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A Short Note on the Tsergo Ri Landslide, Langtang Himal, Nepal

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ABSTRACT

The large-scale mass movement at Tsergo-Ri (Langtang valley) in north-central Nepal was mapped in detail and an engineering geological map was prepared. Five different phases of displacement, deposition and erosion of the landslide are reconstructed. The present morphology of the area is largely the result of the above movements.

INTRODUCTION

Scott and Drever (1953) attributed the rock fusion exposed on the sliding surfaces in the Langtang valley to movements along faults in the vicinity of the Main Central Thrust (MCT). On the other hand, Heuberger et al. (1984), based on geomorphological and petrological studies, concluded that the rock fusion was triggered by a Quaternary landslide with a displaced mass of about 10 km^3. This spectacular mass movement provides a classic example for the study of the phenomena of mega landslides. This paper presents the preliminary results of the investigation on the Tsergo Ri landslide.

The Langtang valley is situated in north-central Nepal and essentially runs parallel to the High Himalayan Range. Morphologically, this area represnts a zone of the highest uplift in the Himalayas. The Tsergo Ri landslide is located in the Himalayan Gneiss Zone (Langtang Migmatite Zone) consisting of migmatites and gneiss in the vicinity of the MCT. The rocks in the area gently dip to the NE and are overlain by the rocks of the Tibetan Tethys Zone. The Himalayan Gneiss Zone overthrusts to the south along the MCT (Fig. 1).

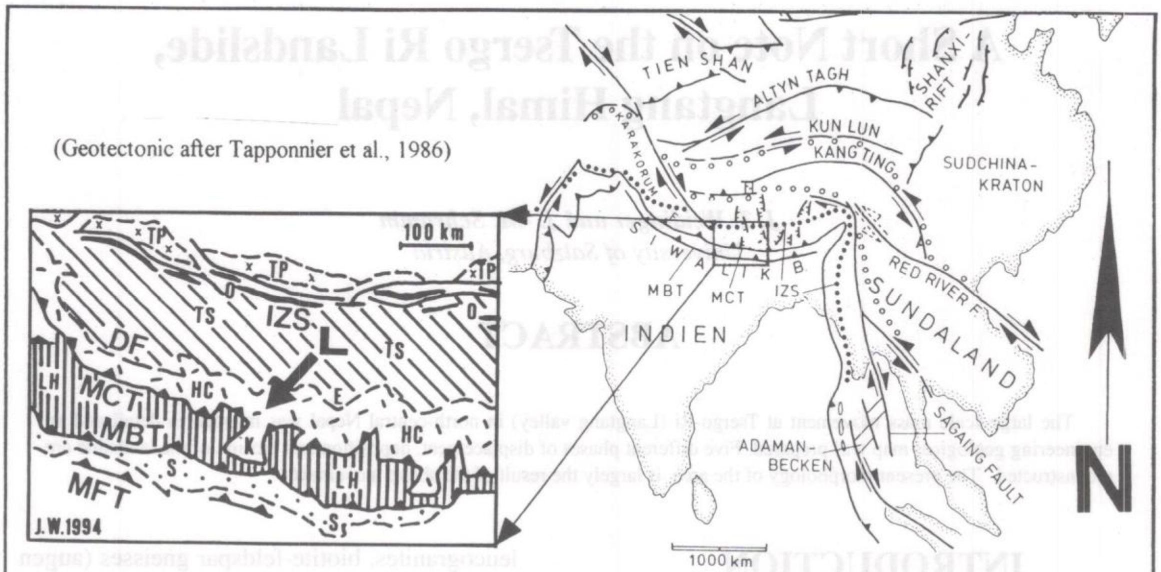
ENGINEERING GEOLOGY

The Quaternary mass movement (fission track age about 4x10^4 years) affected only the hard rocks in the region, i.e. a series of migmatites and leucogranites, biotite-feldspar gneisses (augen gneisses), biotite-sillimanite gneisses and biotite-garnet-tourmaline gneisses. An engineering geological map was prepared in 1:12,500 scale. The results of detailed field studies and interactive analyses (eg. sliding surfaces, joint density, geohydrology/electrical conductivity) are shown in Fig, 2. Table 1 summarises the deformational history of the rocks in the area due to the tectonics of the Himalayan orogeny, while Table 2 shows the deformational history due to the landslide. The results of the study may be summarised as follows:

1 .The analysis of exposed primary and secondary sliding surfaces (hyalomylonitic) helped to delineate the area affected by the landslide and the direction of movements (towards SW and WSW).

