development as *kames,* and therefore possessed escarpments from the very start. There is no doubt that the mudflows and alluvial fans mentioned above are the most striking forms, since they constitute the most significant post-Late Glacial (younger than 12870 ±180 YBP, Holocene) debris deposits laid down in the Shaksgam valley. They tend to be *autochthonous* or rather deposited directly in the mouth of short tributary talwegs. But there are also gravel terraces which have built up along the valley and are preserved at three different levels at least, namely at 20, 60–40 and 120 m above the present gravel floor of the Shaksgam river (Fig 72 -2; 73 -1 bottom right; 37 -0; 138 No. 20). The lowest and most recent level is represented on a larger scale (Fig 51 -2; 52 -2; 138 No. 11) in the junction of the Muztagh valley, as well as SE of the mouth of the "southern Aghil pass-valley" (Fig 70 -2; 138 No. 22), whilst minor remnants of the 40–60 m terrace (still reaching 60 m here) have been preserved in this valley chamber of the Shaksgam valley on the orographic left (Fig 70 -1; 138 No. 24). Another minor example of this 40–60 m terrace has been preserved a little further down valley, again on the orographic left in the area of the junction of the two still glaciated Karakorum gorges (Fig 83 on both sides below No. 7), which run down to the Shaksgam valley from the S (Fig 83 -1; 80 -1; 79 -1; 138 No. 23). Deposited from the glacier outlet positions of three Holocene stages of *Shaksgam glaciers,* these three *gravel floor terraces* are classified as Nauri Stage (V), older Dhaulagiri Stage (VI) and middle Dhaulagiri Stage ('VII) and are numbered -0, -1, and -2. In accordance with the nomenclature for High Asia, which is applied here (Kuhle 1982, p. 118), the assignment of moraines (numbering on the left) to glaciofluvial gravel floors (numbering on the right) is as follows:

Main Ice Age	0 – No. 5	Older Dhaulagiri Stage	VI – No. -1
Ghasa Stage	I – No. 4	Middle Dhaulagiri Stage	'VII – No. -2
Taglung Stage	II – No. 3	Younger Dhaulagiri Stage	VII – No. -3
Dhampu Stage	III – No. 2	Stage	VIII – No. -4
Sirkung Stage	IV – No. 1	Stage	IX – No. -5
Nauri Stage	V – No. -0	present glaciation	– No. -6

The fact that terraces set in in the Shaksgam valley is evidence of the maximum Holocene extent of the Shaksgam glacier. The glacier stage concerning the gravel floor terrace -1 (Fig 70 -1) is to be classified as the Older Dhaulagiri Stage (VI), and terminates at a maximum distance of 15 km from the lowest glacier tongue, that continues to reach the Shaksgam valley (Gasherbrum glacier tongue, Fig 83, visible in the background below No. 1 on the left). At that same time the three large Shaksgam glaciers further up-valley - the Kyagar-, Teram Kangri- and Urdok glaciers - were still flowing into the Gasherbrum glacier, being the one with the lowest tongue end position. The same applies to the outward-lying Skyang glacier. Together the glaciers formed a *dendritic valley glacier system, verging* on a minor ice stream net. It follows that, belonging to the Middle Dhaulagiri Stage 'VII, terrace -2 extended some kilometres *further up valley* than -1, where it reached the *next younger* glacier outlet of this glacier system. The lowest remnant of terrace -2 reached by the author is shown in Fig 83 (-2) (cf. Fig 70 -2). Fig 37 shows the *most up-valley* terrace remnant of a glacier mouth outwash plain -0 in its topographical context. The distance to the *present* Gasherbrum glacier end is 35 km (Fig 138 No. 20). The *next older,* and therefore *higher,* terrace of a glacier mouth outwash plain must be assumed to be *down-valley* from the junction of the Muztagh valley. In accordance with the nomenclature which has been introduced here, it must be numbered 1, as it belongs to the Sirkung Stage IV, the last *Late Glacial* glacier position. Older than 12870 ±180 YBP, this stage must have had a much more depressed ELA than all the other Holocene stages, the most powerful advance of which had been the neo-Glacial Nauri Stage V (c. 4000–4500 YBP). The terrace -0 mentioned above is part of it. Regarding the development of both the Muztagh glacier and the Shaksgam glacier during the Sirkung Stage IV, it follows that a confluence of the two ice streams to a joint superior *Shaksgam glacier system* is also likely in view of the absence of terraces No. 1 in the confluence area (cf. Chapt. 4.2). Up to the terrace remnant No. -0 furthest up valley (gravel floor of the Nauri Stage V) in the Shaksgam valley at 3900 m asl there is an altitudinal difference of 400 m, and thus an *ELA difference* of 200 m (ie 400:2) from the present Gasherbrum (Shaksgam) glacier end at 4300 m asl. Fluctuating between 240 and 560 m, it thus fits into the pattern of neo-Glacial ELA depressions which can be observed in many places in High Asia (Kuhle 1987 c, p. 205 and 1986 e, pp. 441–452; Shiraiwa & Watanabe 1991, pp. 404–416). According to this, the *depression value* of c. 200 m for the Nauri Stage V is on the *low side;* it is explained by simultaneous *important glacier elongation* of almost 35 km (cf. above), resulting in *enlargement of the surface,* which may have replaced *part* of the vertical descent of the glacier tongue by the increase in its ablation.

