Geomorphic changes induced by the April-May 2015 earthquake sequence in the Pharak-Khumbu area (Nepal)

Monique Fort

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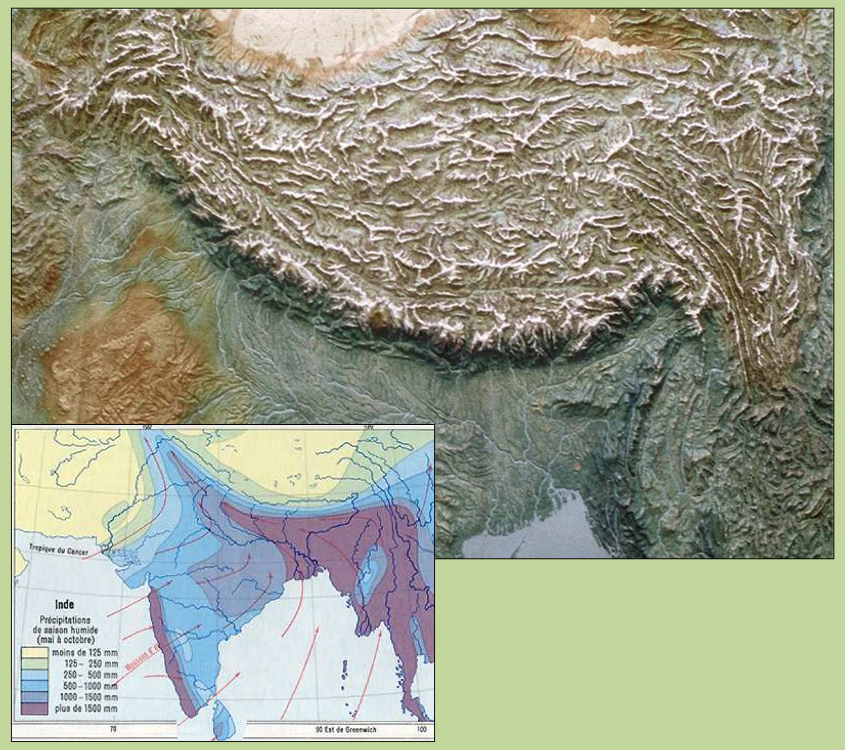
Dept of Geography, UMR 8586 PRODIG, CC. 7001, Univ. Paris-Diderot-SPC, F - 75 205 PARIS Cedex 13, France (fort@univ-paris-diderot.fr); ANR-13-SENV-0005-02 PRESHINE

1. INTRODUCTION: MAIN ISSUES

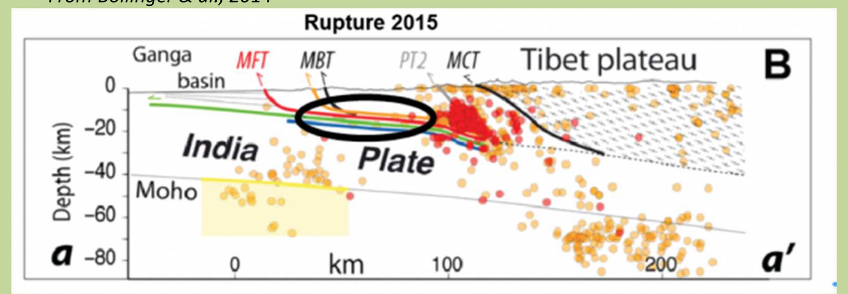
Landsliding is a common process shaping mountain slopes. There are various potential landslide triggers (rainfall, bank erosion, earthquakes) and their effectiveness depends on their distribution, frequency and magnitude. In a Himalayan context, the effects of monsoon rainfall can be assessed every year whereas the unpredictability and low frequency of large earthquakes make their role in triggering slope instability more obscure.