2 .The dip of the primary sliding surface corresponds with the pre-existing mylonite zones in the surrounding gneisses and migmatites. In addition, the Pangshungtramo Peak (situated W of the landslide deposit) was recognized as a former barrier that was affected during the crash of the sliding masses.

3. The rock mass within the landslide was classified on the basis of joint density (eg. compact, jointed, fractured, shattered, cataclastic and pulverized). This classification helped to assess the extent of loosening of the rocks and to estimate


(Geotectonic after Tapponnier et al., 1986)

Legend: L - Landslide, **K** - Kathmandu, **E** - Mt. Everest. Main thrust and fault zones: **IZS** - Indus-Zangbo-Sutur, **DF** - Detachment fault, **MCT** - Main Central Thrust, **MBT** - Main Boundary Thrust, **MFT** - Main Frontal Thrust. **S** - Siwaliks, **LH** - Lesser Himalaya, **HC** - Himalayan Crystalline, **TS** - Tethyan sediments, **O** - Ophiolites, **TP** - Transhimalayan plutons.

Fig. 1 Location map of the Tsergo Ri Landslide (after Tapponnier et al. 1986)

the mechanical stresses affecting different parts of the sliding mass. A system of strike-slip faults generated by the sliding movement along the Dranglung valley separated the masses into a blocky part (NW) and a brecciated part (SE).

4. Detailed geohydrologic mapping proved to be an additional tool for detecting the position of the sliding surfaces. The physical properties of water correlated well with the degree of rock loosening. As the disintegration of the rock increased, the elcetrical conductivity increased (0-800 µs)

5. The presence of a series of compact but roatated blocks in the sliding mass, and the mechanical stress within the basement can be interpreted on the basis of statistical analyses of joints and faults.

6. The geological structures, petrography and morphological analysis were helpful for the reconstruction of the position of the parent lodge and the broken crest of the landslide. An important pre-existing neotectonic structure associated with the leucogranitic intrusions was identified in the area. The chronology of events during and after the sliding were established with the help of 'silent witnesses'(mylonites and pseudotachylites).

RECONSTRUCTION OF EVENTS

At least five different phases of mass movements (displacement, deposition, erosion and related processes) can be recognized in the Tsergo Ri landslide. The present geological and the morphological features of the area are the results of these movements (Fig. 3a, 3b, 3c, 3d).

PRE-EVENT PHASE

The mylonites and pseudotachylites represent the 'silent witnesses' of tectonic and seismic activities related to the overthrusting along the MCT during the Himlayan orogeny, and date older than the landslide events. In general, they gently dip to the NE (also to the SW) and in the landslide area they have