The presence of gravel floor terrace remnants must not lead to the conclusion that the up-valley Shaksgam valley glacier occupied the valley over its entire breadth, nor that all the alluvial debris fans and mudflow cones are younger than the particular glacier stage in which the valley cross-profile in question was still reached by the glacier. This applies particularly to the progessively lower and relatively young outwash gravel floor terraces (-1 and -2) further up valley. On the contrary, by being laid down against the body of the valley glacier as a base, these fans and cones were *syngenetically* deposited as *kame formations.* This approach allows the entire period to be available for the formation of all these *very substantial* and *thick* formations of fan and cone forms in the Shaksgam valley (Fig 27 □ above; 37 □; 39 ■; 69 ◆; 71 X; 73 □; 77; 82 X; 84, right half ▼ inter alia) during which the surface of the valley glacier in particular valley cross-profiles clearly remained *below* the snow line. This was just the case during the youngest Late Glacial period, or, in the case of the Shaksgam valley section in question, the floor of which now stands between 4000 and 3850 m asl (Fig 138 between Nos. 22 and 20) approximately during the Sirkung Stage IV. The idea of such a prehistoric process of sedimentation using the valley glacier ice as a base is supported by the above-mentioned observations from the bank basins (margin valleys) of the K2- and Skamri glacier (Chapt. 4.1.1.). Where ever the glacier tongues leave out a relatively wide *bank basin* or an *ablation gorge* - as a rule on *one* valley side only; on *both* sides only in the vicinity of the tongue end - the space between valley flank and glacier margin is infilled by debris cones and talus slopes from the immediately adjacent valley slopes, and by mudflows and alluvial fans from the tributary talwegs (Fig 10 ▷ far right; 12 ▽; 14 X; 16 ◆; 23 a ■; 28 ▽; 30 ▽; 34 x; 35 ▷; 47 ▽). On its ENE bank the Shaksgam glacier developed a *wider* area of bank basins in which those fans and cones were *syngenetically* filled. It is the WSW-facing side of the valley which, thanks to its *exposure to radiation,* has thawed out more (Fig 39 ■; 69 ◆; 71 x; 82 x). In the area of the tributary gorge exits on the orographic left-hand side of the valley, *kame-like* alluvial debris fans (-1) could not be accommodated before the older Dhaulagiri Stage (VI) (Fig 79, 80 and 83 -1). This is the reason for the exposure of *material from lateral* and *ground moraine* over long distances at this flank. The form of the moraine has *not* been preserved because it is covered by small debris cones and debris talus which accumulated from above (Fig 83 ▽, centre third of the photo 84 ▼ right half). On the other, orographic right-hand, valley side moraine material *from the same period was deposited against* the intermediary cones and fans; this, however, took place in a position (on the outer bank) which was exposed to a later Shaksgam river, so that moraine material of such recent origin has *not* been preserved. Markedly older - ie in this case *Late Glacial* - morainic material (Sirkung Stage IV and earlier) - belongs to a considerably *wider* Shaksgam glacier: that fact explains why, in some places, corresponding *ground moraine material* (basal till) can be found at the *base* and in the *core* of fans and cones (Fig 81 x; 82 x; 85 ■). Cones and fans consequently began to develop on the orographic *right* (Fig 138, from No. 22 to No. 21) - though further down the valley on the *left* side as well, where 5 to 10 km *down the glacier* a bank basin developed at the same time (Fig 73 □; 138 from No. 23 to 12). As *deglaciation progressed* and the ice receded, they spread out over the ground moraine. It follows that their formation *began* when the ELA was raised above the level of the glacier surface of particular valley cross-profiles. When the snow line was noticeably lower than now, the construction of these *kame-like lateral glacial margin accumulations* was initially most actively intensified by the intervening layers of glacier, firn and eventually snow in the catchment areas of the tributary valleys, gorges, and wall gullies (Fig 27 O; 37 O; 69; 80; 84 below No. 2). Activities on the orographic right-hand flanks of the Shaksgam valley have meanwhile largely been reduced to the seasonal melting of snow (Fig 37 O left), whereas on the orographic left the N-facing Karakorum hanging glaciers in the heads of tributary valleys continue to be effective (Fig 80 and 83 on both sides of No. 7). Besides the large fans and cones which were first started in *late-Late Glacial* times as kame-like bank formations and continue to develop through current glacifluvial undercutting, much *more recent* debris fans and debris cones can be identified as well. Fig 72 provides an example for this: small, recent as well as larger debris cones (▽) have been set into the outwash gravel floor terrace -2, and must therefore be younger than c. 2000 YBP. The older gravel floor terrace -1, together with material from older ground moraines, has been removed from this outer bank *before* the sedimentation of -2 began. Further down valley, the adjacent alluvial debris fan (□) shown in Fig 72 must be *even younger* than terrace -2, since it has been deposited in the denudation space previously occupied by terrace -2, which had been placed in front of the junction of a tributary valley. Set into its surface, the larger debris cone contributes, albeit on the margin, to the covering of terrace surface -2 (▽ above □). This cone is therefore bound to be still younger than the alluvial debris fan (□). Its comparatively large size can be explained by the size of the wall gorge with its high-rise catchment area (↓).

The question of the *overall thickness* of debris fillings and gravel floor, which is showing the most recent glacio-fluvial traces on its surface, ie the thickness of loose material in the present valley floor (Fig 84 ◇ □; 85 □ ■), can only be answered *vaguely.* Judged by the *steeply flanked* trough form (Fig 116 □), or by the *obtuse angle* formed where the *box-shaped* insert of the gravel floor meets the trough flanks (Fig 120 □), the valley floor of the Shaksgam should lie *several hundred* metres below the corresponding thickness of loose material (Fig 37 □ -6; 39 -6; 71 □). It is doubtful whether the loose material consists solely of weathered detritus and gravel. Rather more likely are insertions of ground moraine layers from the Early Glacial, Late Glacial and Main Ice Ages (cf. below). Regular post-Main Ice Age *gravel infilling* during deglaciation, which can be observed in these longitudinal valleys of High Asia, has only been partially reversed by Late Glacial to Holocene incision (cf. above), and argues for the fact that both the *moraines of several* Pleistocene *ice ages* and gravel from intermediate *inter-glacial periods* have filled the Shaksgam trough.

4.5.2 Loose rock in the Yarkand valley and its tributaries

"The N-Aghil pass-valley" or upper Surukwat valley N of the Aghil pass (36°10'–17'N/76°32'–40'E; Fig 138 No. 25) visited by the 1986 expedition belongs to the upper catchment area of the Yarkand valley. The 4863 m-high Aghil pass forms a flat valley-head (Fig 86 ⌒; 87 ⌒). This valley-head area has not been reached by glacier ice since at least 1655 ± 180 YBP (Tab 2, sample No. 20.10.86/1), though the sample locality, which suggests the *absence* of glacier ice, is situated 140 m N *below* the pass culmination (Fig 87 O). The age of the sample affects the position *near the talweg.* This had been previously reached by the *tongue ends of hanging glaciers,* which flowed down from the good 6000 m-high Aghil main ridge to the W and E. Minor hanging glaciers and firn shields *continue* to be present on the E and W exposition of the two valley flanks (Fig 86 below - - - -; 87 near the bottom left-hand margin and in the centre; 88). The sample was taken from an erosion edge of the present meltwater stream (talweg of the upper Surukwat valley, N of the Aghil pass; Fig 138 No. 25). It had been uncovered by thawing permafrost. The *permafrost table,* too, is evidence of the *climatic proximity* to glaciation in this location. In the light of what has been said above, it is possible, though not certain, that glacier ice was still reaching this valley cross-profile during the older Dhaulagiri Stage VI (c. 2400-2000 YBP). It is, however, certain that the *outwash cone* (gravel floor) of the glacier of that stage was deposited here. This implies that the valley cross profile was probably last reached by the glacier end during the *neo-Glacial* Nauri Stage (V). There is another sample locality somewhat further down valley (Fig 138 No. 26), close to the talweg at 4630 m asl (Tab 2, sample No. 20.10.86/3), which must have been free from ice since at least 6205 ± 145 YBP (Fig 87 ↓↓↓). In accordance with the age of the peat on the *outwash cone* (glacio-fluvial gravel floor), the latter is to be classified as belonging to the early Holocene or late Late Glacial period. In the same locality, and again above the permafrost level, more recent and cover-forming outwash cone material in an overlying peat-horizon can be *dated as at least* 355 ± 80 YBP. It is likely to be from the middle or younger Dhaulagiri Stage ('VII or VII), ie to be less than c. 2000 or 440 YBP (Kuhle 1987c, p. 205 Tab 2). The analyses (Fig 57a/b/c) show that the three samples (20.10.86/1/2/3) are directly *glacially-induced* sediments consisting of a mixture of granite and limestone debris with another fine grain-size peak with the clay fraction, which is typical of moraines (Vagners and Dreimanis 1971). The area down-valley from the upper Surukwat valley (Fig 88; 89; 90) has consequently been free from ice for more than 6200 years. Since deglaciation during the late Late Glacial period (Sirkung Stage IV) its valley floor has been filled by *gravel-fields* (Fig 88 □; 89 □◇) from the adjacent small valleys as well as from younger *mudflow cones* (Fig 88 ○; 89 ○; 90 ○). The *highest*, ie *late Late Glacial*, lateral moraines are preserved at 4300 m asl on the orographic right (Fig 88 ■; 138 No. 27). They are classified as Sirkung Stage IV, and belong to a *snow line depression* of c. 500 m (at present, the lowest ice margins occur at 5200 m asl, IV ice margins at 4200 m asl ⇨ ELA depression of 500 m). Here there are both *lateral moraines* with crests (◆) and *kames* which, being glacigenic lateral formations, left behind *kame terraces* (■). Fig 91 provides an insight into the next lower valley chamber where the above-mentioned upper Surukwat valley, leading down from the Aghil pass, joins a western source branch of this valley system. The valley floor consists of interlocking *gravel-fields* or *outwash cones* (–2 to –6) of *historic* to *present* glacier ends of this catchment area (Fig 138 No. 28).

