New Indicators of a Former Tibetan Ice Sheet and an Ice Stream Network in the Surrounding Mountain Systems: New Field Observations and Dating on the SE-, S- and W-margin of Tibet from Expeditions in 2004-2009

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Great Karakoram: South side

In 2006 detailed researches between the Skardu basin and the source branches of the Hushe valley showed that 600 up to 2500m above the current gravel floors of the main valley and the present glacier surfaces, ground moraine covers on the valley flanks and even glacier polishings (35°30'52"N 76°20'20"E) are preserved up to abrasion and polish lines. In the left flank of the Ghondokhoro glacier valley sedimentary remnants of ground moraine (35°33'30"N/76°25'E) are preserved up to 4480 m, whilst flank polishings occurred up to at least 5000 m; trough profile lines were found even higher. In the confluence area of the Charakusa glacier valley, on the flanks of the Masherbrum and Aling glacier valley (35°29'15"N 76°19'E), corresponding findings prove a maximum former valley glacier level. Down-valley of the Hushe settlement key glacigenic forms (35°24'10"N/76°21'30"E) up to c. 5400 m document an ice thickness of 2000 m. 30 km down the Hushe valley, in the confluence area with the Saltoro- and Shyok valley, ground moraines with erratics and polishings (35°16'N/76°24'E) on all valley flanks evidence an ice thickness of c. 1700 m above the 5 km wide gravel floor of the river during the last glacial period (LGP), plus a valley bottom filled with loose sediments more than 500 m-thick. 20 km down the Shyok main valley there was the Ice Age inflow of the Thalle glacier branch near the Bragar settlement. 33 km further down the past Shyok glacier a confluence occurred with the largest main glacier, the Indus glacier. Coming from the SE, it flowed down from the valley chamber of Kargil, where the Suru glacier joined from the S, from the Zanskar (Kuhle 1998). Glaciogeomorphological evidence (34°38'N/74°58'E) suggests a c. 1500 m thick, 25 km long Indus parent glacier from this Shyok glacier confluence up to the Indus valley near Skardu. With that, the S-side of the Masherbrum-range has been reconstructed as one part of the c. 125,000 km² extended Karakoram-ice stream network. Near Skardu there was inflow of the 2000 m-thick Shigar glacier with the feeding areas of the Braldu (LGP-Baltoro) and Basna (LGP-Chogolungma) glaciers (Kuhle 2001). The comparison of glacial-geological and glaciological relative dating with cosmogenic nuclide (CN)-tests and of ^{14}C- with OSL-data prove an LGP-ice-stream-network during the Marine Isotope Stage (MIS) 3-2 (Kuhle 2010, Hewitt 2009).

Dolpo

Research in the Bheri Khola began in 1995 (Kuhle, 1998) and ended in the Barbung Khola, N of the Dhaulagiri Himal and Dolpo (Kanjiroba, Do Tarap). Up-valley of Tripurakot (29°02'N/82°46'E), with a minimum ice thickness of 400 m and a height of the thalweg of 1900 m (Kuhle 1998), the valley flanks of the Bheri Khola that to the E passes into the Barbung Khola and those of its side valleys (Suli Gad, Tarap Chu etc.) are mantled by large-scale ground moraine covers with erratic material up to 4400 m (e.g. in the Barbung Khola above Seri) (28°53'N/83°21'30"E). In the middle Suri Gad (3200 m) there are more than 100 m-thick ground moraines. Below the Poksundo Tso they are dovetailed with Late Glacial end moraines of Stages III and IV. The Poksundo Tso itself has been dammed up by such an end moraine. In the Chhura Khola between Bagla and Numla and in the upper Tarap Chu, in the wide S-Tibetan valley of Dho, large-scale ground moraine covers may derive from a relief-filling glaciation. The Tarap gorge up to Khanigau (inflow of the Barbung Khola) was filled with ground moraine more than 100 m thick. The accompanying LGP- ice level runs up to 4800 m. From the valley of Kakkot down the Barbung Khola, as far as the Tarap Chu, over 200 m-thick ground moraine does occur. Lake sediments 500 m above the thalweg (28°52'50"N/83°09'20"E) prove a Late Glacial lateral valley (Stage IV) at 3700 m. Near Kakkot LGP-ground moraine covers and polish bands reach c. 4600 m. Thus, a further section of the S-Tibetan ice stream network - here W of the upper Thak Khola - is reconstructed in detail.