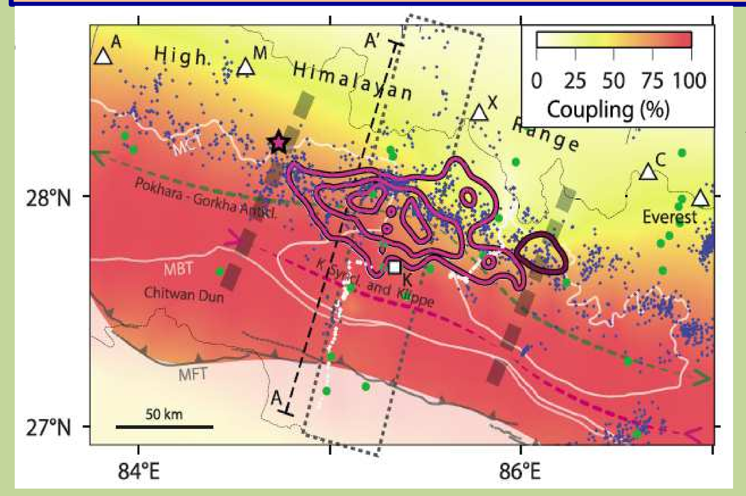
2. APRIL-MAY 2015 EARTHQUAKE SEQUENCE

A 7.8 magnitude earthquake struck central Nepal (Gorkha District) on 25 April 2015 and was followed by many aftershocks exceeding magnitude 5, including another strong 7.3 magnitude earthquake on May 12, 2015 (Dolakha District). This seismic crisis provides an exceptional opportunity to assess the disruptions that earthquakes may cause in "regular" geomorphic systems controlled by rainfall.

From Bollinger & al., 2014

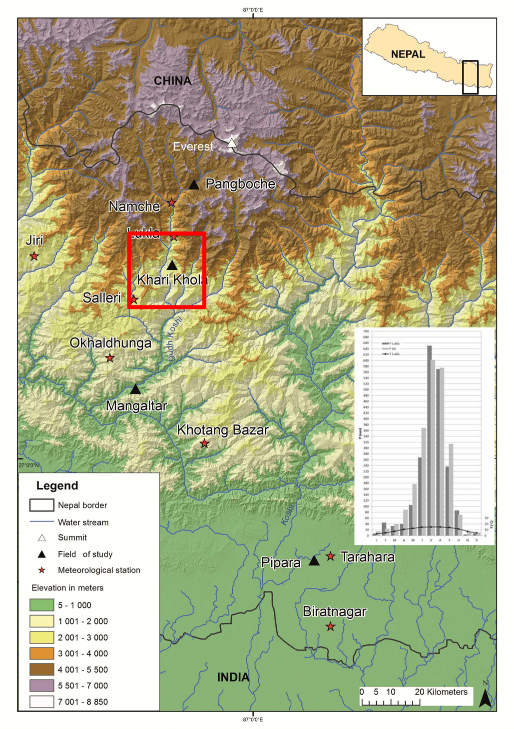


From Sapkota et al.2012 and from Bollinger, pers. comm.



← *Interseismic coupling distribution on the Main Himalayan Thrust (MHT) deduced from GPS (green circles) and leveling (white circles). Slip contours of the 2015 Gorkha earthquake (25 April) and its main aftershock (12 May) are indicated by pink and brown lines, respectively (Grandin et al. 2015).*

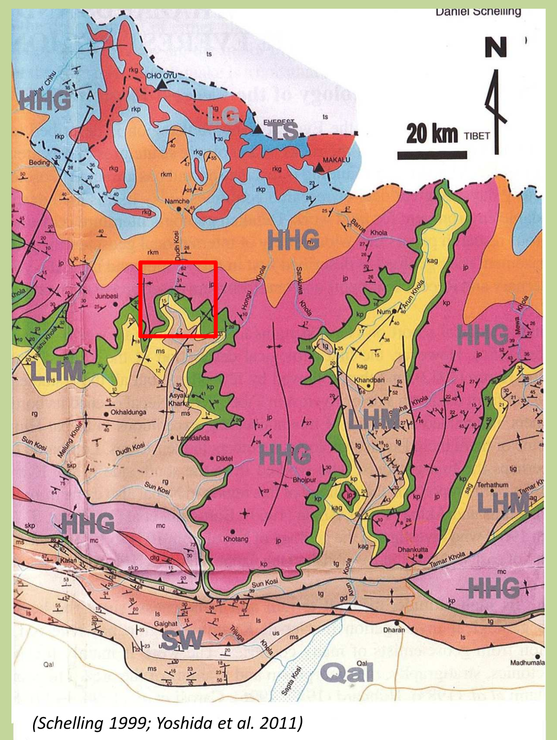
3. LOWER KHUMBU – PHARAK AREA



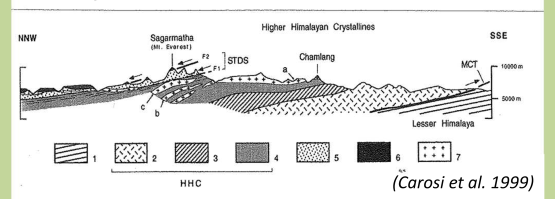
(from Smadja et al. 2015)