Developing approximately since the middle Dhaulagiri Stage 'VII, ie for c. 2000 years, these gravel-fields (–2 to –6) possess terrace steps up to 12 m high (■). In places where the valley floor drops below the 4000 m-line, very thick *Late Glacial* gravel-fields, which by dissection are transformed in terraces, take over *abruptly* (Fig 92 Nos. 3, 2, 1; 138 No. 29). They are superimposed by more recent *local moraines* from small, steep hanging glaciers of directly contiguous catchment areas (Fig 92 ■). Further up valley, at 4000 m asl, these gravel-fields dovetail with *Late Glacial main valley terminal moraines,* which must be classified as Dhampu Stage III (Fig 138 No. 29). Three distinctly separate terrace levels can be discerned (Fig 92); No. 1 belongs to the Sirkung Stage IV, representing the youngest level and lying 50 m above the present talweg. No. 2 (Dhampu Stage III) reaches c. 130–140m, and No. 3 (Taglung Stage II) 200–260m. The two older, ie higher, terraces in particular consist of glacio-fluvial gravel deposits and re-deposited gravel, with even *older moraine material* (from the Taglung Stage, and before) worked-in or washed-out by the activities of *outwash cones* near the lateral ice margin (Fig 92 ↓ inter alia). The picture shown in Fig 92 was taken from a ridge of outcropping slates, which juts out abruptly towards the middle of the valley, followed by a glacigenic *ravine-like,* narrow and steep passage (Fig 138 No. 46) of the Surukwat bottom contour line.

Interspersed with several metre-high cataract steps it shows *potholes* in the rock-floor of the talweg and on its flanks, suggesting a *sub-glacial* formation caused by hydrostatic meltwater pressure. Since their formation requires a rise of the ELA *beyond* the 4000 m line, the *Late Glacial Period* of our chronology is the *only* one possible. Down valley the ravine-like, steep and narrow passage – which could be interpreted as a Late Glacial *ice margin position* – the now even richer *glacio-fluvial gravel deposits* continue in the form of terraces up to 300 m-high (Fig 138, Nos. 30, 31). The highest terrace begins with a steep surface incline (Fig 26 ▽ No. 3), which subsequently flattens out (Fig 22, No. 3). The enormous glacio-fluvial infilling of the W-Surukwat valley begins here, at 3750 m basic height asl. The greater part of its gravel bodies belong to the Late *Glacial period*. All in all eight generations of terraces can be discerned (Fig 22 ▼▲). The lower terraces, only a few metres to decametres-high, are younger. They belong to the post-Late Glacial period, and were deposited in a *deep* erosion incision (Fig 22 Nos. –5 to –0) in the form of thin gravel *bands* or gravel *field segments*. The incision had been created in the Late Glacial gravel deposits by the meltwater discharge of the melting remnants of the Late Glacial ice stream net (Fig 22, Nos. –5 to –0). A *typical* feature of glacier outlet gravel floors (valley outwash) canalized by a valley is the rapid *loss* in sediment thickness and the vertical displacement these terraces experiences on their way down the valley. Over a distance of 10 km, their heights, whilst retaining their *proportionality* to one another, thus decrease to *less than half* (Fig 22, cf. No. 3 on the far right with No. 3 on the far left, cf. 26 No. 3 with 94 and 95 No. 3). The *same* glacio-fluvial terrace sequence occurs (Fig 22 ▼▼, far left; 95 Nos. 1–3 left) in the opposite, eastern, source branch of the Surukwat valley, which is five times longer than its western counterpart (Fig 138 No. 32). The gravel body likely to be the oldest one (Fig 22, far right, at the base of terrace section No. 3), has been TL-dated at its base as approximately 12 Ka (dating by E. Drosdowski, Torun Academy, and S. Fedorowicz, TL-Laboratory, Gdansk University). In this valley very well preserved *glacier striae and polishings* (Fig 40, 41, 93, 124) have been found *below* the level of the gravel terrace surfaces, at locally exposed outcropping valley flank surfaces on the orographic right

(Fig 138 No. 46). These polishings must consequently be classified as older, ie as belonging to the *older Late Glacial* to the last *Main Glacial period* (cf. Chapt. 5.3). It is highly likely that a large part of such striae is *buried* under these gravel deposits. Over the 5 km stretch from the confluence of the two Surukwat source branches (Fig 95; 126 background) to its junction with the Yarkand valley, the Surukwat valley shows continuations of the *glacio-fluvial* gravel terraces (cf. Fig 96 ▼ No. 3; 126 ▼ Nos. 1-3). These forms appear as steps on three levels, and dove-tailed with *mud-flows,* which are in consequence also part of the *middle - to late -* Glacial period (cf. above) (Fig 97 ▼ Nos. 1-3). Here, on the lower Surukwat valley and in its continuation down the Yarkand valley, the maximum terrace height (No. 3) decreases to c. 100-80 m (Fig 98 ▼ No. 3). In this area there are outcrops of thin strata schists (mica schists). The glaciated knobs of the Yarkand valley, which are formed in these rocks of the Main to early Late Glacial period (Ghasa Stage I) are partly buried by sediments (at times up to half their height), ie covered by gravel (Fig 138 No. 33; 96 ▲; 98 ▲; 99 ▲; 100 ▲; 101 ▲ left). In the ensuing down-valley section of the Yarkand valley, the oldest terrace areas take up a strikingly large amount of room (Fig 98 □ right, No. 3) and have been preserved over almost the entire width of the valley. This is explained by the fact that the river was confined by a gorge. From this point a *glacigenic ravine* has been cut into the rock threshold with the aforementioned glaciated knobs (Fig 102, 96 ↑). This ravine lies at 3400 m asl (Fig 138 between Nos. 33 and 34), and thus *so far below* the Late Glacial snow line that *sub-glacial meltwater* was able to form and carve out this cut in this area, though the valley glacier surface was much higher at the time. The glacier retreat from the valley cross-profile was *initially* followed by glacio-fluvial infilling, and subsequently, when the Surukwat river cut into the valley floor, by its removal. From now on, the river followed the ravine; it was therefore confined to this narrow valley floor section, with the result that these *further* terrace areas remained intact. In this confluence area the Yarkand river, too, has been similarly confined by a ravine (Fig 138, No. 34). Here it passes through an extremely narrow trough profile (Fig 99, middle section of the photo).

From here, and over a distance of 40 km up the Yarkand valley (10 km beyond the Mazar military station, till No. 36 in Fig 138), the valley floor infilling with gravel terraces remains conspicuously small by comparison with the Surukwat valleys (cf. Fig 105 ▼, 110 ▼). They are only partly preserved in this valley, and their thicknesses do not exceed a few decametres (Fig 60, 103 and 104 ▼). The late *Late Glacial* gravel floor deposits dovetail with *alluvial fans* and *mudflow cones* from adjacent steep tributary valleys and from valley flank gullies, or have in part even been transformed or replaced by them (Fig 138 Nos. 35 and 36; 105, O). The mudflow cones and fans tend to be noticeably younger rather than of comparable age (Fig 109, O). Predominantly from the *Holocene,* they *continue to develop* (Fig 106 x, 107 x, 129 x). The two largest preserved terraces attain heights of several metres above the present river level (Fig 104 and 105 ▼).

Organogenic material (Fig 108 □, Tab 2, samples 24.10.86 1b/1c/1d) indicates that the age of these gravel deposits is more than 1925 to 5935 C14 years, thus making them the *oldest* dated gravel sediments in the Yarkand valley. Moreover, dating of lower surfaces of gravel terraces (Fig 60 ▼ in low elevation above the receiving stream; 110 ▼ far left) and surfaces of alluvial fans in the Yarkand system of the section mentioned before established them as being approximately 110 (even 40) - 155 YBP (localities: Fig 65 ↓; 108 x □), as shown by the historic to current glacio-fluvial activities between the Aghil mountains and Kuenlun (Tab 2, sample 24.10.86/4; 25.10.86/1/3). Fig 55 (Nos. 1, 3, 4, 5, 7, 10), 66 (Nos. 1, 2, 3, 4, 6, 7); 67 (a/b); 74 (a/b); 56 (24.8 and 24.10.86) and 68 describe the *sedimentological* features of these *Holocene* gravel floor terraces and even younger deposits of the Yarkand river (localities: Fig 138 Nos. 37, 38, 39).

