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New Data on the Pleistocene Glacial Cover of the Southern Border of Tibet: The Glaciation of the Kangchendzönga Massif (8585 m E Himalaya)

Kuhle, Matthias, Prof. Dr., University of Göttingen,
Department of Geography, Goldschmidtstr. 5, 3400 Göttingen, FR Germany

Topography

In the winter of 1988/89 sample investigations were made of the history of the glaciation in the eastern Himalayas. Traverses from 600 to 5300 m in altitude concentrated on the Tamur-Ghunsa valley system (27°–28° N, 87°–88°15' E) and the northern side of Kangchendzönga, the source region of the present Kangchendzönga glacier, and from the breach through the Himalayas west of Jannu (7710 m) down the southern slope where the settlement of Dhoban lies 90 km down valley below the lowest former end moraines. In the Tamur three catchment areas – all more than 7000 m high – are confluent above 7000 m near the settlement of Hellok (at 1600 m). Here the Ghunsa Khola and the Simbua Khola from the northern, western and southern slopes of Kangchendzönga are confluent in the main valley that runs from the 5095 m Tiptala pass at the edge of the Tibetan plateau (Fig 01).

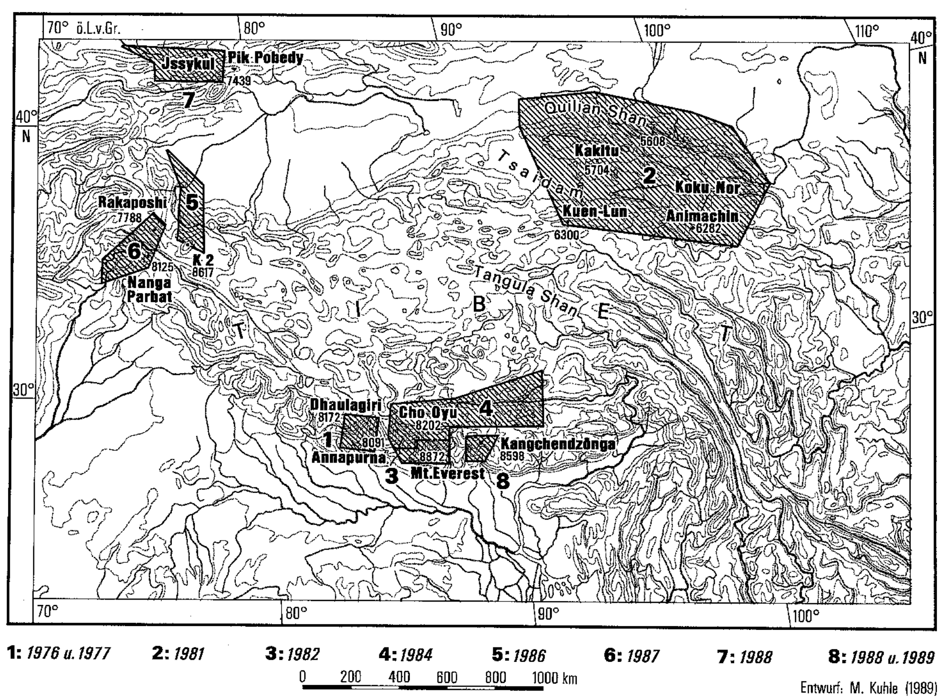


Fig 01
The Kangchendzönga area (No. 8) is the eighth area of investigation by the author

Fig 1 View from the meadow of Pangpema at 5200 m looking east to the Kangchendzönga glacier north of the main ridge of the Himalayas and north of the 8585 m high Kangchendzönga. The glacier is covered with weathering debris and is of dendritic valley glacier type. The mountains in the background, all above 7000 m, provide the avalanche flows feeding the alimentary basin of this ice stream. It is clear that the level of the ice has fallen considerably during the last two or three hundred years. The source branch on the orographic left side, rather to the right of centre in the photo, is fed from the 3000 m high north slope of Kangchendzönga. These are the largest glaciers of the Kangchendzönga group, some 25 km long. The level of the ice of the 'little ice age' is shown by three triangles (▽▽▽). The ridge of rock in the centre of the photo (□) was completely overflowed by glacier ice during the maximum glaciation; this may be estimated as being from at least 400 m to 600 m thicker in this upper alimentary area than at present.
(Photo: M. Kuhle, 7. 1. 89)

