Cosmogenic ^{3}He dating of the giant landslide of Tacna (Andes western margin, Peru)

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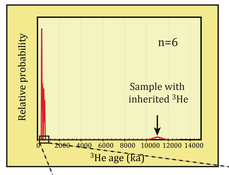
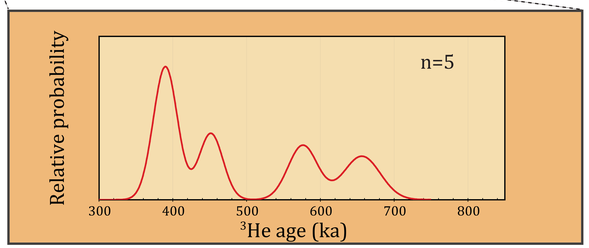
Introduction - goal of the study

Several giant landslides are reported on the western margin of the Andes, in Peru and northern Chile. It is important to understand the dynamics and the timing of these qutarnary formations, not only because landlsides are natural hazards, but also because they could be used to get constraint on paleoclimate variations and, possibly, on the occurence of past earthquakes. However, none of these landlsides is directly dated and little is known about their triggering mechanisms. The goal of this work is thus to test the possibility of applying cosmogenic ^{3}He dating to these landforms. Here we focus on the giant landlside of Tacna (Southern Peru).

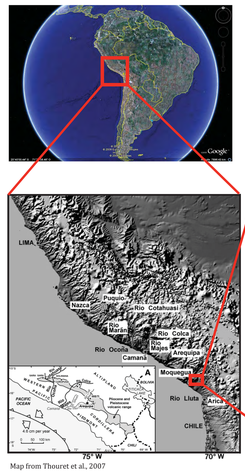
Cosmogenic ^{3}He results



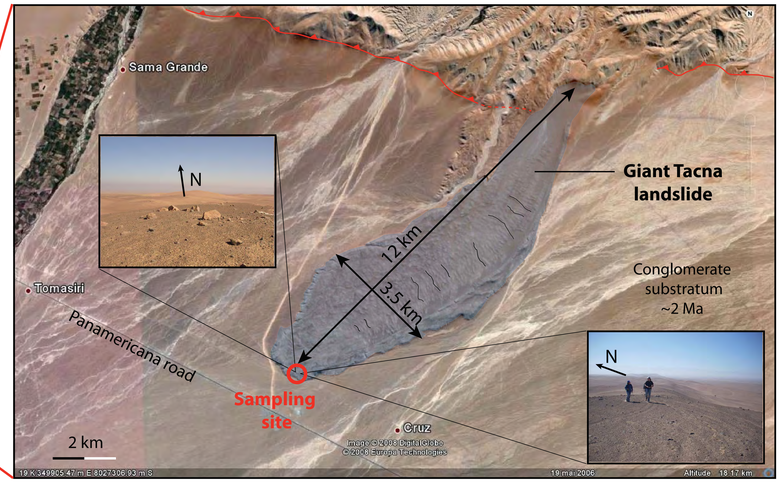
These ages are calculated using a sea-level high latitude spallation production rate of 128 at/g/a (Blard et al., 2006). Geographic and geomagnetic scaling were done using (Stone, 2000) and (Dunai, 2001), respectively. These ages were obtained using an erosion rate of 0.1 m/Ma. The production from thermal neutron capture on ^{6}Li by was calculated following (Phillips et al., 2001) and (Dunai et al., 2007) and using a Matlab code kindly shared by Willy Amidon.



Geological settings

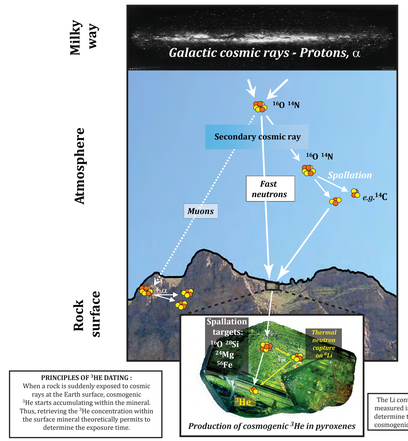


Map from Thouret et al., 2007



The giant landslide of Tacna emplaced on conglomerate of the western margin of the Andes, in Peru. The substratum conglomerate (Moquegua formation) is dated at ~2 Ma (Audin, pers. communication), which provides a maximum age for the landslide. The lanslide is mainly made of cobble and boulders (see pictures), which are typical material of debrisflow. Many boulders are from andesites rock bearing pyroxenes and amphiboles, which are well-suited mineral for cosmogenic ^{3}He dating.