Attention is to be drawn to the significant difference between the graph of cumulative grain sizes taken from *glacio-fluvial* terrace sediments (Late Glacial to Holocene gravel fields, Fig 55 Nos. 3, 4, 7 and 10) to those sediments of predominantly fluvial genesis in the recent talweg area of the Yarkand valley (Fig 55 Nos. 1 and 5). The proportion of pelites, typical of *glacier milk,* is significantly reduced in the *river sediments,* so that 82% of its fraction remain the *sand spectrum range.* The difference between *gravel-field features* and the *examples from moraines and mudflows* (the graphs of which are almost the same; Fig 55 Nos. 6 and 9) is far smaller than between *outwash gravel fields* and purely *river sediments.* Most of the gravel-field samples of the Yarkand valley and its tributaries continue to show the fine grain peak typical of moraines (Dreimanis & Vagners 1971) (Fig 67b; 74 a/b). In this case it is evidence of the sedimentological *proximity* of the moraine, and thus of the glacier, as an *essential* feature of glacier outlet outwash plains or *sanders.* The first four columnar diagrams of Fig 56 (24.8.86/1/5; 24.10.86/1/1a-d/2) illustrate how much the *morphometric* features of quartzite grains in the terraces of the Yarkand system vary in relation to the *transport distances.* 24.08.86/1/5 (cf. also Fig 68) are taken from *short* tributary valleys. 24.08.86/1/1a-d/2 are from the *long* Yarkand main valley. The high proportion of "fresh" material is explained by the omnipresent supply of solifluidal and denudation *slope debris* but also by glacigenic fractures caused by small glaciers in the tributary valleys. The significant proportion of "dull" material indicate aeolian processes typical of arid, or *semi-arid* climatic regions.

However, this requires qualification in so far as the characteristic of "dullness" can *also* be observed in glacigenic processes, like the grinding of lower and ground moraine, which produce grain surfaces with polished edges and a dull grain surface not unlike that of SiO_2-grains transformed by aeolian processes only (Fig 68◁◁). In this respect the 50-65% of "dull" components of the tributary valley samples 24.08.86/1/5 are more informative about the *short* distance of only a few kilometres to the present glacier ends of the Kuenlun than about aridity. As stressed before, Fig 105 shows very clearly how relatively little debris material and terrace material fills the floor of the Yarkand valley section higher up. In this context attention must be drawn to the considerable present *denudation and solifluction* processes which shift the detritus on the slopes by c. 2–6 cm/year downhill (Fig 105 ▷). It would have filled the valley floor disproportionately more, had there not been *glacial* removal during the ice age – with *several* repeats during the Pleistocene (cf. Kuhle 1991d, pp. 139, 141, 170). Even these tributary valleys without a *short* connection to higher mountain massifs of the Kuenlun, and consequently with no glacigenic supply of material from ice margin positions on the edge of larger valley glaciers during the Late Ice Age and Holocene, are noticeably *poor in debris and gravel* as compared with present material weathering (Fig 109, 110 left half of the photo). It is essential for this approach to bear in mind the spatial differentiation of valley sections with *directly* adjacent high mountains, and thus Late Glacial *supplies of glacigenic material* as it occurs, for instance, in the area of the W Surukwat valley, where glacio-fluvial accumulations of vast dimensions are a typical feature (Fig 138 No. 31; 22 ▼ Nos. 1–3). Here it belongs to the *post-Main Ice Age* (cf. above). It is necessary to bring to mind the details of this strange, but at the same time *characteristic,* distribution of the quantitites of debris within these valley courses in their dependence on the distance from Late Glacial and Holocene glaciers in order to draw the right conclusions in the summary of this paper (cf. summary chapter 4.5.3).

4.5.3 Loose rocks in the "Vale of Kudi" and the gravel-fields up to the N-foreland of the Kuenlun (Tarim basin)

This sub-chapter has to fill an additional systematic function. In doing so it closes the spatial gap between the Yarkand valley area and the Kuenlun S-slope together with the Kuenlun N-escarpment, down to the mountain foreland in the Tarim basin. The Fig 54, 21, 53, 25, 59, 58 and 111 represent the S to N down-valley succession of cross-profiles of main valleys and tributary valleys with their *infilling of loose rock* between 5000 m, or – as the case might be – 6000 m (Fig 21) and 3000 m asl. Fig 21 and 53 show valley cross-profiles adjacent to areas of the Kuenlun main ridge, which are still glaciated, including the Holocene and Late Glacial moraine discussed above (cf. Chapt. 4.3, Fig 138 No. 15). The gravel-fields here possess *narrow* linear outlines along a talweg (↓) confined by high moraines. Fig 54 depicts an equally high valley floor (as Fig 21 and 53) though it is almost entirely *lacking* in moraines and loose gravel rocks (Fig 138 No. 16). The talwegs of this most southerly catchment area of the "Vale of Kudi" extend up to high hollows or troughs, the glacier of which is melted away quite *suddenly* after filling them completely throughout the Ice Age. They have *not* experienced *any* Late Glacial to Holocene glacier activity since. This is due to the fact that these high hollows or troughs are not flanked by *any* peaks which rise substantially above their level, ie by potential late-Late Glacial to Holocene glacier catchment areas. That is the reason why at present there are no glaciers, but *only* snow patches on these mountain ridges (Fig 54). The sample locality No. 17 (in Fig 138) has already been mentioned with regard to the Late Glacial moraine sequences in the "Vale of Kudi" and its tributary valleys (Chapt. 4.3). The C14 dating of sample No. 20.08.86/2 shows that the lowest, only 2 m-high terrace is more than 1610 ± 90 years old (Tab 2). Apart from alluvial fans of tributary valleys there are no higher terraces in this location at 3740 m asl. The same terrace representing the *characteristic level* not only emerges upstream at 4000 m asl (in the area of Fig 25◀) but also down-valley in the main valley below near the Kudi settlement at about 3000 to 3200 m (Fig 58 ▼) and repeatedly (Fig 138 No. 40) in the tributary valleys (Fig 59 ▼). Fig 57/d provides information about the fine grain composition of this gravel terrace at 3740 m. At this height- interval, the loose rock valley floor in the main valley, including the present river bed (□), is only a few hundred metres wide (Fig 58). Judged by valley walls, which drop steeply below the valley floor, the *gravel thickness* might be estimated at one hundred metres or more (Fig 58 and 59). But a deposit of unclassified rock, like diamictites, is not to be excluded either. The undercutting of the outer banks in the bedrock (Fig 58 ↗) is an indication of a *different* prehistoric genesis of the valley profiles from that of the present fluvial processes – a *glacigenic* one, in fact (cf. Chapt. 5.4). The autumn waterflow (late October 1986) of this mountain river or stream in the "Vale of Kudi" near Kudi is about 0.7–1.2 m^3/sec. In the lower course of this valley further north, up to about 20 km down stream from the Kudi settlement remnants of several metre- to decametre-high glacio-fluvial gravel-field terraces with sporadic *accumulation of rough boulders* are preserved above the present valley floor in narrow ledges along the rock-walls. This is quite evidently Late Glacial moraine material (outwash) which has been washed out *near ice margins* – a fact that can be deduced from the size and packing density of the boulders (Fig 138 No. 41).

