Recent geomorphological processes in the Nagar region, Hunza Karakoram

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1. Introduction

Landforms in the Himalaya and the Karakoram provide evidence for the nature of very dynamic landscape evolution. The Himalaya and the Karakoram are in the collision zone of the Indian and Asian plates (Searle, 1991; Zanchi, Gritti, 1996; Searle et al., 1999 and others) where the orogenic movements are still very active. The challenge of searching for landform development as the geomorphological record of active orogeny (Owen, 1989; Kalvoda, 1992; Fielding, 1996) is in the Hunza Karakoram traditionally integrated with the investigation of recent climate-morphogenetic changes of relief and landscape patterns (Paffen et al., 1956; Schneider, 1959, Wiche, 1959; Goudie et al., 1984a; Li-Jijun et al., 1984; Finsterwalder, 1996). The nature of the Hunza Karakoram has been studied for more than a century (comp. e.g. Finsterwalder, 1989). The first observations of glaciers (Workman, Workman, 1910; Mason, 1929, 1930, 1935) indicated the extraordinary features of natural hazards in the Karakoram (Hewitt 1968, 1969, 1988; Gardner, Hewitt, 1990; Kuhle et al., 1998). The other topics of the research in the Hunza Karakoram have been the dynamics of glaciers (e.g. Zhang Xiansong, Shi Yafeng, 1980; Dong Biu et al., 1984; Goudie et al., 1984b; Oswald, 1984; Kalvoda, 1987), and, especially, glacial history in the Quaternary (Derbyshire et al., 1984; Kuhle, 1988a, b, 2001; Xu, 1991; Meiners, 1997, 2001; Owen et al., 2002). These studies are also connected with the Late Glacial and Post Glacial sedimentary record of geomorphological processes (Derbyshire, Owen, 1990; Iturrizaga, 1999, 2001) and very high erosion rates (Foster et al., 1994; Bhutiyani, 2000; Shroder, Bishop, 2000) in the Karakoram and western Himalaya.

The Nagar region is situated between the Hunza River and the Hispar glacier in the morpho-tectonically conspicuous Karakoram suture zone. Observations of landform patterns of peculiar relief types between the Distaghil Shar (7 886 m) and Hunza valley (2 000 m) suggest extremely high rates of denudation, sediment transfer and deposition (Ferguson, 1984; Whalley et al., 1984; Kalvoda, 1990). The vertical hierarchy of variable high-mountain reliefs is striking (Hewitt, 1989; Owen, Derbyshire, 1989; Derbyshire, 1996) which ranges from the extremely cold extraglacial ridges of the Great Karakoram Range through the heavily glaciated and periglacial areas to the seasonally cold/warm humid and/or semiarid Bualtar, Nagar and Hunza valleys. Distinctive vertical climatic zoning also influences variable features of morphostructural and lithological control of characteristic weathering phenomena (Cílek, Kalvoda, 1983; Goudie, 1984; Waragai, 1999).

Research on the present-day landforms and the main features of climate-morphogenetic processes and phenomena in the Hunza Karakoram (Goudie, Kalvoda 2004) gives evidence for 1) recent evolution of extremely dissected high-mountain relief, and 2) present-day natural hazards and risks. These aspects of the geomorphology of the Nagar area in the Hunza Karakoram can also contribute to the knowledge of a long-term integration of climate-driven morphogenetic and active tectonic processes in dynamically evolving mountainous regions of collision orogeny.

2. Recent climate-morphogenetic processes

Recent climate-driven morphogenetic processes can be described in the framework of extraglacial (Photos 1–4) and glacial (Photos 5–8) zones, the periglacial zone (Photos 9–13) and seasonally cold/warm humid and/or semiarid zones (Photos 14–16). The extraglacial high-mountain zone with a rock-cut landscape of alpine-type ridges (Photos 1, 4, 13) displays a dynamic integration of deep weathering with major glacial and nival morphogenetic processes (Photo 2, 7, 8). Gentle lithological and fracture control of georelief on the crystalline rocks is suppressed in these areas and, on the contrary, its presence is conspicuous at lower lying large slopes (Photos 9–10) and in the periglacial zone (Photos 11, 12).