Fig 2
Looking ESE from the meadow of Ramthang at 4650 m up the Ramthang glacier as far as its upper source area, the 7992m Kambachen, a western bastion of the Yalung Kang. The Ramthang glacier is largely supplied by ice avalanches which detach from the upper ice terraces on the west flank of Kambachen (▼▼▼) which is witnessed by the abundant surface and end moraine accumulations (■■■).
(Photo: M. Kuhle, 6. 1. 89)

Methodology

In the sample area the considerable relief and close connection with Tibet are noteworthy. Just as in some parts of northern Scandinavia, as in Kebnekaise or the Narvik plateau, where in situ sheets of blocky debris and periglacial features mask the former glaciated surface, so in Tibet the typical forms of a glacial landscape do not occur, partly because of lack of relief and sedimentary rocks, partly because of the arid cold conditions and also because of low viscosity of the south Tibetan ice cover (Kuhle 1988a: 471). But here in the marginal mountains (the Himalayas) is found the strong erosive activity of the steep outflow glaciers from the Tibetan plateau channelled into the valleys. These are both wetter and warmer (than in Tibet) and thus the higher velocity of the glaciers makes them easier to detect from glacial polishing. In addition they form marginal and end moraines from which may be derived the depression of the snowline (equilibrium line altitude) and thence associated temperature reductions and moisture variations (the latter from calculated models of mass flow; Kuhle, Herterich & Calov 1989). Whereas the evidence for local ice cover provided by contemporaneous estimates of ice thickness can only be extrapolated over at most a few kilometers to give maximum possible ice thickness information, the use of ELA estimates allows ice cover reconstruction over much wider distances since the altitudinal climatic boundaries vary on a much broader scale.

Contemporaneous Glaciation

The much reduced present glaciation (in comparison with maximum and late glacial times) is confined to upper parts of the Kangchendzönga group with its 8500 m peaks and provides valley glaciers of alpine dimensions only in the 25 km Kangchendzönga glacier (Fig 1), the 11–13 km Ramthang (Fig 2), Jannu (Fig 3) and Yamatri glaciers as well as the Yalung glacier with its more than 20 km. These glaciers are avalanche-fed to the extent of 70–90% and because of this show clear superficial morainic cover beyond the firn line, suggesting a climatic equilibrium line altitude (ELA) of 5560 m. The orographic ELA is at 5720 m with northern exposures, some 70 m higher than with southern ones (5650 m). On the average the orographic ELA lies at 5600 m with western exposures and locally on Yamatri glacier with SW exposure it reaches down to 5250 m. The cause of the lower equilibrium heights with southern than with northern sides is the higher windward side precipitation with both summer and winter maxima, the resulting moist adiabatic warming on the lee side north slope and the marked enhancement of mass there. Where dark radiation-absorbing rock surfaces reach up to 5800 m above valley floors at 4800–5400 m this latter factor is very effective.

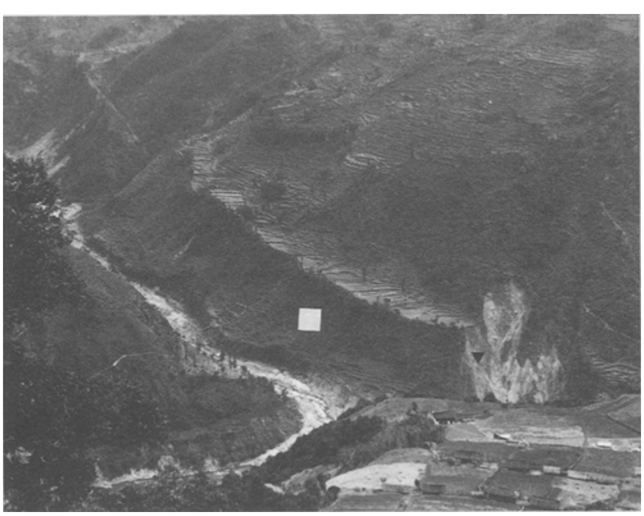
Glacial Conditions at Post-maximum Period