For reasons of expedition logistics, the northern continuation of this Kuenlun valley system up to the mountain foreland, ie into the Tarim basin, was subsequently studied further east, in the "Vale of Pusha" beyond the Akaz pass (3270 m asl; Fig 138 No. 42). The Fig 112 and 113 show complimentary perspectives of the lower section of the "Vale of Pusha" (Pusha settlement: 37°20'N/77°08'E) and of its *glacio-fluvial gravel field*, which forms the valley floor (Fig 138 No. 43). These are *Late Glacial* gravel- fields of the Ghasa Stage I (Kuhle 1982, pp. 154–55), which cover the floor of the glacier tongue basin between the Main Ice Age moraines in a cord-like gravel field (Fig 112 No. 4; 113 No. 4). It is possible to discern at least two terrace levels at 10–6 m (Fig 112 ▼ No. 4) and 25–20 m above the present talweg (Fig 113 ▼ No. 4), which are evidence of two *early Late Glacial* accumulation phases of the Ghasa Stage I. The terrace heights decrease towards the valley exit as such glacio-fluvial accumulations tend to do. Hundreds of small *"special alluvial fans"*, which have been pushed out of the gullies of the inner moraine slopes (Fig 112 ▽), are set into their surfaces (Fig 113 ●). *Late Glacial gravel-field segments* of this kind run through the tongue basins of the piedmont glaciers of the main ice ages in repeated patterns of *parallel stripes*, extending from W to E over a distance of more than 100 km S of the Yehcheng settlement (Fig 113 No. 0; 114 No. 0). These gravel-field cords pour into the mountain foreland proper of the Tarim basin (Fig 114 No. 4) from the exit of these *Main Ice Age end moraine valleys* or *tongue basins* from an altitude of approximately 1900- 2100 m asl. Having been channelled by the parallel striped end moraines over a distance of 15-30 km, the gravel-fields were now able to *fan out* widely (Fig 138, Nos. 44, 45) from here, ie from the position of the Main Ice Age glacier margins and glacier outlets (Fig 114) and to settle down as *very extensive gravel fields* with scarcely any relief, which extend as far down as c. 1500-1400 m asl (Fig 115 Nos. 5 and 6). They reach the present *circle of irrigated oases* in the interior of the Tarim basin at the point of their transition to *limnic* sediments in *terminal basins*, which used to be lakes even in Late Glacial times. This is the case in the S-N profile near the Yehcheng settlement. In the more constricted N-Kuenlun mountain foreland beyond the *very extensive* ranges of Main Ice Age end moraines (see below, Chapt. 5.4), some of the younger Late Glacial sections of gravel-fields spread over the much more extensive Main Ice Age gravel-fields (Fig 138 No. 44 above No. 45), which in turn must have covered those of older Pleistocene ice ages (Fig 115 Nos. 5 and 6). The graphs 2 and 8 in Fig 55 (Fig 138 ✧ N of No. 45) show the *grain size composition* in these gravel field fans in the foreland with surface inclinations of 1-2° over a distance of 60 km from the bedrock at the foot of the mountains, as well as the *qualitative* difference between them and the *channelled* gravel-fields with shorter transport distances in valleys (graphs 3, 4, 7 and 10). On the other hand, the contrast with graphs of *purely fluvially-transported* deposits (graphs 1 and 5) is just as evident. Fig 66 demonstrates the *essential contrast* of the grain size composition of two more samples (17.10.86/1/1A) from the same locality of *gravel-fields* in the *foreland* (Fig 138 N of No. 45) (graphs 5 and 8) to other channelled gravel-fields from tributary valleys of the Yarkand (graphs 1, 2, 4 and 7). Showing a proportion of more than 75% of *dulled* quartzite grains, Fig 56 (17.08.86/2) stresses the high proportion of *aeolian* processes involved in shaping the grain surfaces of the pelitic components of this glacio-fluvial sediment (Fig 138 N of No. 45). The reason for this is to be seen both in the *aridity* of the climate in the Tarim basin, which continues to expose the bare gravel-fields to deflation and corrasion and the time available since at least 18 Ka BP (Fig 115 ○, No. 5 and 6). Fig 127 gives a directly visible rendering of the high proportion of dull grains in the range of >63 μm.

It must be remembered that, within this study, which focuses on the *Main Ice Age glaciation*, the detailed descriptions and analyses of *outwash gravel-fields* from the Main Ice Age to the post-Glacial period via the Late Glacial to historic times (Chapt. 4.5.1.-4.5.3) have the function of providing evidence to demonstrate how *fresh* and *youthful* these glacio-fluvial infillings of valley floors are, and how entirely *different* these post-Main Ice Age processes must have been from the preceding ones which gave the valleys their forms. It has been shown that the *present formative processes* in the main valleys *cannot explain* their shaping (cf. Chapt. 5.4).

5. Maximum Prehistoric Glacier Infilling of the High Mountain Relief between the Karakorum Main Ridge and the North Kuenlun Foreland (Fig 138)

In the course of the description of geomorphological and sedimentological traces of maximum prehistoric glacier infilling, the general topographical sequence from the highest, *present,* glacier areas of the Karakorum to the *lowest,* former ice margins in the mountain foreland of the Kuenlun is here being *repeated* for the fourth time. Related to the description of present glaciation (Chapt. 3), the Holocene to Late Glacial glacier positions (Chapt. 4.1 to 4) and the outwash gravel-fields (Chapt. 4.5.), this S-N sequence has hitherto dealt with the mountain thresholds of the Aghil and the Kuenlun, which have been inserted, running from W to E. This has been repeated three times in this S-N profile, beginning each time *at the top* again, at the present glaciers, and subsequently following three downward profiles every time. This would even have to apply to the *maximum* ice infilling of the relief, unless its level, the *glacier surface,* had moved across these ridges at some *transfluence passes* and maintained a S-N descent. Disregarding the possibility of such glacier transfluences, even glaciation - which is, after all, never superior to the relief but within its surface - would have had no alternative other than following the direction of the present valley inclination with its *ice flow.* It follows that, in this respect, the twin thresholds of the Aghil and the Kuenlun ridge also continue to hold their own for the maximum glaciation. The description has to start *twice* again at the top, descending from heights of more than 5000 m asl first to 4000 m (Shaksgam valley floor), then to 3300 m (Yarkand valley floor), and finally to less than 2000 m asl (Kuenlun foreland). It should be mentioned in advance there is no lowest glacial margin position between the Karakorum N-slope and the Kuenlun, since the altitude of the entire area is too high. For this reason, reconstructions of the maximum height of *abrasion* and *polishing lines* and *ice levels* were carried out in the valley systems of the Shaksgam and the Yarkand. At that time the *entire* valley relief had been *infilled with ice.* The *lowest* glacier end positions were only formed beyond (north of) the Kuenlun mountains where the foot of the mountain ends in the Tarim basin.

The investigation consequently begins in the Karakorum N-slope as the highest, more than 8000 m-high feeding area, by examining the *highest preserved* of the abrasions and polishing lines, more or less unambiguous evidence of which is found in smaller and larger remnants. Though the local Ice Age glacier levels are the highest, and far above the present glaciers, they also show the *smallest* height difference to the valley floor levels there. Only the main valley floors and longitudinal valley floors further down, which are now *free of glaciation,* manifested the greatest ice thickness during the Main Ice Age, whereas up the main valley, and especially up the tributary valleys the gap between the Main Glacial ice level and the present one has been *closed save* for a vertical distance of a few hundred metres. This observation gives some idea of a Main Ice Age valley glacier net with very well balanced, and by contrast with the present glacier surface inclinations, markedly *flatter,* surface inclination curve. The overall picture of the *Ice Age glacier surface geometry,* which *flattens* the mountain relief in this way, shows that it was underpinned by the *greatest* thicknesses of ice where the valleys are incised most deeply. In other words, that the ice was thinner where the valley floors extend far beyond the *Ice Age snow line,* and far into the present glacier region. Glaciation of peaks and ridges *above* the valley ice level was, if anything, *less* than now, as the *upper climatic glacier line* had been lowered equi-directionally with the climatic snow line (cf. Chapt. 3.1.1; cf. Kuhle 1986i: pp. 344/45). However difficult it may be in a particular case to arrive at an exact classification of remnants of flank abrasions and polishings or even abrasion and polishing limits of the valley flank sections, the *concept of an overall level* of Ice Age glacial relief-infilling succeeds quite well, providing two-, or even three-dimensional *interpolations* of height- levels for intervening areas from both sides, even from the opposite valley flank for more or less great horizontal distances.