Snow- and ice free debris in the glacial zone above 5 000 m a.s.l. has often a typical red-brown colour which is very well known from cold deserts and/or semi-deserts. Weathering rings were described by Cílek and Kalvoda (1983) with a depth of several cm. Deep frost weathering increases pore volume and therefore also susceptibility to moisture due to sunshine in the day. The intensity and duration of temperatures below freezing point led to deep rock disintegration and macrogelivation (Photos 3, 4). By contrast, shallow freeze-thaw cycles are effective for microgelivation.

The valleys and ridges of the Hispar Karakoram are overfilled with glacier masses in high altitudes above ca 6 000 m a.s.l. (Photos 5, 12). However, large ice source areas often contrast with very narrow canyon-like lower parts of valleys (Photos 10–13). The recent rapid retreat of the glaciers (Photos 6, 10, 14) is accompanied by a distinctive increasing of the active periglacial zone which is a dominant phenomenon of the present-day changes of landform patterns. It raises not only the volume of transported products of denudation (Photos 11, 16), but in this rugged landscape also the level of geomorphological hazards, including frequent and extremely risky high-magnitude rapid events of mass movements triggered by earthquakes, glacier surging, avalanches, flash floods and landslides.

The Hunza Karakoram is a region of frequent natural disasters (Photos 8, 15) with high risks involved in all types of human activities. It was Kenneth Mason (Professor of Geography at Oxford University and Fellow of Hertford College) who described the extremely dangerous process of glacier surging and rapid advance of the tongue of the side-glaciers in the Hispar Karakoram region more than 75 years ago. Also a large area of Nagar oasis originated on fossil landslide and glacier accumulations with recent large slope movements.

3. Dynamics of erosion and exhumation of rocks related to morphotectonic processes

The geomorphological analysis of landform patterns in the Nagar region of the Karakoram related to morphotectonic features of relief-building processes in the Late Cenozoic can also be used for an evaluation of the dynamics of erosion and exhumation of rocks during ongoing collision orogeny.

The denudation of the near-surface part of Great Karakoram rocks from the Neogene to the present time is caused by their orogenic uplift as well as global or regional changes of climate. The recent landform changes are a consequence of the high intensity of climate-driven morphogenetic processes with very effective erosion and transport of weathered material in periglacial and seasonally cold/warm mountain zones. This phenomenon is in a striking contrast to the relatively small range of long-term denudation and transport of weathered material in the northern cold and semi-arid climatic region of Tibet (Fielding 1996).

Foster et al. (1994) studied apatite separated from samples collected from elevations of 5 300 to 8 611 m in the K2 region of the Baltoro glacier. The apatite yielded fission-track ages of 2.1 ± 0.6 to 4.3 ± 1.4 Ma, and suggest an initial, apparent denudation rate of 3–6 mm/yr commencing after 5 Ma. One zircon from 6 600 m gave a mean fission-track age of 32 ± 6 Ma. The mid-Tertiary zircon age delimits the maximum amount of Pliocene denudation to 7 000 m. The total amount of denudation at the present mean surface elevation of approximately 6 000 m was estimated to be approximately 6 000 m.

Shroder and Bishop (2000) thought that rapid erosional unroofing of the Nanga Parbat Massif was initiated at 12–10 Ma. Averaged rates of maximum incision from areal denudation for mass movements, glacial and river erosion for the past ca 55 ka are recorded between 2.2 and 1.1 cm/yr. Similarly as in these (above mentioned) neighbouring regions, a striking phenomenon of the Hunza Karakoram is that the oldest relics of sediments in protected accumulation landforms are younger than 2×10^5 years but most of them are from Upper Pleistocene time and younger than 50×10^3 years. On the contrary, the total amount of denudation at present-day rugged high-mountain georelief (Photos 12, 13) can be estimated at approximately 6 000 m per 1 Ma.

The dynamics of recent geomorphological processes in vertical climate-morphogenetic zones of the Nagar region shows that glacial, nival and cryogenic processes are very effective at destroying the rock massif uplifted during collision orogeny. However, rapid unroofing and exhumation of deeper parts of the rock massifs needs also vigorous transport agencies, e.g. transgression of glaciers and intensive activity of winds in extraglacial and glacial zones and/or rapid action of water in periglacial and seasonally cold/warm zones.