Method : surface exposure dating using cosmogenic ^{3}He



PRINCIPLES OF ^{3}HE DATING : When a rock is suddenly exposed to cosmic rays at the Earth surface, cosmogenic ^{3}He starts accumulating within the mineral. Thus, retrieving the ^{3}He concentration within the surface mineral theoretically permits to determine the exposure time.

The Li content of the pyroxenes was measured in each samples in order to determine the production rate due to cosmogenic thermal neutron capture.

Helium measurement

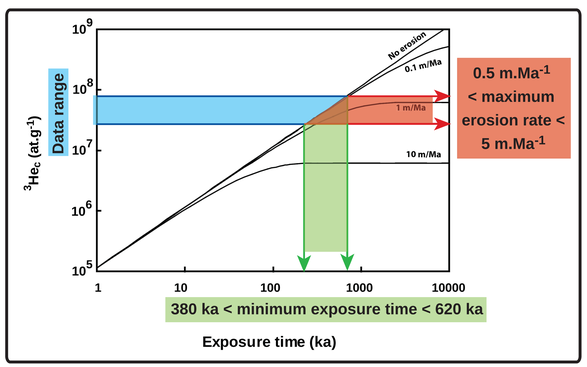
Helium was measured in the Caltech noble gas lab of Ken Farley. Helium was extracted from pyroxenes by fusing the minerals in a high vacuum furnace at 1600 °C. Both helium isotopes (^{3}He and ^{4}He) were then measured using a MAP mass spectrometer by peak jumping.

The ^{3}He$_c$ concentration was calculated by making a complete ^{3}He budget (Farley et al., 2006):

$$^3He_c = {}^3He_{total} - {}^3He_{mag} - \int_0^{Tc} P_n.dt$$

- ^{3}He$_{total}$ is the helium-3 concentration extracted by fusing the sample.
- ^{3}He$_{mag}$ was determined by prelimary vacuum crushing.
- The closure age Tc was measured by (U-Th)/He* dating.
- The nucleogenic production rate, P_n, was constrained by measuring the whole rock chemical composition (including U and Th).

Analysis of erosion



Equation of production
Lal, 1991

$$^3He = \frac{P}{\varepsilon * \rho / \Lambda} * \left(1 - e^{-\varepsilon * \rho / \Lambda * t}\right)$$

ε : erosion rate (cm/a)
ρ : rock density (g/cm^3)
Λ : attenuation length (g/cm^2)
P : local ^{3}He production rate (at/g/a)

Assuming the pre-exposure ^{3}He inheritence is null, our ^{3}He$_c$ data implie that the surface of the landslide experienced erosion rates lower than 5 m.Ma^{-1}. Such low erosion rates are consistent with those estimated by Kober et al. (2005) in the Atacama desert. This suggests that the present-day hyper-arid conditions might have persisted over the last 500 ka.

Conclusions

Preliminary cosmogenic ^{3}He$_c$ ages from the giant lanslide of Tacna indicate that:

* The landlside probably emplaced between 400 ka and 1Ma.
* The erosion rate over this period of time remain limited (< 5 m.Ma^{-1}), suggesting that the present-day hyperarid conditions persisted during a long period of time.

Future work

* The measurement of another radioactive nuclide (such as ^{10}Be$_c$ $T_{1/2}$ = 1.3 Ma) will permit to solve the production equation for both erosion and time.
* Numerical modeling of the landslide dynamics will probably permit to place constraints on the climatic conditions contemporaneous to the landlisde emplacement : was this landslide the results of wetter conditions or a giant earthquake?
* Cosmogenic dating of other landslides in this region will provide important constraints about the reccurrence time of these events.