



**HAL**  
open science

# Geomorphic impacts, age and significance of two giant landslide dams in the Nepal Himalayas: Ringmo-Phoksundo (Dolpo District) and Dhampu-Chhoya (Mustang District).

Monique Fort, Regis Braucher, Didier Bourles, Valery Guillou, Lila Nath Rimal, Natasha Gribenski, Etienne Cossart

## ► To cite this version:

Monique Fort, Regis Braucher, Didier Bourles, Valery Guillou, Lila Nath Rimal, et al.. Geomorphic impacts, age and significance of two giant landslide dams in the Nepal Himalayas: Ringmo-Phoksundo (Dolpo District) and Dhampu-Chhoya (Mustang District).. EGU General Assembly 2014, Apr 2014, Vienne, Austria. 1 p. hal-01262118

**HAL Id: hal-01262118**

**<https://hal.science/hal-01262118>**

Submitted on 26 Jan 2016

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Geomorphic impacts, age and significance of two giant landslide dams in the Nepal Himalayas: Ringmo-Phoksundo (Dolpo District) and Dhampu-Chhoya (Mustang District).

Monique FORT<sup>(1)</sup>, Régis BRAUCHER<sup>(2)</sup>, Didier BOURLES<sup>(2)</sup>, Valéry GUILLOU<sup>(2)</sup>, Lila Nath RIMAL<sup>(3)</sup>, Natasha GRIBENSKI<sup>(4)</sup>, Etienne COSSART<sup>(5)</sup>

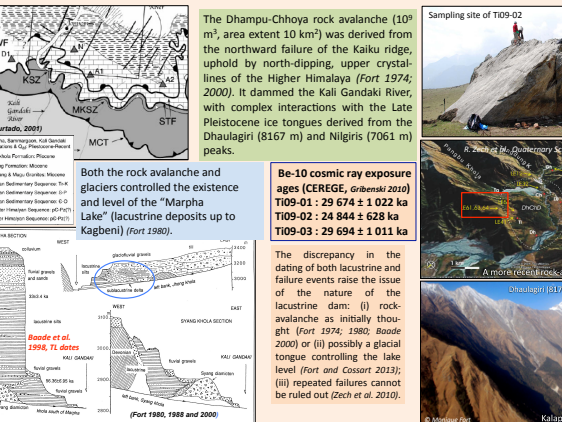
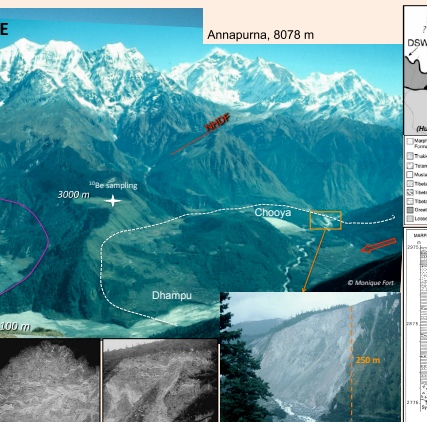
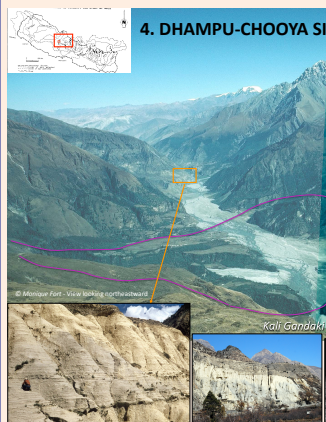
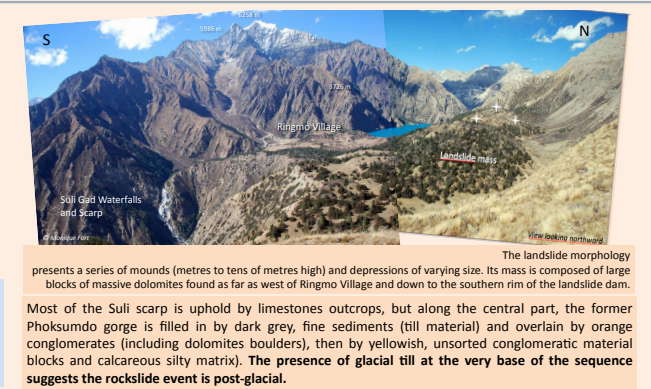
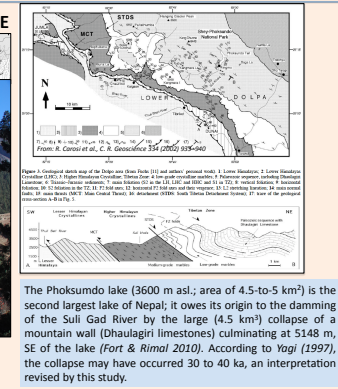
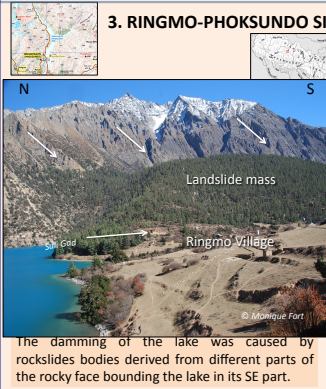
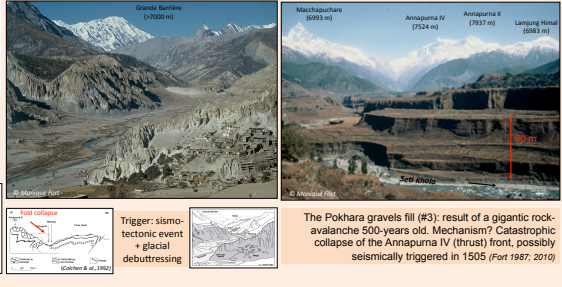
(1) Dept of Geography, UMR 8586 PRODIG, CC. 7001, Univ. Paris-Diderot-SPC, F- 75 251 PARIS Cedex 05, France ([monique.fort@paris-diderot.fr](mailto:monique.fort@paris-diderot.fr)); (2) Aix-Marseille Université, CEREGE CNRS UMR 6635, 13545 Aix en Provence, France; (3) Department of Mines and Geology, Lainchaur, Kathmandu; (4) Department of Physical Geography and Quaternary Geology, Stockholm University, SE-106 91 Stockholm, Sweden; (5) UMR 8586 PRODIG, Univ. Paris1-Sorbonne, 2 rue Valette 75005 Paris, France.