4. Conclusions

The high intensity of recent denudation and transport of weathered and eroded material correlates with a striking absence of older Quaternary sediments and suggests a long-term influence of these geomorphological processes on the exhumation of deeper parts of the Earth's crust and the dynamics of orogenic uplifts of the Karakoram. It also is suggested that extreme exhumation of deep crystalline rocks in the Hunza Karakoram is the result of morphotectonic processes as well as effective tuning of paleogeographical changes in extension of the main climate-morphogenetic zones during the Late Cenozoic.

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Photos 1–16 by Jan Kalvoda

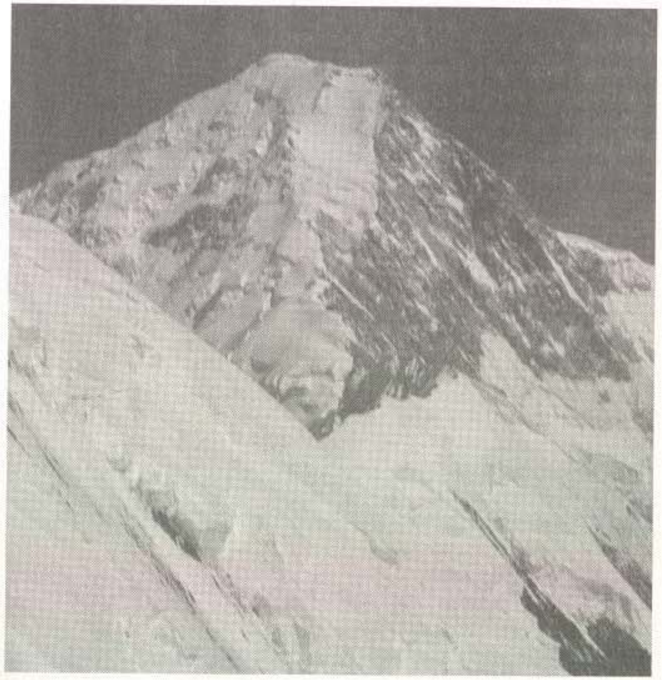

Photo 1 Detachment area of snow- and ice avalanches from granodiorite rock-slopes of the summit crest of the Trivor Massif (7 728 m) deeply weathered by frost and covered by hanging glaciers

Photo 2 Fresh snow and ice masses in the catchment area of the Gharesa glacier are accumulated in a set of small cirques above 6 000 m a.s.l. These cirques are divided by sharp ridges and pillars built by very fractured crystalline rocks of the Great Karakoram Range

Photo 3 Extremely dissected high-mountain relief with conspicuous morphostructural features in the contiguous zone of the Great Karakoram Range with Haramosh and Malubiting Massifs (7 458 m) of the northwestern Himalaya