The ice margins of the historical, neoglacial and late glacial in a complete sequence were followed down the Ghunsa Khola and then further down the Tamur valley and brought into agreement with the provisional nomenclature established (before TL and C^{14} dates were available) in the western Himalayas (Kuhle 1982: 150–170; 1986: 441–452; 1987: 205). At Kangbachen meadow marginal moraine terraces indicate a confluence of the glaciers of the upper Ghunsa (Kangchendzönga, Ramt-

Fig 3 Looking ESE from 4260 m upward to the Jannu glacier. The dominant peak in the background is the 7710 m Jannu which is part of its source region. The steep relief determines the dominantly avalanche supply of this 12 to 13 km ice stream. The last 7 or 8 km course of this glacier is covered with surface moraine; the glacier tongue is incised some 70 to 100 m into the 'little ice age' moraines. The distal ridges in the foreground are in contact with transitional forms between sander sheets and alluvial fans which are seen still to carry fluviatile gulleys (↙↙). In the immediate foreground is the 12-channel computerised automatic climatic station designed by the Lambrecht firm of Göttingen.
(Photo: M. Kuhle, 1. 1. 89)

Fig 4 Looking south down valley from the orographic right slope of the Ghunsa-Khola at 4200 m. This is a characteristic trough valley with the satellite peaks of Jannu (6600 m and 6300 m) to the left. In the foreground below are the end moraines of the present and sub-present Jannu glacier (●). Further down valley are the end moraines of the Nauri stadium at 3600 to 3650 m (□) and in the background the valley-blocking moraines of the Yamatri glacier belonging to the Nauri stadium V (□). In front of these lies the glacial tongue basin of the Ghunsa glacier where lies the settlement of Ghunsa. This portion of the valley shows the transition between the terminal ice positions of the Neoglacial through to the youngest of the late-glacial. During the glacial maximum the valley was completely filled with ice up to the easily seen valley shoulders. Ice thicknesses of more than 1000 m must have been reached here (– – – – –).
(Photo: M. Kuhle, 1. 1. 89)

Fig 5 An orographic left bank morainic terrace at the outlet of the Simbua Khola where it joins the main valley of the Tamur seen looking east. On it is sited the settlement of Hellok (□). This represents the Ghasa stadium I which reaches down to 1500 m and is considered to be the oldest stage of the late-glacial. The terrace has a form recalling a fluvioglacial terrace. However its steep gradient and the glacigenic diamictite seen in the section on the right (▼) betrays its marginal or end-morainic character.
(Photo: M. Kuhle, 23. 1. 89)



hang and Jannu glaciers) with the Sharpu glacier and must be an example of the youngest stage of the Nauri stadium (V). The associated glacial terminal must be extrapolated to 3600 m since there is no end moraine (Fig 4 □ centre). This is the same age as the end moraine of the Yamatri glacier where it blocks the Ghunsa valley down to 3400 m (Fig 4 □ background). During the Sirkung stadium (IV), the youngest late glacial stadial, the Ghunsa glacier reached the glacial tongue basin in which lies the settlement of Ghunsa (3400 m, Fig 4 □ background) and came into contact with the Yamatri glacier which at the same time reached down to 3200 m in the Phele basin.