FIG. 1

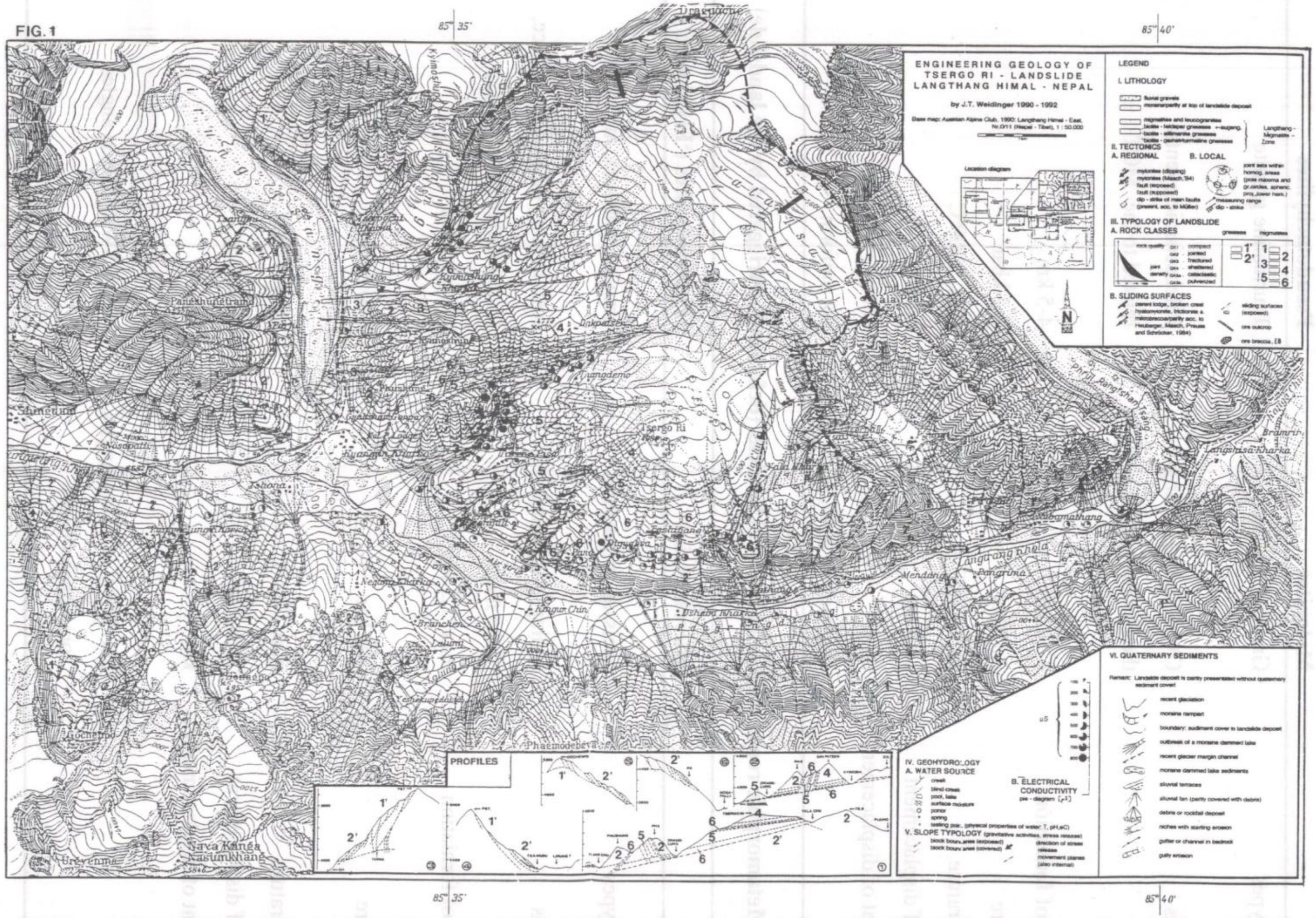


Fig. 2 Engineering Geological Map of the Tsergo Ri Landslide, Langtang Himal

Table 1 Metamorphic rocks with deformational fabrics (deformation due to tectonics)

	Mylonites	Pseudotachylites
Rock types	Granites, gneisses	Tourmaline granite
Genesis	Overthrusting during the Himalayan Orogeny	Paleoseismic events related to the MCT
Depth of formation	8-10 km	4-5 km
Pressure	2.5 kbar	1-2 kbar
Temperature	300-400^{0}C	max. 1200^{0}C
Rate of displacement	cm/year	cm/Sec
Amount of displacementc	m-m	cm-m
Dip	changing (SW, N, NE)	not uniform

Table 2 Metamorphic rocks with deformational fabricks (deformation triggered by the landslide)

	Microbreccias	Hyalomylonites ('Frictionite')
Rock types	gneisses, migmatites	granites, gneisses, migmatites
Genesis	sliding, partly fusion of the mass	fusion along the sliding surface, fusion within sliding mass
Depth of formation	max. 1.5 km	max. 1.5 km
Pressure	100 bar	100 bar
Temperature	max.1700^{0}C	max. 1700^{0}C
Rate of displacement	50 m/Sec	50 m/Sec.
Amount of displacement	km	km
Dip	due WSW with low angles, sometimes steeper	due WSW with low angles