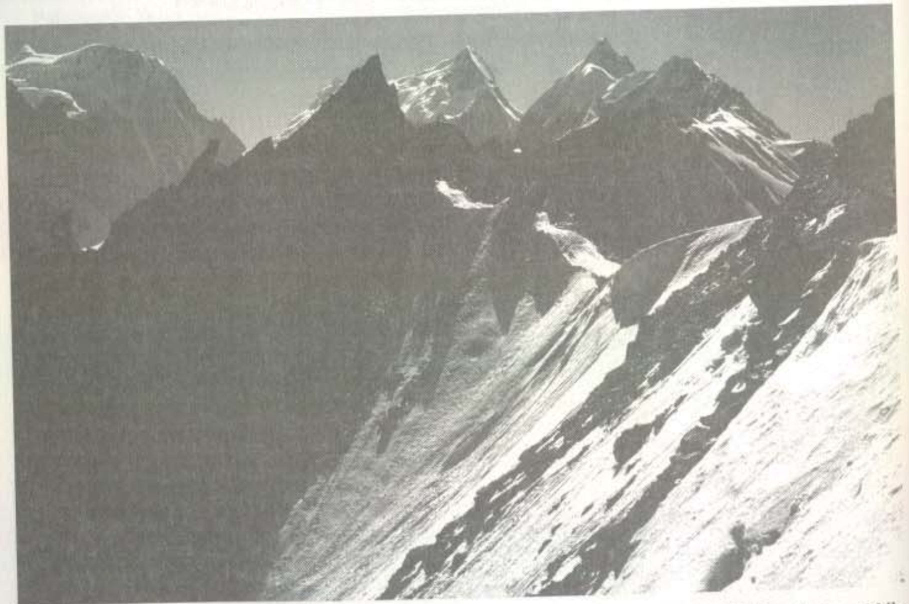

Photo 4 Strongly glaciated ridges of crystalline rocks of the Distaghil Shar Massif (7 886 m, in the middle of horizon) are surrounded by long crests with steep cliffs cryogenically weathered up to depths of several metres and partly covered by block eluvium and diluvium

Photo 5 Broad cirque floors filled with ice- and snow masses (5 800–6 200 m a.s.l.) of the western catchment area of the Trivor Massif under heavily glaciated mountain crests

Photo 6 The Lupar Shar Massif (7 220 m), east of the Hunza valley with series of hanging glaciers feeding the Lupar Shar valley glacier, is built of lightest granodiorites and black gneisses of the Great Karakoram Range. The surface moraine of the valley glacier is formed by colour-diverse stripes of disintegrated crystalline rocks. Light-coloured are granitic rocks, darker gneisses and grey black schists

Photo 7 Detachment area of avalanches and rockfalls in the zone of hanging and slope glaciers of the granodiorite and gneiss walls south of the nameless peak of elevation point 7 000 m a.s.l. in the Hispar Mustagh region

Photo 8 Detail of detachment planes of a hanging glacier on granodiorite crest (6 000–6 400 m a.s.l.) southwest of the Distaghil Shar Massif

Photo 9 Retreating slope glacier with its terminus at 5 000 m a.s.l. positioned above the middle part of the Gharesa glacier on recently exhumed rocky slopes of gneisses with large features of exfoliation

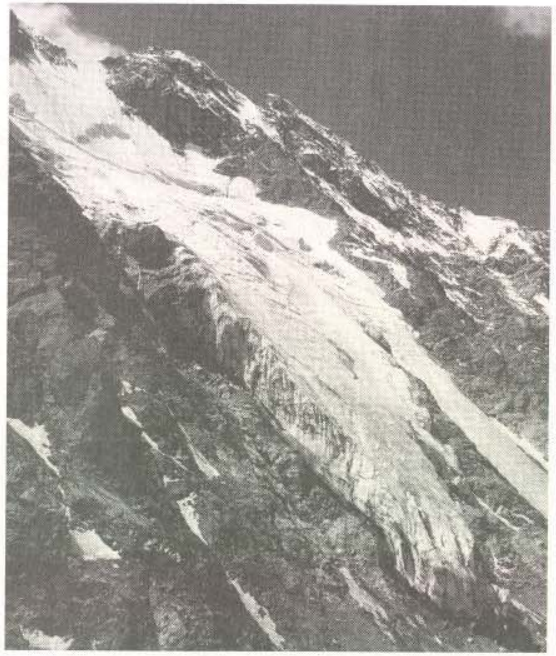

Photo 10 The lower part of the Gharesa glacier (3 800–4 000 m a.s.l.) displaying a system of glacigenous, periglacial and slope sediments. The highest right lateral moraine is of Upper Pleistocene age. The Holocene decreasing of glacier volume with recent retreat of its terminus and lithologically different surface moraines is striking (comp. explanation of the Photo 5). In the background, the Batura Massif (7 980 m) above the canyon-like Hunza valley is conspicuous. (Note: Professor Kenneth Mason from the School of Geography and Fellow of the Hertford College in Oxford surveyed the lower crest on the picture (in the middle) and Hispar valley more than 75 years ago.)