The next lower basin used by the settlement Killa at 2800 m was reached in the Dhampu stadium (III) by the compound Ghunsa glacier with its decakilometre tributary streams and a further affluent from southern Tibet (witnessed by polished valley margins). At least two further marginal moraine traces can be detected here on the orographic right slopes which supported up to 600 m of ice thickness in the valley cross section at the Kyapara meadow. They belong (provisionally) to the Taglung stadium (II) and may be extrapolated to a vague ice margin in the gorge section of the Ghunsa Khola between 1900 and 2100 m. The oldest, very clearly late glacial ice (Ghasa stadium (I)) reached the confluence of the Tamur and Simbua Khola at 1500 m. Here the left bank settlement Hellok and the right bank one Lelep stand on the lateral moraine terraces up to 100 m high or more with their fields and farm buildings (Fig 5 □). The related ELA for the Simbua glacier (and the tributary area of the Yalung glacier) is calculated to be at ca 4400 m, representing a depression of the ELA of 1250 m. The ELA of the Ghunsa glacier may be calculated as 4150 m, a depression of 1390 m. All exposures, including those to N and E, are found on the Ghunsa glacier so that its ELA may be taken to be a climatic snowline. Considering also the largely SW-exposed SW Simbua glacier, a mean climatic ELA of 4275 m and thus a depression of 1320 m, derives.

Glaciation at Glacial Maximum

The maximum glacial ice terminal at 890 m lies 610 m below that of the Ghasa stadium (I) with a horizontal distance of 19 km. No end moraines occur in this section but traces of accumulation near the settlement of Marijam (near Hellok), only 350 m above the lower limit, suggest an intermediate terminal position between the settlements of Tapethok and Shirwa at 1380 m altitude. These are taken for the Pre-Ghasa ice stagnation (O ½) (cf Kuhle 1982: 153). The lowest maximum glacial terminal is witnessed by much higher marginal forms lying above Tapethok and Khejinim. Clear evidence for this are the slope polishings on the orographic left slope and the 'glacial mills' (potholes) 500 m up valley from Shirwa and above Midlung (Fig 6). A further 1.5 km in from the end moraine on the orographic left are striae and roches moutonnées up to 250 m above the valley bottom (Fig 7).

Fig 6 Looking north up valley into a trough of glacial origin on whose slopes can be seen many glacial striae. In the foreground can be seen sub-glacial meltwaterforms such as eddy-produced hollows in the massive gneissic rocks on the left slope 50 m above the floor of the Tamur valley 500 m above the settlement of Shirwa at 1400 to 1420 m. (Photo: M. Kuhle, 26. 12. 88)