The Pharak, a "middle mountains" (2000-4500 m) area, is affected by monsoon rains (3000 m/yr at 2500 m) and characterised by steep hillslopes, shaped by different geomorphic processes according to slope height and aspect, rock type and strength, inherited landforms, stream connectivity and current land use changes.

This study focuses on the south of Lukla (Phakding District), and more specifically on the Khari Khola catchment and its surroundings. The area lies at the transition between the Higher Himalayan crystallines and the Lesser Himalayan meta-sediments.



(Schelling 1999; Yoshida et al. 2011)

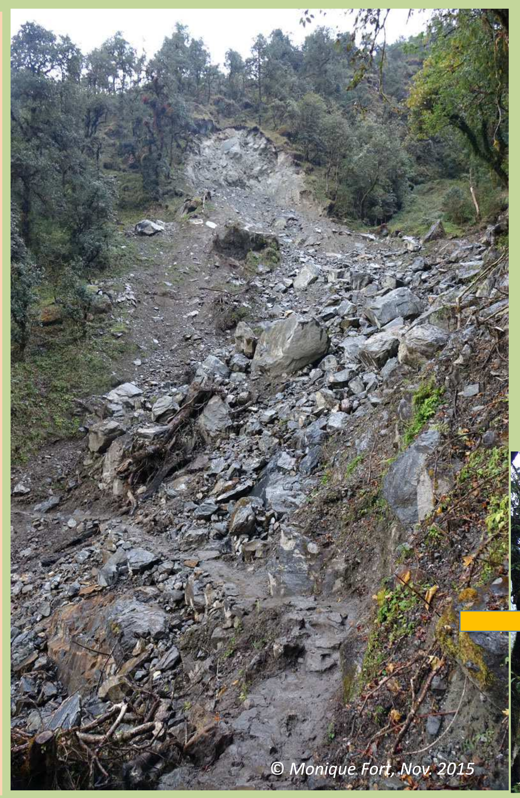


(Carosi et al. 1999)

4. METHODS

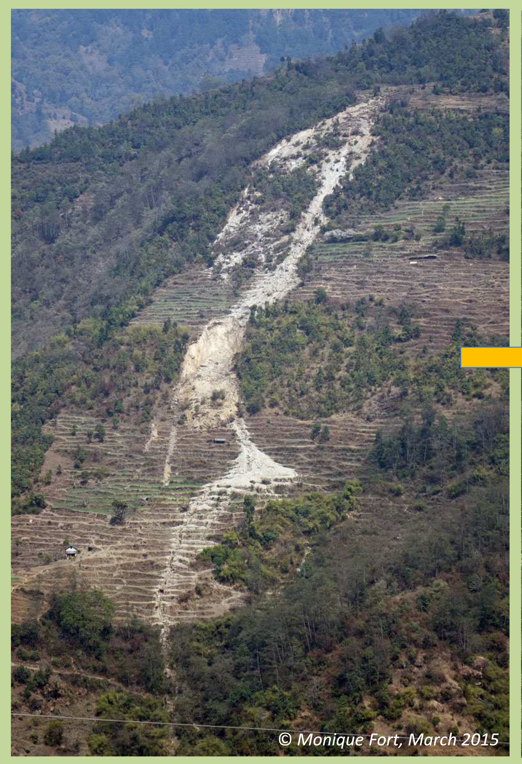
On the basis of our diachronic observations (March and November 2015), we surveyed and mapped new earthquake-induced slope instabilities such as rock falls, rockslides, landslides and debris flows and a combination of several of them. Interviews with local people also helped to assess the exact timing of some events. While the first M 7.8 earthquake produced significant impacts in the northern Khumbu area, the M 7.3 aftershock seems to have been more destructive in Pharak. Yet, the observed geomorphic changes are not as great as in the zone between the Gorkha and Dolaka Districts.

