The Use of Diachronic Sets of Photographs in Geomorphology

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I remember when I met Corneille at Jomosom, in May 1974, and when the police officer told us, "You have a new French president". Corneille and I were both at the end of a long trip during which we were cut off from the outside world. Corneille was with Dobremez, just back from Dolpo; they were very tired and nearly starving. I had been working alone with my stones and sediments for several weeks in the Kali Gandaki area. I needed desperately to talk to someone. I was relieved and very pleased to meet them. The trip back to Pokhara was a highlight of my journey in Nepal. I learned a lot from them about the environment and the people of that country. I was particularly impressed by Corneille speaking Tibetan, either in the Tukuche gompa with monks, or along the trail when he gave a Khampa rider hell for nearly pushing me out into the roaring gorge of the Kali Gandaki. Although I have walked down the Kali Gandaki many times since, I still have very vivid memories of what I saw and discovered at that time with Corneille.

More than twenty years later, many things have changed in this area. Jomosom has become an important administrative and touristic place, at the crossing of several trekking trails. Lodges have popped up like mushrooms; the local economy has been boosted by the influx of Westerners; landuse patterns have diversified (more fruit trees and irrigated fields). Despite the tremendous development of aerial transport to Jomosom, the Kali Gandaki Valley is still a busy trekking road linking the arid Himalaya to the wet, hot, subtropical areas of the Pokhara Valley. Its importance has even been recently reinforced by the opening of the Baglung-Pokhara road, easily reached from Tatopani downstream, thus avoiding the long climb up to the Ghorepani pass.

However, other, more subtle changes have occurred along this ancient trekking road. These changes, related to superficial geomorphology (i.e., landforms), are usually not perceptible at human scale because they involve processes which occur over a much longer time scale than human life. Yet, in the central Himalaya of Nepal, the natural, erosional forces are so active that their impact can be assessed by comparing the same landscape observed at different times. Selected photographs taken from the same site provide a good record to estimate the nature and the magnitude of the change.

The first set of photographs illustrates the Kali Gandaki Valley looking upstream from the suspended bridge of Tatopani. The left one (1A) dates from May 1974 (with Corneille), and the right (1B) is

1A. The Kali Gandaki Valley in 1974 (view from the bridge of Tatopani)

1B. The Kali Gandaki Valley in 1994 (view from the bridge of Tatopani) from April 1994. The gorges there are very deep, with a difference in elevation of about 6000 m between the bottom of the valley (1100 m) and the Nilgiri Peak, partly visible in the background (6839 m). The landscape is marked by very steep, rocky walls, contrasting with a few alluvial, cobbly terraces built up by the Kali Gandaki only a few thousand years ago. The river flows in a narrow channel, and the zones without vegetation correspond to the level of high flow reached each year during the monsoon season. Villages and crops are located upon the terraces, the only flat and "safe" areas supposedly out of reach of floods (see 2A).

The comparison between the photographs 1A and 1B (i.e., an interval of 20 years) shows a major change — a debris cone — that has accumulated on the lower part of the left bank of the valley, thus diverting the course of the Kali Gandaki towards its right bank. The terraces of the left bank have been nearly buried under the debris. This event, which occurred during the 1993 monsoon, provided more material for the Kali Gandaki River to carry further downstream. However, the coarser bedload had been deposited shortly and not far from the debris slide, as can been seen in the foreground of photo 1B.

Other consequences of this type of event can be observed in the next set of photos. Photo 2A (taken in April 1994) illustrates the effects of the diversion of the main river caused by such debris accumulation. This photo represents the Kali Gandaki River (looking upstream) between the villages of Tatopani and Dana. The right bank of the river (on the left) has been severely eroded, thus displaying the coarse, bouldery and cobbly material that has built up the terrace landform. This erosion means that a significant part of the terrace (a few thousands cubic metres), and of the fields upon it, have disappeared into the river, being replaced by a new, major river bed where high flood channels are still visible. Since the event, the river has more or less reoccupied its former bed as shown in the upper right corner of the photo.

Photo 2B represents the same type of feature (an eroded bank of an alluvial terrace) several years after the occurrence of the event which had created it. The village of Tatopani, located upon the right bank terrace of the Kali Gandaki (photo taken in April 1994, looking upstream) was severely damaged during summer 1987, when the Kali Gandaki suffered from exceptional flooding caused by heavy and incessant rains between July 29 and August 1 (*Rising Nepal*, 6 August 1987). The swollen river triggered several landslides, which in turn diverted the river, causing the lateral erosion of the bank opposite the landslide (estimated eroded volume of the terrace of about 10, 000 cubic metres), and thus causing a large loss in Tatopani bazaar: the Dhopa bridge to Beni was damaged, eight houses together with the small hydro-electricity office were washed away, seventy people died. Compared to photo 2A, photo 2B shows how fast the recovery after such an event can be. After only seven years, Gramineae and small trees have grown along the scarp, making the boulders and cobbles hardly visible in some areas. The former flood plain of the Kali Gandaki is now temporarily re-occupied by people (a *goth* on the flat, sandy accumulation is visible in the central foreground). For those not familiar with this Himalayan environment, confusion might easily arise between these landforms and those at least several thousand years old. Yet, the absence of soil development provides good evidence for the recentness of the event.