5.1 The Maximum Prehistoric Glacier Levels which can be Shown to Have Existed in the Karakorum North of K2 (Catchment Area of the Muztagh Valley)

Beginning with the K2 valley, where the 1986 expedition was able to carry out investigations into the highest valley heads in the Karakorum main ridge, the highest preserved abrasion and polishing limits (- - - -) above the recent glacier feeding areas were found to be running 400–600 m above the present glacier surface (Fig 1a) This is a value which polishing limit remnants in the feeding area of the Aletsch glacier in the Bernese Alps also indicated for the reconstruction of the Main Ice Age raising of the Jungfrau firn, thus confirming the comparatively *minor heightening* of the catchment area levels in question. Higher values (around 600 m) can be recognized at the N-wall of K2 itself, thanks to increased steepness at the base following glacial undercutting of the banded Falchan gneisses. In Fig 5 (- - - - centre) the *undercutting* is particularly clear at the shadow line of the K2 N-spur. On the W-source branch of the K2 glacier, which leads up to the eastern "Sarpo Laggo pass" (Fig 1a No. 6), the ice thickness during the Main Ice Age had been reduced to 400 m and less as a result of the over-running of the aforementioned c. 5800 m-high pass (Fig 1a - - - - between Nos. 2 and 6). In the entire catchment area of the K2 glacier the glacier surface was thus located between 5800 and c. 6000 m asl.

Fig 5 (- - - - left) shows the reconstruction of the level on the orographic right-hand valley flank. Its continuation down-valley is shown in Fig 6 (- - - - right). In this exposure the Ice Age increase in the glacier thickness to the S, up to the middle coupe of the present K2 glacier, is very noticeable (- - - - background). Convex glacigenic abrasion and polishing forms (◆) are characteristic here. At the same time the intervening destruction of outcropping metamorphic sedimentary rock (quartzites and Baltoro black slate, cf. Geological Map of K2, 1:25 000, Desio 1968) by frost weathering, is striking. After the deglaciation of the rock flanks it led both to the *formation of debris covers* with solifluction dynamics (▷) and of young *talus cones* (Fig 35 ▽; 10 △). Weathering is aided by the positioning of the *outcrop layers* up to the slope surface. Fig 1a, 6 and 10 show the maximum height of the prehistoric K2 glacier surface as far as it is preserved at the valley flank on the left side (Fig 6 - - - - left side; 10 - - - - centre). Towering up to 2000 m above the present glacier surface (Fig 1a No. 4, 6 Nos. 1, 2; 10 Nos 2, 3) this steep, shaded ENE-exposed valley flank continues to be *transformed* by ice and snow-induced rock falls and is forming a dense *network* of *wall gorges* and *gullies.*

Small hanging glaciers and firn shields, some of which developed only in post-Glacial times, contribute to the process of breaking-up the valley wall (Fig 1a, 5, 6 ◇). Fig 7, 10, 11, 28, 30, 32, 35 (- - - -) assist in the reconstruction of the maximum prehistoric ice level at the great *ice barrier* to the N, the Karakorum main ridge formed between the S-slope and N-slope. Eight kilometres away from the K2 peak the ice thickness (- - - -) increased to about 700–800 m. This is the confluence area of the third orographic left-hand tributary glacier (Fig 10 and 11 below No. 4). During the Ice Age and even now the tributary glacier system on the orographic left-hand has in turn been divided into three source branches, and connected with the main glacier (K2 glacier), by a *confluence step.* Relatively steep even during maximum glaciation this *steep step* in the rock floor explains the *ascent of the glacier surface* into this tributary glacier system (Fig 10 and 11 - - - - in the background, below Nos. 3, 4, 5, or 4, 5). There is a 7315 (7330) m-high mountain at its source (Fig 1 No. 4); *during the Ice Age* the 1000 m-high scarp of this structure descended steeply to what was then the glacier surface. Two and a half kilometres further down valley another tributary glacier joins on the orographic left; it used to flow into the Ice Age K2 glacier with a 500–600 m greater thickness than now (Fig 10 - - - - right, below No. 7; 11 - - - - below No. 6), where *exaraction grooves* and abrasion and polishing lines caused by detersion and detraction are recognisable (- - - -) above some glacial *abrasion* and *rock polishings* (◆ ◆). The catchment area of this tributary stream is certain to be higher than 6000 m (No. 7 = 6040 m); indeed, it is likely that even peaks of more than 6500 m (Fig 11 and 12 No. 6; 6540 m according to T. Myamori's map (1978) Baltoro Muztagh in Mountaineering. Maps of the World p. 128) follow on here. Up to now, this area has remained completely unexplored. In spite of this, the Italian 1929 Geographical Expedition described a 6540 m mountain here as Monte Chongtar. Between the two left-hand tributary glaciers, *two levels* of abrasion or polishing lines can be reconstructed (Fig 10 below No. 6), the lower one of which corresponds to the oldest Late Glacial stage, the Ghasa Stage I (nomenclature Kuhle 1982, p. 154). Further down the valley, where the most northerly left-hand tributary valley joins, another *two levels* of abrasion and polishing lines can be made out; this is particularly clear when viewed from different angles (cf. Fig 11 ---- (below No. 7 and up to the right-hand edge of the picture) with Fig 28 ----). Further perspectives of this valley flank with its considerable *roughness* (cf. Chapt. 4. 1. 1.) are shown in Fig 7 and 14 (----). On the orographic right-hand side, directly opposite that tributary valley on the left side, the 8 km-long Skyang Kangri valley joins the K2 valley directly from the E without any steep steps (Fig 11, left third; 30 right). A 1 km-wide tributary ice stream from this valley drained into the main ice stream of the next higher order (Fig 138 No. 3). In the confluence area the abrasion and polishing lines are evidence of an ice thickness of c. 800 m (Fig 2 right, 11 left, 12 right and 30 ----). A diversion into the Skyang Kangri valley up to its upper end, with the 7544 m-high Skyang Kangri, is to facilitate the reconstruction of the glacier level of the Main Glacial period (Fig 2; 12). Directly N of the Skyang Kangri twin- peak (Fig 2 and 12 No. 1; left 7544 m, and right c. 7500 m asl) the Ice Age glacier level was *higher* than the intermediate valley ridge between the Skyang Kangri and the western branch of the N-Skyang Lungpa glacier (Fig 2 and 12 ---- far left). Since the ridge separating the two glacier systems now was *not* rounded, it can be concluded that a glacier transfluence was largely *missing* at that time. The significant *supply of ice avalanches* (↓↓) from scarp walls, which had, and still has, an effect upon not only the valley head but also over many kilometres from the up to 6640 m- high peaks (Fig 2 No. 3; 12 Nos. 2 and 3) down to the orographic left-hand valley flank, has *obscured* the prehistoric abrasion and polishing lines. The preserved remnants of the truncated spurs and polished *triangular slope facets* (Fig 2---- left half) indicate a prehistoric ice level between 6000 and 5600 m asl, corresponding to a prehistoric glacier surface 600 to 400 m above the present one. In the directions of the confluence area of the Skyang Kangri valley with the K2 valley, an *oldest* – ie *highest* – abrasion and polishing surface bordered by an *ice scouring groove* has been preserved up to 600 m above the present glacier surface level (Fig 2---- right half, 12 ---- right half; 30 a ---- bottom right). Now and in the most recent historical period of glaciation (during stages IX and X), the right-hand side of the Skyang Kangri glacier, together with its margin in the form of an *ablation gorge* (Fig 2 □□ ; 12 foreground and IX, right), which are exposed to the SW and thus to increased radiation, have kept their distance from the valley flank, whereas the Ice Age glacier, as the largest tributary branch of the K2 glacier, on the orographic right, attached itself to the walls of this valley, reaching up to a height of at least 600–800 m (Fig 12 ---- on the right-hand edge; 30a ---- bottom right). The K2 main valley glacier continued down valley at a correspondingly high level below the Skyang Kangri valley junction (Fig 10 right-hand edge of the picture; 30 left half; 30a). Fig 10 and 30 both show the two glacial flank smoothings of the main valley (Fig 30 ◀ ▶) lying *directly opposite* each other, together with the abrasion and polishing lines which run up to 1000 m above the valley floor (----). Due to parallax shift (----), the perspectives of these pictures, which look down on the K2 valley to its junction with the Muztagh valley, render the Ice Age *increase of glacier thickness*, which occurred in this direction, less distinct. Evidence of this was supplied by the author by means of the *loss in height of the valley talweg,* which is greater than *that of the ice scour limits.* Fig 32 and 43 select the area of the junction of the K2 valley with the Muztagh valley in respect of their ice scour limits (----) from opposing observation perspectives. The ice scour limit on the orographic right runs here at about 5200 m asl, somewhat more than 1000 m above the valley floor (□ ◇) in the forefield of the present K2 glacier (Fig 23; 23a). The reason for the absence of moraine deposits from the Late Glacial stage I (= Ghasa Stage, after Kuhle 1982, pp. 154/55) below this ice scour limit, is the persistent lack of height of the snow line (ELA) during the relevant period of the early Late Glacial time. In the same way as the *Main Ice Age* glacier surface (Fig 32 ----) is to be reconstructed *solely* on the basis of the smoothly abraded and polished valley flank rocks (Fig 28 ◀ on the left-hand edge; 32 ▲) and the *suspension* of these smoothings towards the top by means of the *ice scour limit*, since the relevant glacier surface – far above the snow line – must have been part of the *denudation area* of the glacier, and consequently *no* moraine deposition was possible in these valley cross- profiles of the glacier feeding areas, they are still missing here during the *early Late Glacial* period (stage I). The oldest moraines belong to the *middle Late Glacial*: the Taglung Stage II and the Dhampu Stage III (nomenclature for High Asia after Kuhle 1982, pp. 155–57) (Fig 32 II, III). The moraine deposits following on down valley from stage III become more and more *voluminous*, jut out into the valley space like terraces, thereby *diminishing* its volume (Sirkung Stage IV, Nauri Stage V, older Dhaulagiri Stage VI in Fig 32 and 43). The vertical continuation of the moraine deposits of the valley down to its floor can be gathered from Fig 23 and 23a, showing the moraine stage IX and X (■■).

