Glacial Geomorphology and Ice Ages in Tibet and surrounding mountains

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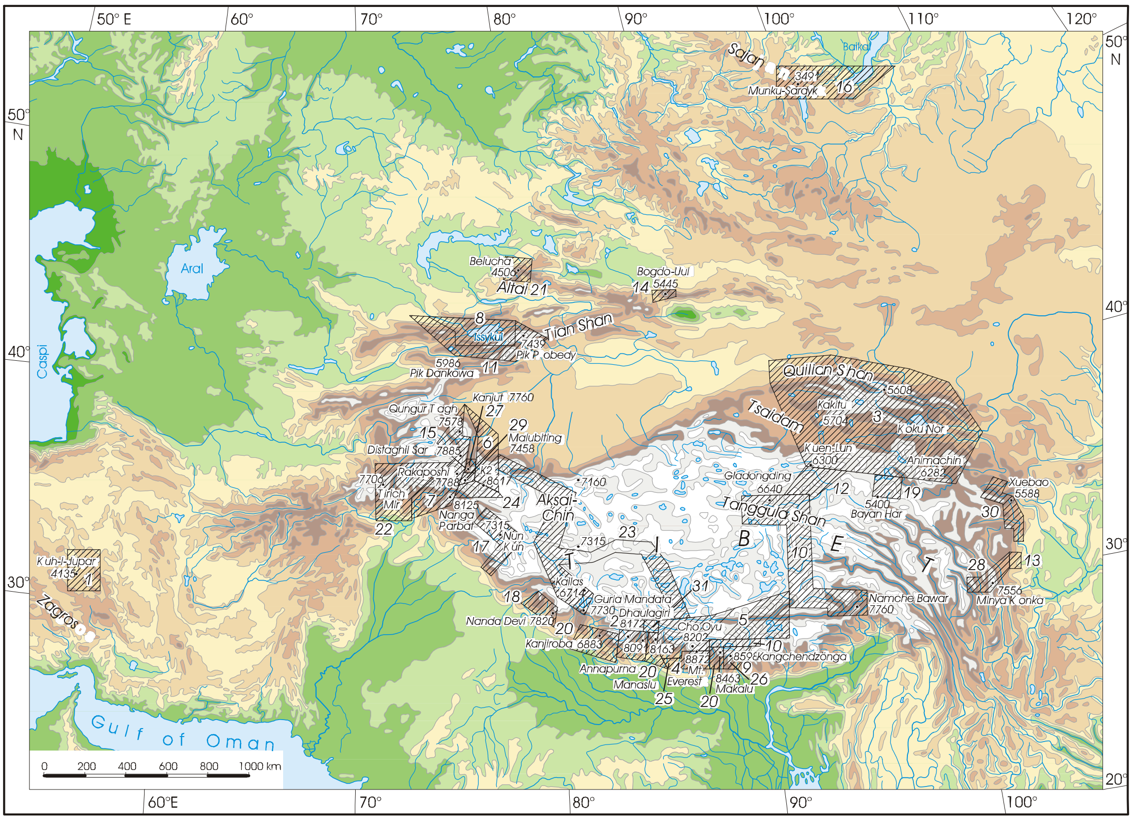
Evidence for an ice sheet covering Tibet during the Last Glacial Maximum (LGM: stage 3-2) means a radical rethinking about glaciation in the Northern Hemisphere. The ice sheet's subtropical latitude, vast size (2.4 million km²) and high elevation (~6000 m asl) (**Figure 2**) caused a substantial, albedo-induced cooling of the Earth's atmosphere and the disruption of summer monsoon circulation. The uplift of Tibet and the reaching of specific threshold values of plateau elevation being synchronous with the onset of the ice ages at ~2.8 Ma B.P. and their intensification from ~1 Ma B.P. onwards, a causal link between these factors seems likely.