### 1. INTRODUCTION: MAIN ISSUES

Large catastrophic slope failures have recently retained much attention in the northern dry Himalayas (Hewitt 2009). They play a prominent role in the denudation history of active orogens at a wide range of spatial and time scales (Korup & Clague, 2009), and they impact durable landforms and process evolution in upstream catchments. Their occurrence mostly results from three different potential triggers: earthquakes, post-glacial debudding, and permafrost melting. We focus on two examples of giant rock slope failures that occurred across and north of the Higher Himalaya of Nepal and assess their respective influence on the regional, geomorphic evolution.

Mass wasting feature	Volume (10 <sup>6</sup> m <sup>3</sup> )	Age	Geological context	Type of failure	Nature of material	Geomorphic impact	References
1. Himmachal (Nepal Himalayas) (See text)	100	1000-1500	HTC (greyish)	Graben collapse	HTC (greyish)	HTC (greyish)	Fort 1987; Weinger 2000
2. Shyok (Himalayas) (See text)	30	20,874 ± 1022 (1.0 ± 0.04) ka	HTC (greenish)	HTC (greenish)	HTC (greenish)	HTC (greenish)	Fort 2002, 2009; B. Bourles et al. 2009; Fort et al. 2010
3. Himmachal (Nepal Himalayas) (See text)	40	1000 ± 100 (1.0 ± 0.1) ka	HTC (greenish)	HTC (greenish)	HTC (greenish)	HTC (greenish)	Fort 1987; 1988; Fort et al. 2010
4. Himmachal (Nepal Himalayas) (See text)	150	1000 ± 100 (1.0 ± 0.1) ka	HTC (greenish)	HTC (greenish)	HTC (greenish)	HTC (greenish)	Fort 1987; 1988; Fort et al. 2010
5. Himmachal (Nepal Himalayas) (See text)	150	1000 ± 100 (1.0 ± 0.1) ka	HTC (greenish)	HTC (greenish)	HTC (greenish)	HTC (greenish)	Fort 1987; 1988; Fort et al. 2010
6. Himmachal (Nepal Himalayas) (See text)	150	1000 ± 100 (1.0 ± 0.1) ka	HTC (greenish)	HTC (greenish)	HTC (greenish)	HTC (greenish)	Fort 1987; 1988; Fort et al. 2010
7. Himmachal (Nepal Himalayas) (See text)	150	1000 ± 100 (1.0 ± 0.1) ka	HTC (greenish)	HTC (greenish)	HTC (greenish)	HTC (greenish)	Fort 1987; 1988; Fort et al. 2010
8. Himmachal (Nepal Himalayas) (See text)	150	1000 ± 100 (1.0 ± 0.1) ka	HTC (greenish)	HTC (greenish)	HTC (greenish)	HTC (greenish)	Fort 1987; 1988; Fort et al. 2010