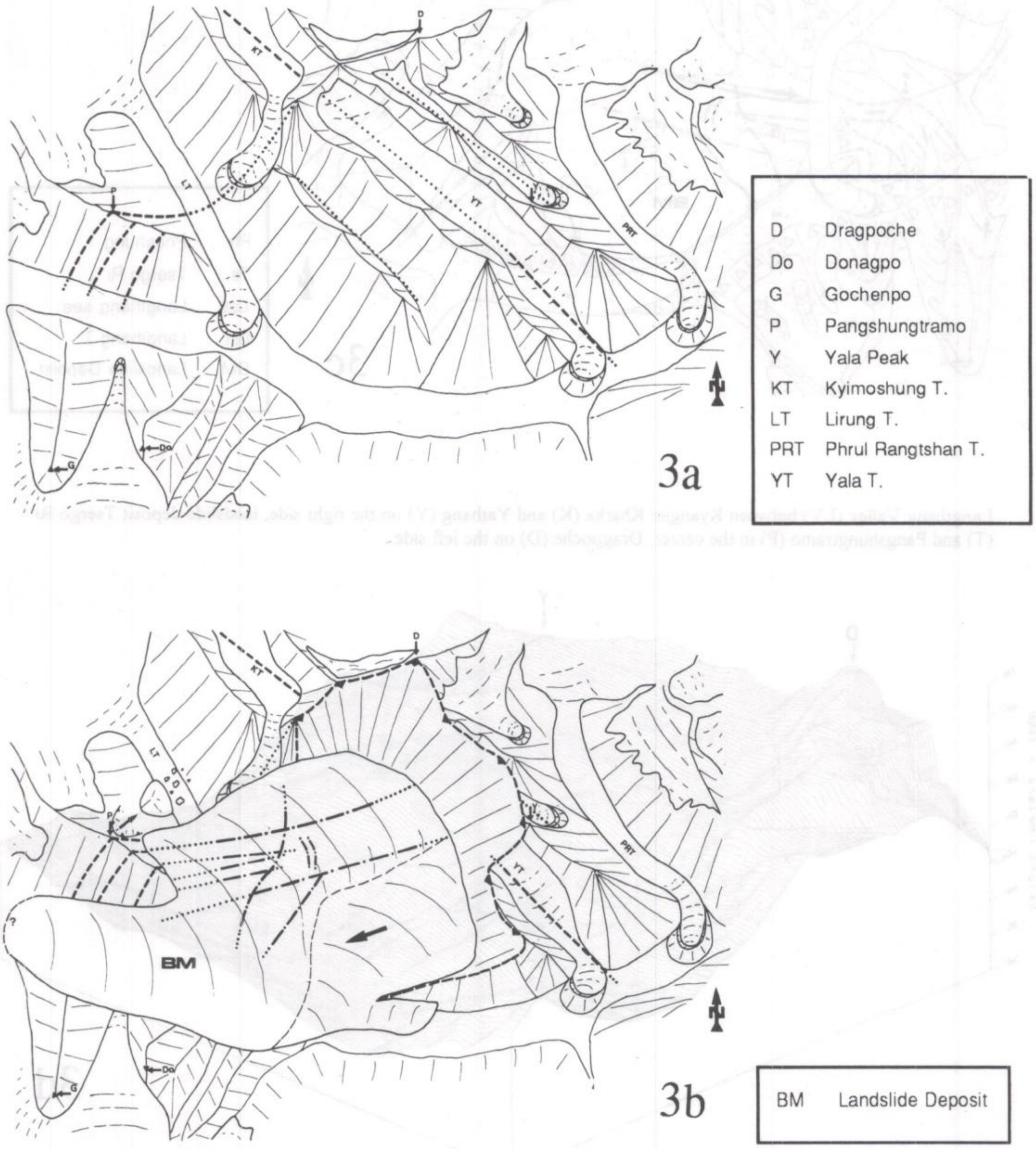
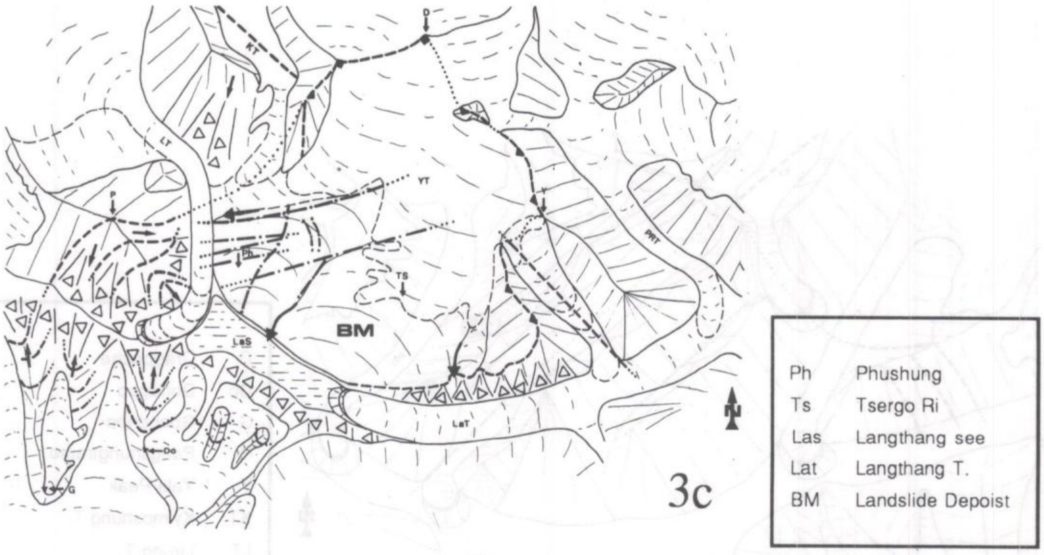


Fig. 3a and 3b Geomorphic process map of the study area (reconstruction of events: 3a. Pre-event phase. 3b. Post kinematic features)



Langthang Valley (LV) between Kyangjin Kharka (K) and Yathang (Y) on the right side, landslide deposit Tsergo Ri (T) and Pangshungtramo (P) in the center, Dragpoche (D) on the left side.