During 35 campaigns of field investigations (**Figure 1**), the ice-age inland glaciation of Tibet has been reconstructed on the basis of classical glacigenic forms of erosion and accumulation as well as on its accompanying sediments and the arrangement of the positions. Absolute datings obtained by different methods classify this glaciation as being from the LGM. With the help of 13 climate measuring stations, radiation and radiation balance measurements have been carried out between 3300 and 6650 m asl in Tibet. They indicate that the subtropical global radiation reaches its highest energies on the High Plateau, thus making Tibet today's most important heating surface of the atmosphere. At glacial times 70% of those energies were reflected into space by the snow and firn of the 2.4 million km² extended glacier area covering the upland. As a result, 32% of the entire global cooling during the ice ages, determined by the albedo, was brought about by this area– now the most significant cooling surface. The uplift of Tibet to a high altitude about 2.8 Ma ago, coincides with the commencement of the Quaternary Ice Ages. When the Plateau was lifted above the snowline (=ELA) and glaciated, this cooling effect gave rise to the global depression of the snowline and to the first Ice Age. The interglacial periods are explained by the glacial-isostatic lowering of Tibet by 650 m, having the effect that the initial Tibet ice, which had evoked the build-up of the much more extended lowland ices, could completely melt away in a period of positive radiation anomalies. The next ice age begins, when – because of the glacial-isostatic reveres uplift – the surface of the Plateau has again reached the snowline. This explains, why



1: 1973, 1974 2: 1976, 1977, 1995, 1998, 2000, 2002 3: 1981, 1998 4: 1982, 2003 5: 1984 6: 1986 7: 1987, 1992, 1995, 2000 8: 1988 9: 1988/89 10: 1989 11: 1991 12: 1991 13: 1984, 1991 14: 1986, 1992 15: 1992 16: 1993 17: 1993, 1996 18: 1993, 2004 19: 1994 20: 1994/95, 2000 21: 1995 22: 1995 23: 1996 24: 1997 25: 1998 26: 1999 27: 1999, 2000 28: 2000 29: 2000 30: 2002 31: 2004

Draf: M. Kuhle (2004)

FIGURE 1. The areas in Tibet and High Asia under investigation by the author since 1973

the orbital variations (MILANKOVIC- theory 1941) could only have a modifying effect on the Quaternary climate dynamic, but were not primarily time-giving: as long as Tibet does not glaciate automatically by rising above the snowline, the depression in temperature is not sufficient for initiating a worldwide ice age; if Tibet is glaciated, but not yet lowered isostatically, a warming-up by 4°C might be able to cause an important loss in surface but no deglaciation, so that its cooling effect remains in a maximum intensity. Only a glaciation of the Plateau lowered by isostasy, can be removed through a sufficiently strong warming phase, so that interglacial climate conditions are prevailing until a renewed uplift of Tibet sets in up to the altitude of glaciation. The chronology of a Tibetan glaciation since ~2.8 Ma B.P. and its intensification since ~1 Ma B.P. has been confirmed by the weakening of the summer monsoon and the intensification of the Asian winter monsoon respectively, which have been evidenced by marine sediment drillings and loess records. Altogether in High Asia at least 13 further glacier positions have been evidenced, including an oldest Riá-position (pre-last High Glacial maximum). They concern a lowest Wurmian ice margin position (Stage 3-2) with ELA-depressions from 1100 to 1300 m, 4 to 6 Late Glacial ice margin positions with ELA-depressions from 1100 to 700 m, 3 neoglacial ice margin positions with ELA-depressions from 300 to 80 m and 6 historical ice margin positions including the current glacier margin with only insignificant snowline depressions of less than 80 m. The geomorphological observation of the moraines in the field was confirmed by more than 1000 petrographical, granulometrical and morphoscopical analyses of sediment samples. All absolute datings were younger than 47 Ka.