Damodar Himal

Research started in 2004 between Mustang (in the W) and Dhud Khola (Manaslu) and in 2007 in all main valleys and their catchment areas. On both sides of the Pangri glacier remnants of ground moraine covers

were mapped at high slope positions. The same applies to the upper Phu Khola - today a large-scale non-glaciated region - with its plane S-Tibetan morphology. Abrasion forms (e.g. at 28°48'50"N/84°19'E) prove that the LGP-glaciers of both the valleys must have had a connected ice level at over 5400 m asl. A more than 1000 m-thick main valley glaciation down the Phu Khola as far as Metagau is evidenced by moraines, flank abrasions and glacier polishings. Erratic material, ground moraines and abrasion forms on the flanks of the Labse- and Kangla Khola confirm an Ice Age ice infilling up to c. 4800 m asl in the confluence area of all three main valleys between Kanguru and Jong Ri (Pisang Peak). The valley head of the Kangla Khola, a truncated valley at 5350 m, shows all characteristics of a transfluence pass. Here, an ice transfluence into the Marsyandi Khola or from there into the Kangla Khola has taken place (Kuhle 1998). The gorge between Metagau and Koto was filled with ground moraine up to 300 m above the current thalweg, so that in the Late Glacial the Naur Khola-parent glacier must have flowed down on a trough-shaped ground moraine layer, the surface of which continues without any steps on that one of the Marsyandi Khola parent glacier (Kuhle, 1998) down-valley between Chame and Thonche.

SE-Tibet between Tsangpo- and Yalong River

In 1989 glaciological investigations started on Namche Bawar in the area of the Tsangpo transverse gorge; in 2000 they continued from the E, from the Dadu- up to the Yalong- and Litang River (Kuhle 1998, 2001) and ended between Namche Bawar and Litang River in 2009. They led to the following glacier reconstruction as to the LGP: in the left side valley of the Jangtsekiang from Yidun down to Yarwa ground moraines have been mapped on the slopes between c. 3000 and 3600 m. In the right side valley (Lanzang River) from Mangkam down to the Jangtsekiang at 2530 m (level of the thalweg), ground moraine and flank polishings on phyllites were mapped 300 m above the thalweg (29°43'N/98°58'E). A subglacial-glacigenic ravine in the valley ground at c. 2550 m and ground moraines on the slopes near Rongme prove an LGM-outlet glacier tongue in the Langcang valley (Mekong) down to at least 2000 m. The corresponding ELA was recorded by cirque bottoms facing S at 3500 m (29°34'N/98°18'E), i.e. below the heights of the Tibetan plateau. In this cross profile the huge, deeply incised western parallel valley with the Saluen River (Nu Jiang) at 2600 m shows enormous deposits of ground moraine up to over 1000 m up the valley slopes (30°03'N/97°22'E), so that a former outlet glacier terminus must have existed up to at least 2000 m. The watersheds between these valleys were locally glaciated with their catchment area being the Tibetan plateau that wascovered by ice above 3500 m (Kuhle 1998). N of Namche Bawar ground moraines are situated down to at least 2000 m (30°01'30"N/ 95°04'E) showing a connected ice-stream network for the steeply cut marginal mountains. These new field findings and laboratory results provide further evidence as to the existence of the Tibetan inland ice (Tibetan Ice Sheet) and its outlet glaciers during MIS 3-2 in places down to 1000 m asl.

Calibration of TCN-data

Quaternary-geological and glaciological (ELA-calculations) assessment of CN (TCN)-data and their control by ^{14}C-datings on the S-margin of Tibet (Khumbu) showed that the CN (TCN)-datings carried out at a height of more than 4000 m are overestimated by a factor of 6.5, so that moraines formerly classified as belonging to the LGM are of neoglacial origin.

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