iCRONUS meets CRONUS-Earth: Improved calculations for cosmogenic dating methods - from neutron intensity to previously ignored correction factors

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Factors included in the analysis of cosmogenic inventories

Low-energy neutron calculations:

Implemented: diffusion approach - updated cross-sections; give more consistent results, eliminate instabilities.
In progress: MCNP (to be reported in December), and new transport approach.

Sources of data: neutron libraries; MCNP software.

Spatial and temporal scaling:

Implemented: new energy-dependent scaling (ratio of production rates, P, see table).
In progress: different discretizations of geophysical data (to be reported in December).

Sources of data: cosmic-ray surveys; geological records.

$P_{spallation}/P_{activation}$ for two rigidities

	2 GV	14 GV
0 m	1.00	1.08
4000 m	1.09	**1.23**

Universal-global correction factors:

Implemented: eustatic sea-level changes (for magnitude of change, see table).
Implemented: paleomagnetic intensity; change depends on location and age.
Implemented: pole position; change depending on location and age.

Sources of data: geological records.

Sensitivity of P to sea-level change

	%ΔP/m	%$\Delta P_{-60\ m}$ [(a)]
0 m	0.09	**+5.0%**
4000 m	0.06	+3.4%

(a) Average in the last 100 ky minus modern level.

Universal-local correction factors (see table):

Implemented: pressure (π)
Implemented: temperature (τ)
Implemented: temperature lapse rate (β)
In progress: effects of temporal changes of π, τ and β.

Sensitivity of P to changes in π, τ and β, and examples from glacial times.

	4000 m	0 m	Typical value	4000 m	0 m
π	0.4%/mbar	0.7%/mbar	+5 mbar	-2.1%	**-3.5%**
τ	0.8%/K	0.0%/K	-10 K	**+8.2%**	+0%
β	1.6%/(K/km)	0.0%/(K/km)	+2 K/km	**+3.3%**	0%

Sources of data: modern climate records; geological and paleoecological records; paleoclimate models.

Local correction factors:

Implemented: topography; (neo)tectonic movement; snow cover(including one snow model).
In progress: more snow models; other factors.

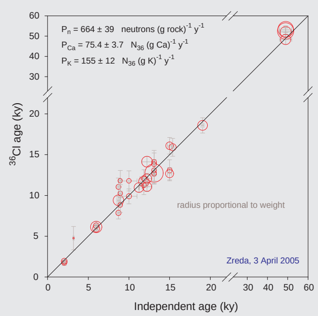
Sources of data: modern climate records; geological and paleoseismological records; paleoclimate models.

Recalibration of the ^{36}Cl system:

Uses data set from Phillips et al., 1996 (Phillips96) plus new high-K samples
Implements the calculations and factors listed above
Average absolute deviation decreased from 15% to 11% for the Phillips96 data set
Fast neutron rate may be lower than modern measurements
Production rate from Ca is robust
Production rate from K is not robust

More accurate production rates will be determined under the CRONUS project in the next 5 years.
For now, we recommend the **interim** production rates shown in the chart on the right.

These production rates include all assumptions and corrections described above; the same assumptions and corrections must be made in age calculations.



Conclusion: In addition to latitude, longitude and altitude, whose effects on cosmogenic production rates have been worked out, the following environmental variables cause large (non-negligible) variations in cosmogenic production rates: eustatic sea-level changes, pressure, temperature and temperature lapse rate. Accounting for these variables improves the internal consistency of calibration data sets. Rigorous models and databases describing these effects are under construction, and will be presented in December.

ABSTRACT

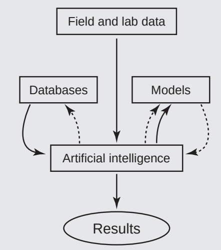
We report progress on two five-year projects whose common goal is to improve cosmogenic dating methods: CRONUS-Earth will improve calibration; iCRONUS will develop a software system based on an artificial intelligence core (thus, the 'i' in the name). Calibrated production rates and correction factors modifying production rates are two critical aspects of calculating cosmogenic ages. Calibration depends on the accurate computation of neutron fluxes at the air-ground interface. The currently-used diffusion equation underestimates neutron fluxes at the surface. Two more accurate alternatives, the physically comprehensive Monte Carlo N-Particle transport code and a simpler analytical transport model, are considered for implementation in iCRONUS. Correction factors are of two types: global (affect all samples) and local (affect only the samples from a specific landform). Global correction factors include those that modify the secondary cosmic ray intensities; the most important are air pressure and geomagnetic cutoff rigidity of the sample site. The size of the correction depends on the location, temporal variations of the geomagnetic intensity, position of the magnetic poles, eustatic changes of sea level, temporal and spatial changes of sea-level pressure, and temporal and spatial changes of temperature and lapse rate. Every landform also requires its own, unique set of local corrections, applied on top of the global corrections. Examples include erosion of landform's surface and sampled surface, (neo)tectonic displacement, topographic shielding, cover, and variable chemistry. Our improved calibration and all correction factors form a framework implemented in the iCRONUS software. We will demonstrate a desktop version of iCRONUS at the meeting.

Acknowledgments

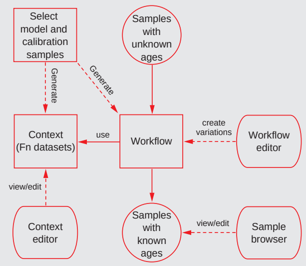
This work is supported by the US National Science Foundation through the **iCRONUS** project (grants ATM-0325929 and ATM-0325812) and the **CRONUS- Earth** project (grant EAR-0345440).

The iCRONUS software

Objectives are to develop, within a uniform framework:
(1) Geological-mathematical models to quantitatively describe the accumulation of cosmogenic nuclides in evolving landforms.
(2) Databases of basic and applied knowledge and data.
(3) An artificial intelligence system for analysis of cosmogenic data.
(4) A software architecture that supports the construction of a component-based software system that enables “plug-and-play” assembly of software tools that embody the features of objectives 1-3 above.



In this first demo, we present a model, with the necessary geophysical databases, for calculation of cosmogenic ages. The context, or the main conceptual system, is defined by the user; workflows, or variations of the context, can be modified at any time. This design will allow the user to add/remove or change assumptions, factors, computational models and data sources, thus allowing a total flexibility during the analysis.



iCRONUS workflow for cosmogenic dating