Landforms on Himalayan slopes are thus constantly changing, either very imperceptibly as creep (a slow downslope movement of grain in soil or disintegrated rock) or more rapidly like landslides, which can be very destructive. Although there are frequently premonitory signs indicating that landslides might occur on a slope (for instance arcuated cracks, bending of tree trunks, scarplets), landslides fail most of the time instantaneously, and as such, represent a major threat to populations and settlements. A simple example was observed in September 1982 on the lower, left slope of the Modi Khola Valley, along the trail joining Birethanti and Chandrakhot: a debris slide/landslide had occurred one month before, following intense rainfalls during the monsoon season (photo 3A). The 10 m-high scar of the slide started just below the house (note the farmer stan-

2A. Erosional effects caused by the diversion of the Kali-Gandaki River (1994, April).

2B. An eroded bank of the Kali-Gandaki River, observed 7 years after the event which created it (1994, April).

ding in front of the house): the 3-to-4 upper meters were cut into the regolith (ferruginous soil and weathered bedrock) whereas the lower part of the scar displayed rocky outcrops of green schists. The displaced mass, a mixture of schist fragments and of vegetal debris, can be seen in the foreground. A new trail (right lower corner) has been established to avoid the unstable part of the slope.

3A. A small, yet common debris slide, affecting both the regolith and the bedrock, west of Chandrakot, Sept. 1982

3B. Same site as on 3A, 7 months later, March 1983. The house has been abandonned.

Six months later (March 1983, photo 3B), the house was abandoned, and the trail had to be moved again (swinging along the edge between the slide and the forest), because the landslide area had grown. When weathered, in fact, these schists become argillaceous, with a great ability to absorb water and thus to become viscous and even to liquefy as mud. As a result, the failure expands in size until a new slope equilibrium is found.

The occurrence of such failure was quite predictable indeed, because the entire slope is underlain by these green (chloritic) schists of the Lesser Himalaya (Pecher 1977), a bedrock among those most prone to mass wasting. Outcrops of chloritic schists are quite recognisable in landscape by the density of landslides like this one, either active or not. When I first climbed up this trail with Corneille in 1974, the slope was entirely cultivated and/or covered with trees, with apparently no evidence of active mass wasting process going on. Yet, the characteristic, undulated morphology, well delineated by the patterns of present terraced fields, was already clearly revealing the existence of "old" (undated) scars of ancient landslides that had since been stabilised.

The slope of Sikha represents one of the best example of this permanent instability that typically affects the slopes of the southern Himalaya. Located on the left bank of the Ghar Khola, a tributary of the Kali Gandaki, this 2000 m-high slope was until recently the major road linking Tatopani to Ghorepani and Pokhara. I have climbed it many times during the last twenty years, and thus I was able each time to observe the change in superficial dynamics that was going on. In 1974 for instance, an active landslide had developed between the villages of Ghara and Sikha (Fort 1974). In 1982, that specific landslide was nearly stabilised and was mostly recolonized by bamboos. That very year however, a new slide had appeared further up the slope between the villages of Sikha and Phalate. During the monsoon season (September 1982, photo 4A, looking westwards), the process was very active, the trail was destroyed, several *bārī* fields were carried away, and a group of houses was directly threatened. The soil was entirely soaked. The crown of the slide displayed outcrops of chloritic schists which in the central part of the slide were nearly liquefied and flowing as mudflows onto the slope. The extent of this failure reached about 250 m across and 700 m in length, thus representing about 1.5 million cubic metres of material removed. Downslope, the slide gave way to a steep torrent directly flowing into the Ghar Khola.

Eleven years later (April 1994, photo 4B), the slide was still a real threat, but some parts were in the process of being stabilised. Although its width (300 m) was larger than in 1982, and some small scale landforms quite different, there were obvious signs of decreasing geomorphic activity such as the smoothening of crown scarp and scarplets, and the recolonisation by vegetation. More specifically, alders (*Alnus nepalensis*, Nep. *utis*) have grown in the axis of the slide on an elongated mudflow (centre of photo 4B), thus taking advantage of the available moisture together with helping in slowing the downslope movement of the mud. These trees, six- to nine-years-old, indicate that the stabilisation started quite rapidly after the "crisis" of 1982.

Yet, in 1994 I also observed a reactivation of the Ghara landslide, twenty years after my first observation. As a whole in fact, this slope is constantly moving and will continue to do so as long as the Himalayan range is young and active.

4 A. The landslide of Phalate, east of Sikha (Myagdi District), September 1982.

4 B. The landslide of Phalate, 12 years later (April 1994), has extended and is in the process of stabilization.

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