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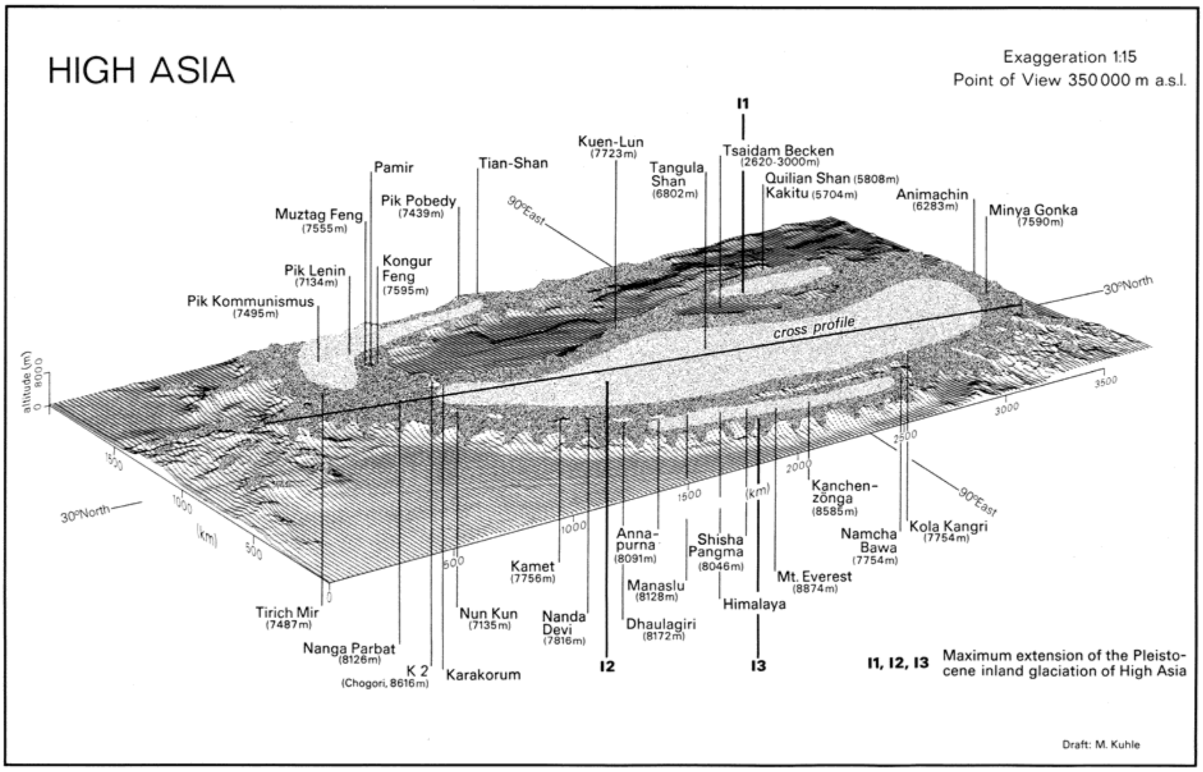

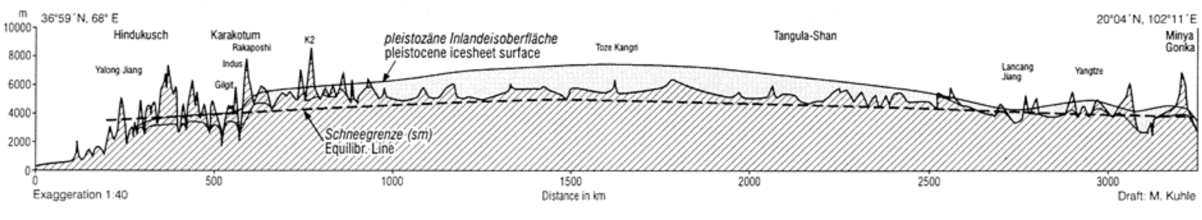

FIGURE 2. (Top) Reconstructed 2.4 million km^2 ice sheet, or ice stream network, covering the Tibetan plateau (Kuhle (1980, 1982a, 1982c, 1985, 1987a,b, 1988c,d, 1990d, 1991a,b,1993, 1994, 1995b, 996a,b, 1997, 1998, 1999, 2001, 2003, 2004) with three centres I1, I2, I3. Only peaks higher than 6000 m rise above the ice surface.(Bottom) Cross profile of the central ice sheet from Hindu Kush in the west to Minya Gonka in the east.