Surface exposure dating of pre-LGM erratic boulders on the Montoz anticlina

Angela Graf[a*], Stefan Strasky[b], Susan Ivy-Ochs[c], Naki Akçar[a], Peter Kubik[d], Martin Burkhard[e] † & Christian Schlüchter[a].

[a] Institute of Geological Sciences, University of Bern, Balzerstrasse 1-3, 3012 Bern, Switzerland
[b] Institute of Isotope Geochemistry and Mineral Resources ETHZ, NO CO62.5, Sonneggstrasse 5 8092 Zürich, Switzerland
[c] Institut für Teilchenphysik, ETH Hönggerberg, 8093 Zürich, Switzerland
[d] Paul Scherrer Institut c/o Institut für Teilchenphysik, ETH Hönggerberg, 8093 Zürich, Switzerland
[e] Institut de Géologie; Rue Emile-Argand 11; CH-2007 Neuchatel; † deceased in August 2006
[*] Fax: +41 31 631 48 43, e-mail: angela.graf@geo.unibe.ch

During the last glacial maximum, the alpine Rhone ice reached the southernmost anticline of the Jura Mountains but penetrated only into a few valleys floors. However, relict glacial deposits, e.g. erratic boulders of alpine origin, are found beyond the limits of this ice extend. In view of the need to establish an absolutely dated glacial chronology of the Jura Mountains we use in situ produced cosmogenic nuclides to date surfaces of erratic boulders found on the top of the Montoz anticlines. This area lies beyond the extent of the LGM and is thus appropriate to test the Surface Exposure Dating (SED) methods on old erratic boulders. Cosmogenic nuclides are produced in the upper few centimeters of a rock surface as a function of exposure time to cosmic rays. By using both radionuclide ^{10}Be and noble gas ^{21}Ne, we could rule out pre-exposure, (resulting in an overestimation of the true deposition age) because when a surface is covered, ^{10}Be starts to decay while ^{21}Ne is stable, so that resulting ages of a boulder would be different.

We collected samples from four different erratic boulders distributed on both sides of the anticline. MO-04-01was found on the northern slope, MO-04-02 is located almost on the top, and MO-04-03&-04 are lying on the southern slope. Thin section analyze of the pale-greenish gneissic Montoz boulders show whitish feldspar-quartz lenses in an oriented matrix composed of muscovite, epidote, and chlorite, with zircon and opaque minerals as accessories. They are most probably Arolla gneisses from the Dent Blanche nape.

To calculate surface exposure ages, we used the sea level, high latitude production rates of 5.1 and 20.3 atoms.g^{-1}SiO$_2$.yr^{-1}, for ^{10}Be and ^{21}Ne, respectively (Stone, 2000; Niedermann, 2000; Gosse and Stone, 2001). Production rates were scaled to geographic latitude and altitude after Stone (2000). Changes in paleomagnetic intensity and non-dipole effects have not been considered, and sea level changes are not yet integrated. The local production rate was further corrected for topographic shielding and the dip of the samples (between 0 and 40°) after Dunne et al. (1999), and for sample thickness after Gosse and Phillips (2001), using an effective attenuation length of 157 g/cm^2 and a rock density of 2.65 g/cm^3. Snow corrected ages were obtained by assuming an over-the-year cover of 7 cm of with a density of 0.4 g/cm^3. Together with vegetation coverage of 5 cm (density of 0.2 g/cm^3), we obtained a rock equivalent layer of 1.01 cm. The apparent ages were then corrected for a conservative erosion rate of 1 and 3 mm/ka. Table 1 shows that the ages of the two larger blocs are higher ages, which makes sense if we consider the probability of sediment cover of smaller blocs (Mo-04-02) and splitting off of rock slabs (MO-04-

03). According to the obtained radionuclides and noble gas ages, the boulders were deposited on the Montoz anticline between 126 and 184 ka, corresponding to Marine Isotope Stage (MIS) 6. Glacigenic sediments that can most probably be attribute to this glacial advance are found S and N of Bern in the Thalgut carry and in the Meikirch drill core respectively.

In this study, we successfully applied surface exposure dating on older erratic boulders in mid-latitude, and attribute the deposition of these boulders to the glacial advance during MIS-6. This implies that glaciations between this extent and the LGM, (i.e. MIS 5d, 5b and MIS-4) must have been of smaller extent.

Sample	Altitude (m a.s.l.)	Size (l*w*h) (m)	Heating Temperature (°C); Time (min)	$^{21}Ne_{exc}$ (10^6 atoms g^{-1})	^{21}Ne Age (apparent, ka)	^{21}Ne Age (ε = 3 mm/ka)	^{10}Be (10^6 atoms g^{-1})	^{10}Be Age (apparent, ka)	^{10}Be Age (ε = 3 mm/ka)
MO-04-01	1200	2.2*3.8*0.75	600; 45	6.34 ± 1.22	112 ± 11	124 ± 12	1.35 ± 0.04	99 ± 3	143 ± 17
			800; 20	0.07 ± 0.36					
			1750; 20	0.28 ± 0.66					
MO-04-02	1260	1.6*2.2*0.5	600; 45	5.64 ± 1.78	94 ± 15	103 ± 17	1.09 ± 0.11	75 ± 8	98 ± 11
			800; 20	0.00 ± 0.00					
			1750; 20	0.44 ± 0.80					
MO-04-03	1050	2.8*2.2*1.8	600; 45	3.64 ± 0.94	73 ± 10	80 ± 11	0.73 ± 0.05	60 ± 4	74 ± 6
			800; 20	0.03 ± 0.34					
			1750; 20	0.26 ± 0.50					
MO-04-04	1060	8.0*4.5*1.7	600; 45	5.87 ± 1.12	123 ± 12	138 ± 13	1.23 ± 0.06	107 ± 6	163 ± 21
			800; 20	0.12 ± 0.40					
			1750; 20	0.34 ± 0.66					

Tab. 1. Accelerator mass spectrometry (^{10}Be) and noble gas mass spectrometry (^{21}Ne) data eon data for the Montoz samples, and calculated ages. Apparent ages are corrected for thickness and shielding, the erosion corrected ages contains also correction for snow and vegetation cover. All errors are given with 1σ uncertainties, (^{10}Be without systematic production rate error; ^{21}Ne including statistical, sensitivity and discrimination errors).

REFERENCES

Dunne, J., Elmore D. and Muzikar P., 1999. Scaling factors for the rates of production of cosmogenic nuclides for geometric shielding and attenuation at depth on sloped surfaces. Geomorphology 27, 3-11.

Gosse, J.C., Stone, J.O., 2001. Terrestrial cosmogenic nuclide methods passing milestones toward paleo-altimetry. EOS (Transactions, American Geophysical Union) 82, 86, 89.

Gosse, J.C., Phillips, F.M., 2001. Terrestrial in-situ cosmogenic nuclides; theory and application. Quaternary Science Reviews 20, 1275-1560.

Niedermann, S., 2000. The ^{21}Ne production rate in quartz revisited. Earth and Planetary Science Letters 183, 361-364.

Niedermann, S., 2002. Cosmic-ray-produced noble gases in terrestrial rocks: dating tools for surface processes. In Porcelli, D., Ballentine, C.J., and Wieler, R., editors, Noble gases in geochemistry and cosmochemistry. Reviews in Mineralogy and Geochemistry 47, 731-784.

Stone, J.O., 2000. Air pressure and cosmogenic isotope production. Journal of Geophysical Research 105, 23753-23759.