A little above the junction of the Ice Age K2 tributary stream with the Muztagh valley, the formerly 21 km-long N-Skyang Lungpa glacier joined the K2 valley as the then most *important* tributary glacier (Fig 138 Nos. 2, 3a). Its source was located in two branches running parallel to the Skyang Kangri glacier (cf. above) on the N-flank of the 7544 m-high Skyang Kangri (Fig 138). Fig 32 (---- left third

II, III, IV) shows the highest provable *ice level* including the lateral moraine of the Late Glacial period on the orographic right in this junction area. The confluence point of the talwegs of both valleys is marked in Fig 30a (➤, top), together with *ice scour* limits in the confluences of N-Skyang Lungpa valley, K2 valley and Muztagh valley (----), which are close to one another. During the *Neo- Glacial* glacier advance (c. 4000–4500 YBP, by analogy with datings by Kuhle 1986e, 1986c), the *mountain spur* of the two converging flanks of the N-Skyang Lungpa valley and the K2 valley was *extended* by 1 km (Fig 32 V, V right and V left) through a middle moraine, which was formed by the two lateral moraines of two united valley glaciers. Fig 43 (----) depicts the *highest* provable prehistoric glacier level in the K2 valley – Muztagh valley junction with its gravel floor, which appears as the ice scour limit (---- on the upper edge of the air-photo) in Fig 30a. In the course of the 1986 expedition Xü Daoming found "hard till" at 5000 m asl, and 1100 m above the valley floor in this region (Fig 138 No. 12). It was subsequently dated in the TL laboratory of Gdansk University as $56 \cdot 10^3 \pm 8.4 \cdot 10^3$ YBP.

In order to present the *ice scour limit*, it is now proposed to follow the orographic right-hand flank of the *Muztagh valley* (Fig 43 to the right), from the mouth of the K2 valley up to the Sarpo Laggo glacier (Fig 30a ---- near the left-hand edge; 50 ----). Passing above some *Late Glacial* lateral moraine ledges (III, IV ↓↓), it delimits a heavily scoured, preserved abraded and polished edge (◥) towards the top. The lateral moraines are preserved in places where it was easy to press them into the shadow of the small tributary valley below the 6040 m peak (Fig 50 No. 2). The source branch of the Muztagh valley on the orographic right-hand side, the Sarpo Laggo valley, continues to be glaciated like the K2 valley. It takes the form of a *trough* valley with a *broad* floor and *steeply* ascending abraded and polished flanks (Fig 36, left third; 44 left quarter; 46 ◥ ◤). Besides sharing the classic *over-steepened* and slightly *concave* abraded lower flanks (Fig 36, far left below ◥ ◤), it even has the strikingly *straight* valley flanks, which are typical for many V-shaped valleys, and *smoothings*, which are *direct indicators* of glacial development (Fig 138, No.7; 44 ◥ ◤). Between the confluent tributary valleys of the Sarpo Laggo system perfectly *triangular* glacigenic *slopes* – in the true geometrical sense – have developed here. Such polished rock surfaces have been formed in many places *irrespective* of the nature of the rock or their bedding conditions. Fig 8 even shows crystalline schists with quartzite layers vertically outcropping on the right flank of the Muztagh valley (▲), which have been *whittled down* to form a *smooth surface*. This is a rock sequence exhibiting a *wide variety* of abrasion and polishing resistances. The main valley axis of the Sarpo Laggo valley can be well surveyed over 30–32 km, up to the 6544 m-high Kruksum peak at its head (Fig 36 and 44 No. 1), where a mountain ridge which was *abraded* and *polished round* during the Main Ice Age, the still glaciated, 5931 m- high Karphogang W of the E-Muztagh pass marks an Ice Age minimum glacier level of about 5900–6000 m asl (Fig 44 ----). This was the location of a central, slightly *dome-shaped* heightening of the ice stream network, which was in contact with the Karakorum S-side through several hundred metres-high transfluence thicknesses including three confluence passes (E-Muztagh pass, 5422 m; W- Muztagh pass 5370 m, and the Sarpo Laggo pass 5685 or 5645 m, directly at the valley head). There have been several of such *transsection glacier domes* along the Karakorum; the author suggests reference to this one as the "Sarpo Laggo dome". In the S it was connected with the Baltoro glacier system, and in the W with the Panmah glacier system. Both of the southern ice stream networks belong to the Main Ice Age catchment area of the Indus glacier (cf. Kuhle 1987h, pp. 606/607; 1991, pp. 297–299). It was lying opposite the Shaksgam-Yarkand glacier system, which includes the ice stream networks in question. Fig 44 shows the direction of origin of the two main components (→←, background), which lead down from the Karakorum passes mentioned above. The arrow (→ left) marks the inflow of the ice stream which the 1929 Italian Geographical Expedition had named the Meridional Chongtar glacier. Being the largest tributary stream of the Sarpo Laggo glacier, it was linked with the K2 glacier during the Ice Age via a continuous surface (ie without any breaks in slope) that extended over the c. 5800 m-high "E-Sarpo Laggo pass" W of the K2 (cf. Chapt. 5.1; Fig 1a No. 6; 138). In this way the massif of the 7315 (7330) m-high peak (Fig 11 No. 4) which includes the 6540 m-high Monte Chongtar (or Chongtar peak Fig 11 and 12 No. 6; 50 No. 1) was *enclosed* by the *more* than 1000 m-thick ice streams of K2, the Muztagh and the Sarpo Laggo glacier. Further higher peaks of this Sarpo Laggo catchment area are the mountains of the Lobsang group, including the 6745 m-high Thyor and the 7275 m-high Muztagh tower, which were connected via the Moni glacier. The *maximum thickness* of the upper Sarpo Laggo glacier which it was possible to reconstruct geomorphologically on the basis of mountain forms and abrasion and polishing grooves (Fig 44 ----; 46 ---- left side) reached 700–1000 m *higher* in the present snow line limit (at 5000–5200 m asl; Fig 138, No.7) than the present ice stream. On the way to the confluence with the Skamri glacier in the Muztagh valley (Fig 36 ----; 46 ---- right side; 50 ----) the glacier thickness increased to well above 1000 m. Here the glacier level was around a *minimun* altitude of 5000–5200 m, whilst the level of the present gravel-floor in the valley bottom (No. –6) lies at 3900–4000 m asl. Twice as broad as the Sarpo Laggo valley, the Skamri valley with the presently about 40 km-long Skamri glacier, (also known as Crevasses or, at times, as the Yinsugaidi glacier) flowing off the Panmah Muztagh, reaches the Muztagh valley from the W (Fig 36 and 46, right-hand side; 9; 47; 48; 49; 138 No. 9). Linked with the Sarpo Laggo glacier in the SE, the 7045 and 7090 m peaks of the Chiring group belonged to the S-catchment area of the Ice Age Skamri glacier. Their marginal satellite peaks are depicted in Fig 36, 46 and 47 (Nos. 2, 3, 4). In the west, as an entirely glaciated area of *great mean altitude*, the Drenmang group, which culminates at 6736 m, *continues* to