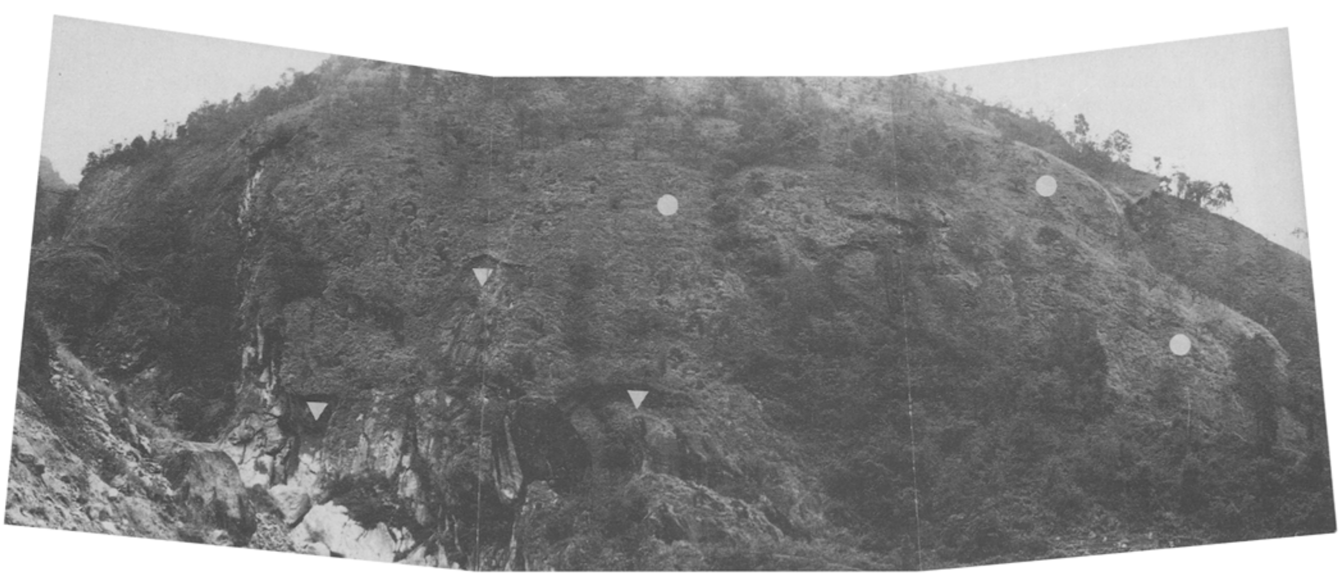


Fig 7 View from 960 m toward the SE 1,5 km up valley from the ice terminal at Thoma and outward from the settlement Midlung to the extensive roches moutonnées and glacial striae on the left flank of the Tamur valley. The valley floor is at 900 m and the striae reach at least 250 m above it (OO). At present linear erosion by the tributary valley entering from the east (the left bank) undercuts these erosive features and induces late incisions (▽▽) and sharp V-shaped gulleys with abrupt steep rock walls in contrast to the smooth roches moutonnées today covered with forest or pasture with dwarf shrubs (OO). (Photo: M. Kuhle, 26. 1. 89)

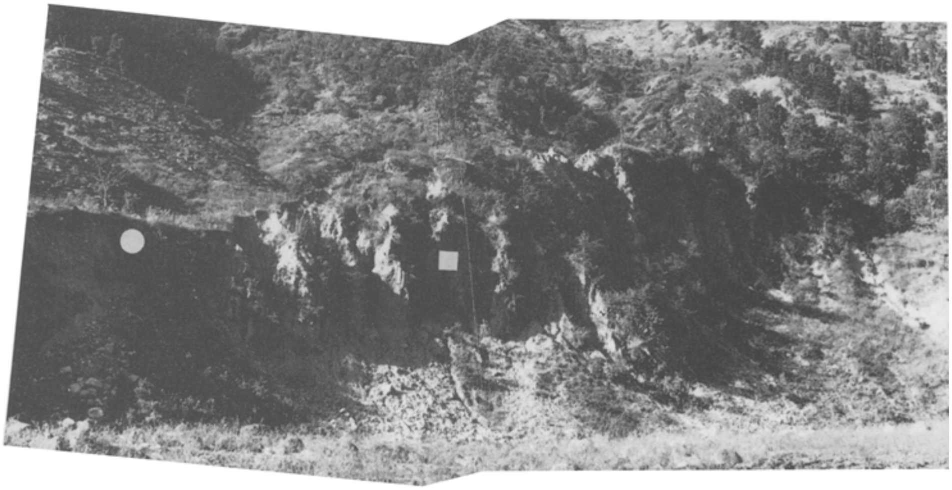


Fig 8
Marginal and end moraines in the glacial tongue basin at Thoma some 40 to 120 m high on its orographic right margin. The moraines are based at a bare 890 m asl. The interior slope of these maximal glacial (Würm) moraines (□) are dissected into earth pyramids. TL samples were obtained here. In association with the ice margin and morainic accumulations there are glacifluvial deposits (○) forming smooth terraces. The former ice margin is better witnessed here by this direct contact of glacigenic diamictite (largely from acid crystalline rocks) with material classified as glacifluvial than by the moraines alone.
(Photo: M. Kuhle, 24. 12. 88)

The maximum glacial terminus reaches to the hanging bridge at Thoma (890 m asl). It is just as clear as the historical terminal positions in the Alps and, in a well developed glacial tongue basin, includes moraines 40–120 m high and classical earth pyramids (Fig 8). There are polished features a further 1.2 km down valley but there are no clear suggestions of morainic remains there. There is little importance to be attached to an only slightly lower ice limit at 1.2 km distance for the determination of the ELA. In view of the considerable altitude of the confluence region (6900 m) the ELA calculated from the ice terminal at Thoma (Thumma, 890 m asl) of 3900 m represents an equilibrium snow line depression of 1660 m. The maximum glacial network of ice streams of the Tamur with its dendritic valley glacier system with components of maximum length of 75–80 km also functioned as the outlet system for south-Tibetan ice north of the main range of the Himalayas; the glaciers in it reached a thickness of more than 1000 m (cf. Kuhle 1982: 57–63).