### 2. DATING METHODS: COSMIC RAY EXPOSURE DATING

AMS measurements of the <sup>36</sup>Cl and <sup>10</sup>Be concentrations were performed at the 5 MV national AMS facility ASTER located at CEREGE, Aix en Provence, France. All <sup>36</sup>Cl concentrations were normalized to the KNSTD1600 calibration material (<sup>36</sup>Cl/<sup>35</sup>Cl = 1.6\*10<sup>-12</sup> provided by K. Nishiizumi) and all <sup>10</sup>Be concentrations were normalized to the SRM 4325 NIST reference material with an assigned <sup>10</sup>Be/<sup>9</sup>Be value of (2.79±0.03)\*10<sup>-11</sup>. The <sup>36</sup>Cl decay constant of (2.303 ± 0.016)\*10<sup>-6</sup> a<sup>-1</sup> corresponds to a half-life (T<sub>1/2</sub>) of (3.014±0.021)\*10<sup>5</sup> years and the <sup>10</sup>Be decay constant of (4.987±0.036)\*10<sup>-7</sup> a<sup>-1</sup> to a half-life of (1.39±0.01)\*10<sup>6</sup> years. Analytical uncertainties include the counting statistics, machine stability (~0.5%) and blank correction, the associated <sup>36</sup>Cl/<sup>35</sup>Cl blank ratio being ~10<sup>-14</sup> and the <sup>10</sup>Be/<sup>9</sup>Be blank ratio ~2\*10<sup>-15</sup>. Cosmic ray exposure ages derived from these cosmogenic nuclide concentrations were calculated using production rates corrected for topographic shielding following Dunne et al. (1999) and scaled to the sites position (latitude, altitude) using the Stone scheme (Stone, 2000) from a sea level and high latitude production rate of 4.5±0.3 atoms of <sup>10</sup>Be g<sup>-1</sup>yr<sup>-1</sup> for <sup>10</sup>Be and integrating all production pathways (spallation, including a spallation production rate of 42.0 ± 2.0 atoms of <sup>36</sup>Cl g<sup>-1</sup>Ca<sup>-1</sup> yr<sup>-1</sup> and at sea level and high latitude, thermal neutron, muon captures and radiogenic production) and the rock's chemical composition for <sup>36</sup>Cl.

Sample ID	Sample weight dissolved (g)	% CaO	<sup>36</sup> Cl/ <sup>35</sup> Cl (10 <sup>-12</sup> )	<sup>36</sup> Cl/ <sup>35</sup> Cl (ppm)	<sup>10</sup> Be (10 <sup>-12</sup> g/g)	Exposure Age of surface (unrounded surface)	Uncertainties
PHOK COS 1	67.29	55.19%	133.8	33.64	2.79	6987	566
PHOK COS 2	69.08	54.76%	382.0	24.08	4.58	20882	1887
PHOK COS 3	72.05	54.59%	314.9	10.42	13.62	20889	1661

**Two consistent <sup>36</sup>Cl ages of 20,885 ± 1675 argue for a sinele, massive event of para-glacial origin**

Field assumptions are confirmed by cosmic ray exposure dating: the landslide dam was formed in response to the collapse of the limestone cliff in one single, massive event. The <sup>36</sup>Cl dates confirm the para-glacial/post-glacial origin of the failure, an event that fits well with the last chronologies available on the Last Glacial Maximum in the Nepal Himalaya (Owen & Dortch 2014). IRSL dating of silts suggests a progressive trend to dryness of these Northern Himalayan regions from Late Pleistocene to Holocene.