The second control factor - **lithology** - also appears significant: weak fractured bedrock supplied rock falls (upper Khari khola catchment), whereas superficial deposits (alluvial, lacustrine, and colluvial soils, including landslide material) favoured larger failures (Paya, Cheubas), particularly because of the **proximity of the deeply incised stream network** (third control factor).

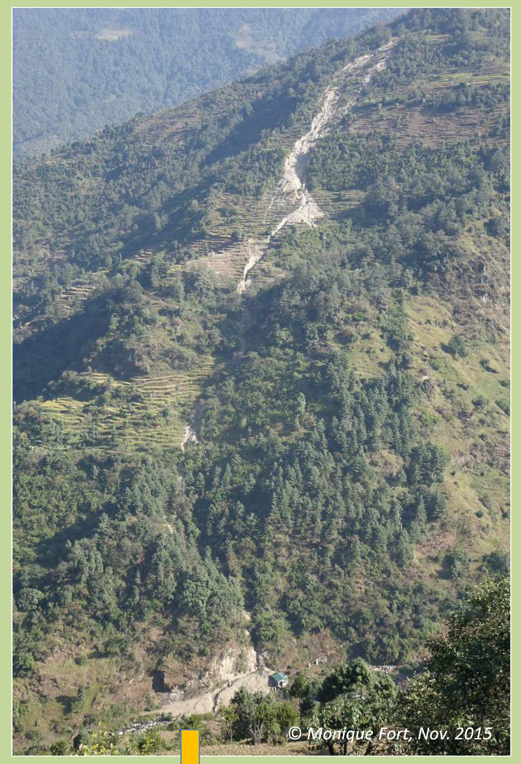


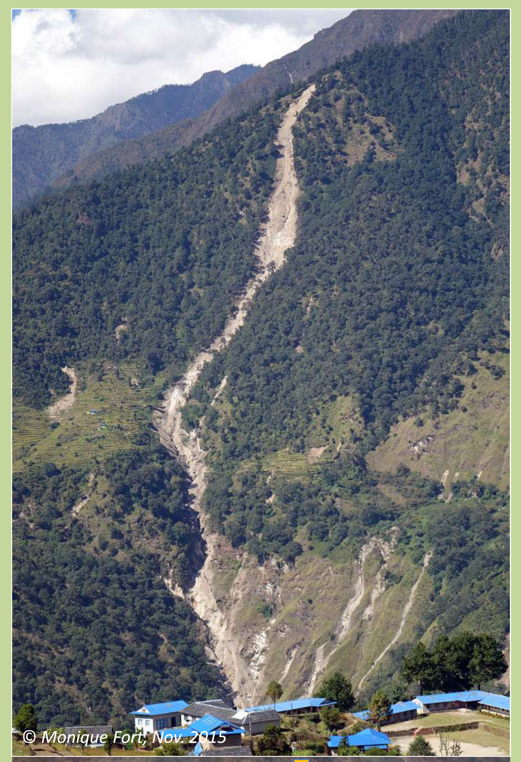
5. LANDSLIDES TYPES AND CONTROL FACTORS

The first control factor is **slope steepness** (>45°) and height (500-1000 m), both favouring landslide initiation near the ridge top and a series of cascading processes.



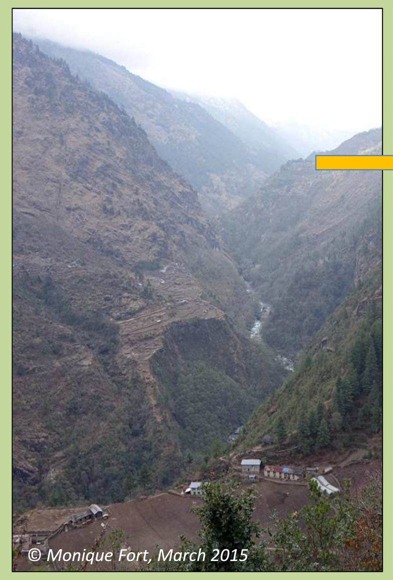
Near Paya (left), slope collapse was controled by the talweg. Older, very coarse debris were removed, destroyed the foot trail and filled in the talweg.