Conclusion and Comparative Summary (Fig 9)

The present-day climatic ELA (equilibrium line altitude) in the Kangchendzönga group lies at 5560 m, about 10–70 m higher than in the central Himalayas (Dhaulagiri-Himal, 450 km to the west; Kuhle 1980: 246; 1982: 168). The difference in exposure between the southern and northern sides i.e. between windward and leeward sides of the Himalayas and southern Tibet results in an ELA difference of 70 m (i.e. 5650 m versus 5720 m asl). This windward/leeward effect can be recognised in the whole arc of the central Himalayas. This overcompensation for the difference in solar exposure was lacking when the monsoon was weaker or even failed during the glacial maximum. The depression of the equilibrium line then of 1660 m (down to 3900 m) is the largest calculated depression so far found for the whole mountain system (the value found in the western Himalayas was 1630 m at the most); to this corresponds the low altitude of the lowest-standing glacial tongues at 890 m asl. It is interesting to compare the second lowest last glaciation ice terminal at 980 m 2500 km to the west in the Indus valley (Kuhle 1988b: 606). Since it is ten times drier there than in the eastern Himalayas (the monsoon being absent) the similar extension of glaciers in spite of this is an indicator of the lack of monsoon during the glacial period. If a lapse rate of 0.6° C/100 m is used the observed ELA depression allows the reduction of summer temperature to be calculated as at least 9.6° C; the very probable reduction of precipitation clearly suggests an even greater cooling than this.

References

Kuhle, M.: Klimageomorphologische Untersuchungen in der Dhaulagiri- und Annapurna-Gruppe (Zentraler Himalaya). Tagungsber. u. wiss. Abhandl. 42. Dt. Geographentag Göttingen. S. 244–247, Wiesbaden 1980.

Kuhle, M.: Der Dhaulagiri- und Annapurna-Himalaya. Ein Beitrag zur Geomorphologie extremer Hochgebirge. Zeitschr. f. Geomorph., Suppl. Bd. 41, 1 u. 2, S. 1–229, Abb. 1–184. Berlin-Stuttgart (1982)

Kuhle, M.: Former Glacial Stades in the Mountain Areas Surrounding Tibet in the Himalayas (27°–29° N: Dhaulagiri, Annapurna, Cho Oyu and Gyanchung Kang areas) in the South and in the Kuen Lun and Quilian Shan (34°–38° N: Animachin, Kakitu) in the North. In: Joshi (ed.): Nepal Himalaya: Geoecological Perspectives. p. 437–473. New Delhi 1986.

Kuhle, M.: Absolute Datierungen zur jüngeren Gletschergeschichte im Mt. Everest-Gebiet und die mathematische Korrektur von Schneegrenzberechnungen. Tagungsber. u. wiss. Abh. 45. Dt. Geographentag Berlin. S. 200–208. Stuttgart 1987.

Kuhle, M.: Geomorphological Findings on the Build-up of Pleistocene Glaciation in Southern Tibet, and on the Problem of Inland Ice. GeoJournal 17,4, 457–511 (1988a)

Kuhle, M.: Neueste Physisch-geographische Forschungsergebnisse aus Hochtibet und angrenzenden Gebieten. Tagungsber. und wiss. Abh. 46. Dt. Geographentag München. S. 605–607. Stuttgart 1988b.