**Note on Infrared Stimulated Luminescence (IRSL) dating**

The IRSL samples, PHOK 2 and PHOK 1, were collected respectively at the top and the bottom of the silty deposits, below the surface soil. IRSL measurements were performed at Montreal laboratory by S. Balescu, S. Huot and M. Lamotte. The corrected IRSL ages of PHOK 2 and PHOK 1, respectively 4.7 ± 0.3 ka and 12.6 ± 0.7 ka, are stratigraphically consistent (Fort et al., 2013).

### 3. RINGMO-PHOKSUNDO SITE

The Phoksundo lake (3600 m asl.; area of 4.5-to-5 km<sup>2</sup>) is the second largest lake of Nepal; it owes its origin to the damming of the Suli Gali River by the large (4.5 km<sup>2</sup>) collapse of a mountain wall (Dhaulagiri limestones) culminating at 5148 m, SE of the lake (Fort & Rimal 2010). According to Yagi (1997), the collapse may have occurred 30 to 40 ka, an interpretation revised by this study.

The Phoksundo lake (3600 m asl.; area of 4.5-to-5 km<sup>2</sup>) is the second largest lake of Nepal; it owes its origin to the damming of the Suli Gali River by the large (4.5 km<sup>2</sup>) collapse of a mountain wall (Dhaulagiri limestones) culminating at 5148 m, SE of the lake (Fort & Rimal 2010). According to Yagi (1997), the collapse may have occurred 30 to 40 ka, an interpretation revised by this study.

The Phoksundo lake (3600 m asl.; area of 4.5-to-5 km<sup>2</sup>) is the second largest lake of Nepal; it owes its origin to the damming of the Suli Gali River by the large (4.5 km<sup>2</sup>) collapse of a mountain wall (Dhaulagiri limestones) culminating at 5148 m, SE of the lake (Fort & Rimal 2010). According to Yagi (1997), the collapse may have occurred 30 to 40 ka, an interpretation revised by this study.

The fact that both Zech et al. (2009) and our team (Fort et al., in prep.) have obtained consistent exposure duration to cosmic ray, from different samples and different laboratories, provides very good evidence of a chronologically, well constrained Dhampu-Chhoya rock-avalanche event, i.e. about 30,000 years ago. Conversely, dating of lacustrine sediments has not been cross-checked to date, and some uncertainty cannot entirely be ruled out.

### 4. DHAMPU-CHHOYA SITE

The Dhampu-Chhoya rock avalanche (10<sup>6</sup> m<sup>3</sup>, area extent 10 km<sup>2</sup>) was derived from the northward failure of the Kali ridge, upheld by north-dipping, upper crystalline of the Higher Himalaya (Fort 1974; 2000). It dammed the Kali Gandaki River, with complex interactions with the Late Pleistocene ice tongues derived from the Dhaulagiri (8167 m) and Nilgiri (7061 m) peaks.

The Dhampu-Chhoya rock avalanche (10<sup>6</sup> m<sup>3</sup>, area extent 10 km<sup>2</sup>) was derived from the northward failure of the Kali ridge, upheld by north-dipping, upper crystalline of the Higher Himalaya (Fort 1974; 2000). It dammed the Kali Gandaki River, with complex interactions with the Late Pleistocene ice tongues derived from the Dhaulagiri (8167 m) and Nilgiri (7061 m) peaks.

The Dhampu-Chhoya rock avalanche (10<sup>6</sup> m<sup>3</sup>, area extent 10 km<sup>2</sup>) was derived from the northward failure of the Kali ridge, upheld by north-dipping, upper crystalline of the Higher Himalaya (Fort 1974; 2000). It dammed the Kali Gandaki River, with complex interactions with the Late Pleistocene ice tongues derived from the Dhaulagiri (8167 m) and Nilgiri (7061 m) peaks.

### 5. COMPARISONS and CONCLUDING REMARKS

**Phoksundo-Ringmo**

- Efficient drainage blockage, but no backwash sedimentation (predominant carbonates + low discharge)
- Prominent knick point: karst + boulder pavement reducing incision => prominent hanging valley
- Triggering factor: glacial retreat («para-glacial collapse»), cf. <sup>36</sup>Cl dates

**Dhampu-Chhoya**

- Efficient drainage blockage, and extensive lacustrine sedimentation (glacial sediment reworking + Spitt shales + glacial- and snow-melt discharges)
- Knick points and associated epigenetic gorges + braided Kali Gandaki valley: delayed incision => relatively hanging valley
- No climate forcing, cf. <sup>10</sup>Be dates => Triggering factor related to the North Himalayan Detachment Fault + foliation dip of Upper Himalayan Gneisses
- Complex interplay between glaciers and mountain wall collapses (Fort 2000)

**References:**

Fort M., 1986. Catastrophic sedimentation and morphogenesis along the high Himalayan front: implications for glacial-interglacial relationships. In: The paleoenvironments of the Himalayas from the Mid-Tertiary to the Present. Centre of Asian Studies, Hong Kong, 371-394.