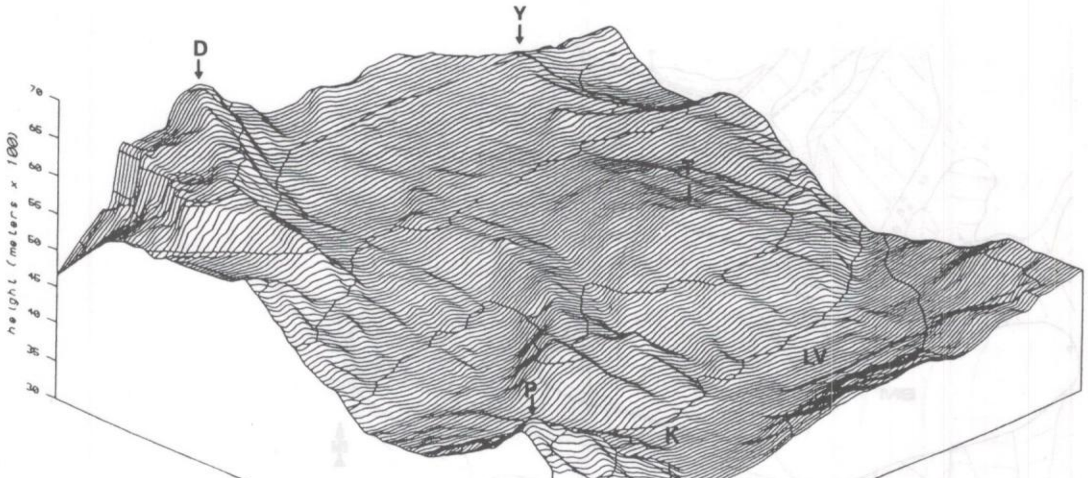


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Fig. 3c and 3d Geomorphic process map of the study area (reconstruction of events: 3c.Post denudation features 3d. Surface plot of the recent features ; view towards the east)

a NW-SE strike. These structures are crossed by a second system of structures dipping steeply due SE, well visible at the eastern flank of the Pangshungtramo Peak. These two intersecting systems mainly contributed to the formation of a niche for the parent lodge (Fig. 3a).

FIRST KINEMATIC PHASE

The specific tectonic structures and the rock inhomogeneity due to the gently SW dipping mylonites and leucogranitic intrusions gave way to the mountain collapse, possibly triggered by an earthquake. The compact sliding of the mass like a sledge created the hyalomylonite ('frictionite'), while the mass itself got heavily brecciated and the footwall broke partly into blocks.

SECOND KINEMATIC PHASE

The northwestern part of the sliding mass crashed against the former eastern flank of the Pangshungtramo Peak and loosened itself extremely. Due to the crash, a small block near the Tsangbu Kharka slided down towards the Langtang- Lirung glacier. The southeastern part of the mass continued its way down the main valley forming the Dranglung fault characterised by strong brecciation.

THIRD KINEMATIC PHASE

While the Pangshungtramo Peak formed a stable barrier, a high angle reverse fault (presently represented by a small dry valley) was formed to the west of the Phunshung Peak. Along the contact with the Pangshungtramo Peak, the landslide debris was pulverized and later eroded by the Langtang Lirung Tsang. The crash also forced the glacier to change its direction from NW-SE to N-S. During the crash, the steep SE dipping structures of Pangshungtramo Peak got activated and created mechanisms for the development of new fractures (Fig. 3b).

FIRST DENUDATION PHASE

The last glaciation of the Langtang valley caused the erosion of most part of the landslide deposits. The erosional process was most active along the main valley of Langtang, the connection to the Pangshungtramo Peak, Kyimoshung, Yala and the Dranglung valley.

SECOND DENUDATION PHASE

During the late and post glacial period, the stress release caused relaxation at the southern part of the main valley, Donagpo and Gochenpo Peak, as well as the Pangshungtramo Peak in the north, and caused block movements towards the Langtang valley. The Langtang-Lirung glacier formed a lake which was later filled with sediments.

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