Kuhle, M.; Herterich, K.; Calov, R.: On the Ice Age Glaciation of the Tibetan Highlands and its Transformation into a 3-d Model. GeoJournal 19,2, 201–206 (1989)

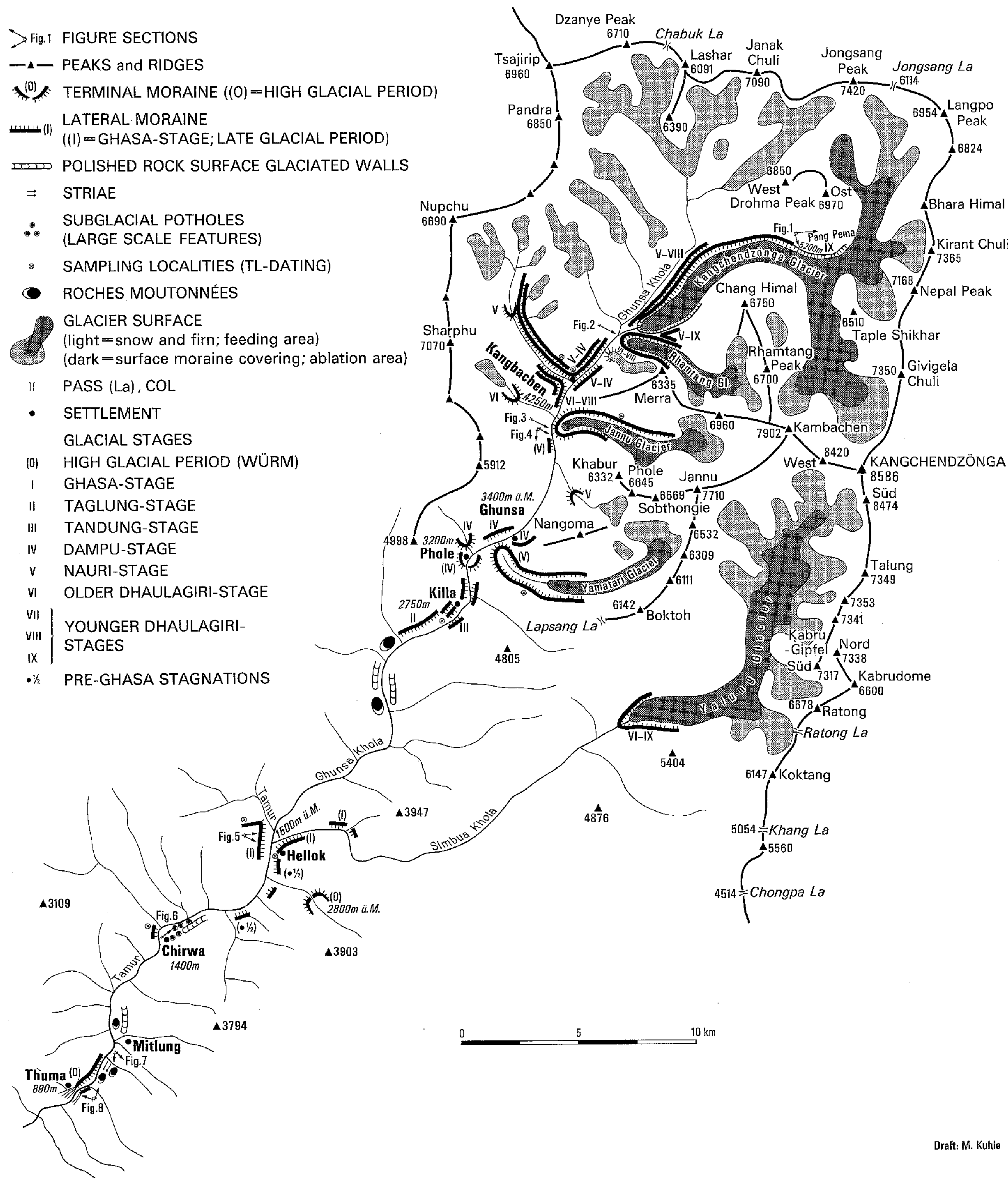


Fig 9 Glacio-morphological scetch of the Kangchendzönga-massif (E-Himalayas)