Fort M., 2000. Slides and Mass wasting processes: their influence on the shaping of the East Ganges (Higher Himalaya of Nepal). Quaternary International, 6, 69-86.

Fort M., 2011. The role of the Dhaulagiri rock slope failure and its geomorphological significance. Annals of the Geological Survey of Nepal, 43, 1-10.

Dunne, A., Brown, D., Muehlen, P., 1999. Scaling of cosmogenic nuclide production rates for geomorphic modeling of depth on steep surfaces. Geomorphology 27, 1-13.

Fort M., 2014. Divergence préliminaire sur la morphogénèse quaternaire de la vallée de la Kali Gandaki (Népal Central). Mémoire 2014 (Népal) CEREGE, Aix, France. 100 pages.

Fort M., 2016. Les formations géologiques de la haute Thakliha (Dhaulagiri de Népal): intérêt paléogéographique, géomorphologique et chronologique. C.R. Acad. Sci. Paris, 346, 100, 100-104.

Fort M., 2017. Spatiotemporal morphogenesis in a continental subduction setting: an example from the Annapurna Range, Nepal Himalaya. Zest. J. Geomorph., Suppl. 86/62, pp. 9-36.

Hewitt, K., 2009. Catastrophic rock slope failures and late Quaternary development in the Nanga Parbat-Hazratnagar Massif, Upper Indus Basin, northern Pakistan. Quaternary Science Reviews, 28, 1055-1070.

Hartford, J.M., Hodges, K.V. and Whipple, K.S., 2001. Neotectonics of the Thakliha graben and implications for recent activity on the South Tibetan fault system in the central Nepal Himalaya. GSA Bulletin, 113(2), 222-246.

Zech, R., Montigny, R., Baudet, J., 2003. Glacier and landslide feedbacks to topographic relief in the Himalayas. PNAS, 100(12), 5173-5177.

Owen, L., Dortch, J.M., 2014. Nature and timing of Quaternary glaciation in the Himalayas - Tibetan orogen. Quaternary Science Reviews, 88, 34-54.

Stone, J.C., 2000. Air pressure and cosmogenic isotope production. J. Geophys. Res., 105, 2373-2376.

Wendinger, U., Berberich, 2000. Landslide dams of the Laramising, Ghazal, Kulu, Rungwa and Barabari in the Nepal Himalayas and related basins. J. Nepal Geol. Soc., 23, 373-380.

Yagi, H., 1997. Origin of the Phoksundo Tal, Dhaulagiri, western Nepal. Jour. Nepal Geol. Soc., 1, 3-7.

Zech, R., Zech, M., Rull, P., Baudet, J., 2010. Deglaciation and landscape history around Annapurna, Nepal, based on 10Be surface exposure dating. Quaternary Science Reviews, 29, 311-321, pp. 316-318.

**Acknowledgments:**

Financial support was provided by Paris Diderot Univ. (UPFR: GHSS and STEP) and by CNRS (Aix-Marseille Univ.), ASTER (Aix-Marseille Université), CEREGE (AMS national facility), CEREGE, Aix-en-Provence) is supported by the INSU/CNRS, the French Ministry of Research and Higher Education, IRD and CEA.

**Permissions for geological and geomorphological investigations** were given by the Dept of National Parks, Ministry of Forests, and free entrance in the Shekphu Khola National Park was delivered by Home Ministry, Government of Nepal. Our very deep appreciation goes to Dr. Sam Subasta (Dept. of Mines and Geology) for his help.

**Both examples confirm that giant landslides play a significant role in the:**

- Destruction of Himalayan topography (Fort 1988),
- Bedrock protection from river incision (Korup et al. 2010),
- Delay of sediment transport outward from the mountain zone (cf. sediment storages & budgets; Fort & Cossart 2013; Blithe, J., & Korup, O., 2013)
- Local controls exerted by topography and climate (eg. magnitude of glaciation + snow <-> discharge) + lithology (eg. sediment supply <-> storage)