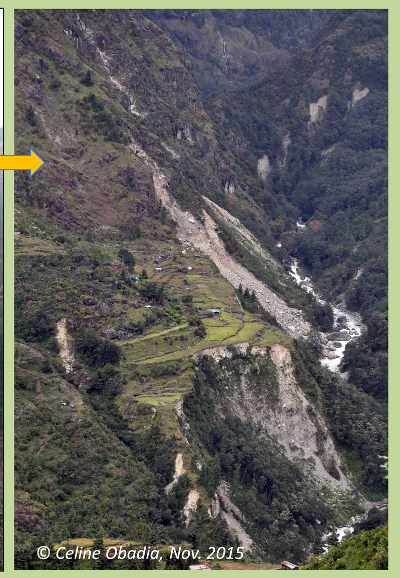




Cascading processes often result in temporary valley damming, as observed upstream of Jubing (right) and near Bupsa (above), with the new hydropower station damaged).

Nakchun (above and right) was very affected. The former debris-alluvial terrace was severely eroded along the Dudh Kosi side. The village remained isolated for several months, due to the rockfalls and debris slides which developed along the the right bank of the river and destroyed the trail (still very dangerous).





6. CONCLUDING REMARKS

Most of the landslides originate on the upper slopes. The limited size and shallow depth of the newly generated slope failures are noteworthy. More generally, these geomorphic changes and their characteristics may be explained by the nature of the 2015 climate: while the 2014-2015 winter was unusually dry, snowfalls and rainfalls were abundant during March and April, hence increasing the pore pressure and the potential instability of slopes and/or snow cover. Conversely, the rather weak monsoon rainfall of the 2015 summer did not take advantage of the many cracks opened by seismic shaking. Yet this may leave only a short delay for large landslide development during the next monsoon seasons.

References:

- Bollinger L., Sapkota S.N., Tapponnier P., Klinger Y. . , Rizza M., Van der Woerd J., Tiwari D.R., Pandey R., Bitri A., and Bes de Berc S. (2014), Estimating the return times of great Himalayan earthquakes in eastern Nepal: Evidence from the Patu and Bardibas strands of the Main Frontal Thrust, J. Geophys. Res. Solid Earth, 119, doi:10.1002/2014JB010970.
- Carosi R., Lombardo B., Musumecci G., Pertusari P. (1999). Geology of the Higher Himalayan crystallines in Khumbu Himal (Eastern Nepal). Journal of Asian Earth Sciences, v. 17, 785-803.
- Grandin, R., M. Vallée, C. Satriano, R. Lacassin, Y. Klinger, M. Simoes, and L. Bollinger (2015), Rupture process of the Mw = 7.9 2015 Gorkha earthquake (Nepal): Insights into Himalayan megathrust segmentation, Geophys. Res. Lett., 42, doi:10.1002/2015GL066044.
- Sapkota S.N., Bollinger L., Klinger Y., Tapponnier P., Gaudemer Y., and Tiwari D.N. (2012). Primary surface ruptures of the great Himalayan earthquakes in 1934 and 1255. Nature Geosciences, DOI: 10.1038/NGEO1669.
- Schelling D. (1999). Geological Map of the eastern Nepal Himalaya (scale 1:650,000). In Le Fort and Upreti (Eds): Geology of the Nepal Himalayas: Recent Advances. Journal of Asian Earth Sciences, v. 17, 577-606.
- Smadja J., Aubriot O., Puschiasis O., Duplan T., Grimaldi J., Hugonnet M. and Buchheit P. (2015). Climate change and water resources in the Himalayas. Field study in four geographic units of the Koshi basin, Nepal. Journal of Alpine Research. « Climate change and water resources in the Himalayas », Journal of Alpine Research | Revue de géographie alpine [En ligne], 103-2 | on line 04 Sept. 2015, URL : http://rga.revues.org/2910 ; DOI : 10.4000/rga.2910.
-Yoshida M., Upreti B.L., Rai S.M. (2011). Guidebook for Himalayan trekkers, Series n°2. Ecotrekking in the Everest Region, Eastern Nepal. Dpt of Geology, Tri-Chandra Campus,Tribhuvan University, 192 p.

Acknowlegments

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