Photo 11 Deeply weathered rocky slopes on granodiorites in the periglacial semiarid zone above the terminus of the Gharesa glacier rimmed by a right lateral moraine of Upper Pleistocene age. Relics of the moraine are partly covered by massive talus scree and gently modelled by occasional erosion by water from thawing snow

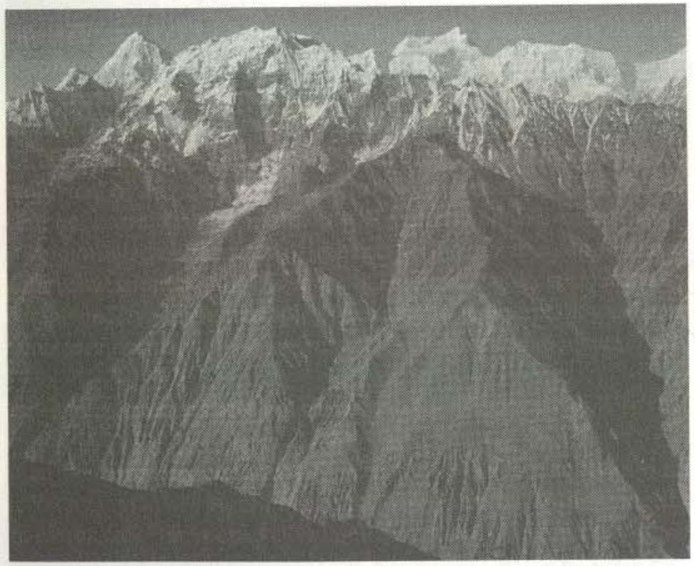

Photo 12 Conspicuous vertical climate-driven morphogenetic zoning of the high-mountain relief between the Hispar valley and Malubiting Massif (7 458 m) originated on different lithological and morphostructural units. In the background (right), the Yengutz Har Peak (7 027 m) is built of Paleogene sandstones, limestones and quartzites. Alpine-type crests above the Hispar valley are formed on the Upper Paleozoic gneisses, micaschists and marbles

Photo 13 Extremely dissected rock relief of the Chogo Lungma ridge (7 000 m) in the Hispar Mustagh region was developed by the integration of orogenetic uplifts with rapid climate-morphogenetic processes in the Late Cenozoic. Glaciated ridges consist mainly of crystalline limestones and dolomites, gneisses and amphibolites of Mesozoic age, large lower slopes are formed on limestones, marbles and gneisses

Photo 14 Glacigenous sediments of the lower part of the Bualtar glacier tongue north of the Malubiting Massif and very close to Nagar village. Huge walls of lateral moraines, in some sites up to 160 m high, originated in the last advance of the valley glacier in the Upper Pleistocene. These moraines are in front of the present-day terminus of the main glacier deeply eroded by the Hispar and Bualtar rivers

Photo 15 Large planar landslide south of Nagar village with the relative height of the detachment area more than 400 m. The slope movements originated on the very steep denudational slope (30–40°), which consists of Cretaceous limestones, marbles and phyllites, in the recently abandoned part of the system of terraced agricultural fields

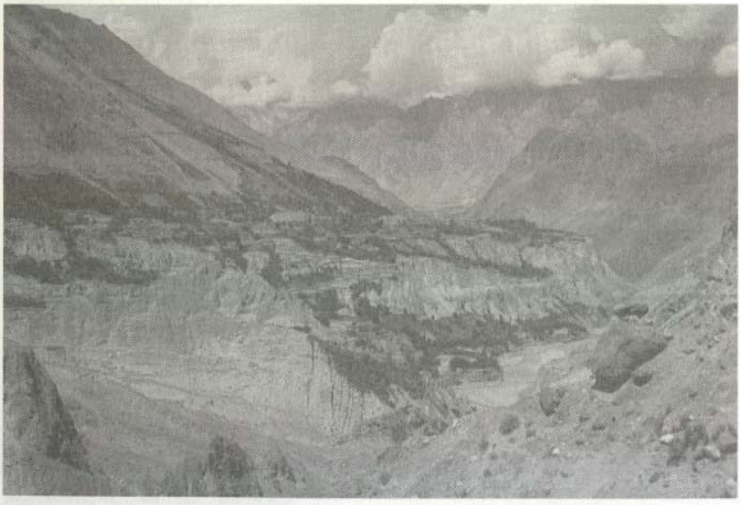

Photo 16 The lower part of the Hispar valley (in the seasonally cold/warm semiarid zone) is filled with a complex of glacigenous, fluvial and slope deposits of Upper Pleistocene to recent ages, reaching the thickness of over 200 m. In the background, the Hunza valley (2 000–2 200 m) appears under the eastern face of the Batura Massif (7 980 m)