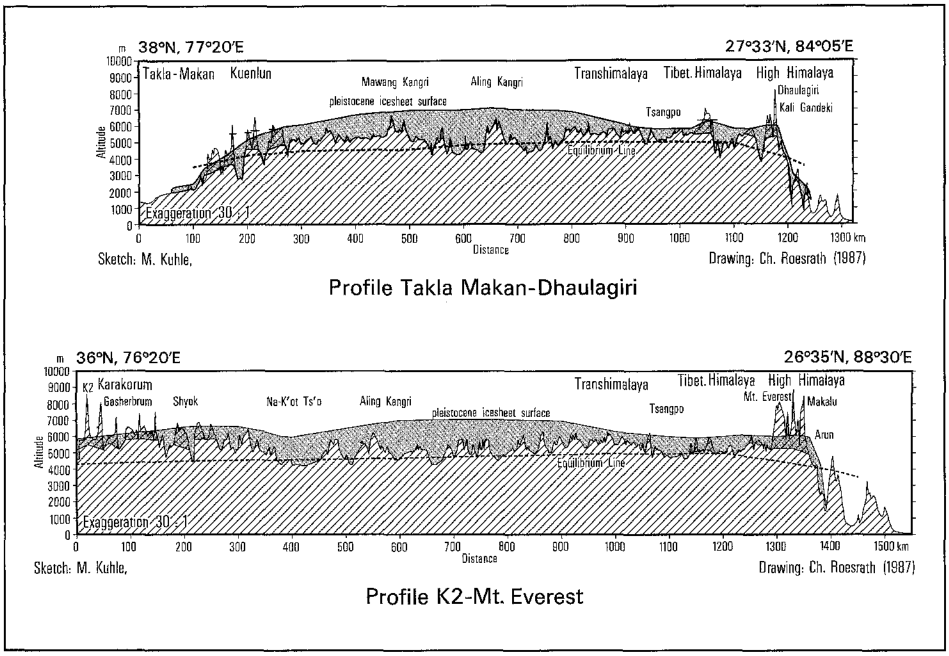


Fig 135 a/b
The two cross-sections give an idea of the Main Ice Age (Würm age) glacier cover of Tibet between a) the High Himalaya in the S and the Kuenlun in the N, down to the Takla Makan desert in the Tarim basin, and b) the High Himalaya and Karakorum, which is also in the north. This establishes the connection between the ice of the Tibetan interior and the particular area under investigation in this paper, which includes the Karakorum, Kuenlun, and the Tarim basin with their contemporaneous ice stream network. Profile /a shows the outlet glacier tongues in the northern Kuenlun foreland, which flow down to below 2000 m asl (cf. Fig 112, 113 and others; also Fig 138, Nos. 43, 44, 55 and 137).

be part of it (Fig 9 and 47 background). The catchment area to the N has its highest point on the 7265 (7295) m- high "Crown" as the highest peak of the Skamri glacier system (Fig 46 and 47 No. 1). By contrast with the K2 glacier system and in view of the *much more extended present* ice surfaces of both the Sarpo Laggo and the Skamri glacier system at *considerably lower* altitudes of the peak catchment areas, it is evident that from a certain minimum height of the relief it is the *valley bottom level* rather than the height of the peaks - but in any case above all the *mean* altitude of the relief - which determines the construction of the present and the large prehistoric glacier areas. The difference from the present glacier system is a *significantly higher* glacier level during the Ice Age. It lay 21 km into the Skamri valley from its junction with the Muztagh valley at 5300–5400 m asl, ie c. 850–900 m *above* the present glacier surface (Fig 9 ----). During the Ice Age, the Skamri glacier had a two-pass link - the one further S being 5475 m high - with the Nobande glacier on the Karakorum S-side in the Indus catchment area. The level of the upper ice stream was thus kept *below* 6000 m. Fig 47, 49, 46 and 36 (in that sequence) show the vertical distance of the *Ice Age abraded* and *polished ledges* (◢ ▲) up to the *polishing grooves* and *ice scour lines* from altitudes of 5400 to 5200 m asl downwards (----). They are indicators of a *minimum ice thickness* of about 1000 m. It is likely that the ice thickness was *much greater* still, and that for two reasons: 1: Due to its *short-term* effectiveness, which must be assumed here, the *maximum height* of prehistoric glacier abrasion and polishing was hardly sufficiently marked in geomorphological terms to be preserved; 2. The valley floor level on which the assessment of the thickness is based, lies *too high*, as it is *still upgrading* now (Fig 9, 36, 46, 47, 48, 49 No. –6 □). The *box shape* of the Muztagh valley, which is a result of *infilling of the valley floors* with loose rock (moraine and glacio-fluvial gravels), suggests a far more than 100 m-lower altitudinal position of the *rock bottom* when it was abraded and polished by the Main Ice Age glacier. This approach is justified in view of the abraded or polished valley flank slopes striking the valley floor gravel at an *acute* angle, or *their continuation* below the loose rock infilling (Fig 9, 36, 46, 47, 49 each of them near the right-hand edge). Fig 47 shows with classic clarity (in the centre, below ▲▲) the *interference* of steeply joining, hanging V-shaped valleys and the polishing of main valley flanks into *glacial cuspate surfaces* (cf. also Fig 49 ▲▲). In summing up this section, it must be said that a *1000–1200 m-thick ice stream* has left the Muztagh valley, ie reached the junction with the Shaksgam valley, the main valley of the next higher order.

5.2 The Reconstruction of the Maximum Ice Thickness between the Karakorum and the Aghil Mountains (the Ice Age Glaciation of the Shaksgam Valley)

The Shaksgam valley is the major northerly longitudinal valley of the Karakorum, and thus one of the original branches of the Yarkand valley. It does not only *drain* the central and western Karakorum, but also drains part of western Tibet. The Shaksgam valley directed the *Ice Age* glaciers and their melt-water run-off north to the Tarim basin, one of the interior basins of Central Asia in an *areic* and arid environment, whilst the Shyok and Nubra valleys,