EUROPEAN SCIENCE FOUNDATION
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RESEARCH CONFERENCES

ESF Conference in Partnership with LFUI

Cosmogenic Nuclides

8 - 13 August 2011

Universitätszentrum Obergurgl, Obergurgl, Austria

Chaired by:

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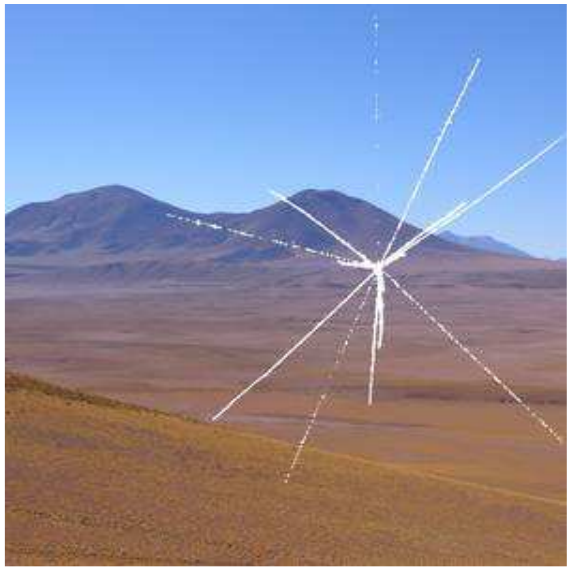

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Conference Highlights

Please provide a brief summary of the conference and its highlights in non-specialist terms (especially for highly technical subjects) for communication and publicity purposes. (ca. 400-500 words)

The conference provided an international forum for methodological development and revision in the field of cosmogenic nuclide methodology; a method that is increasingly used in the Earth Sciences to determine the ages of exposed rock surfaces or buried sediments. Further the method is used to determine long-term rates of erosion and weathering of soil/rocks. The method relies on the production of nuclides by the interaction of high-energy cosmic rays with atoms in the Earth's atmosphere or in rocks/soil at the Earth's surface.

Key members of two international research consortia working on the revision of cosmogenic nuclide methodology were present at the conference, as well as the majority of European practitioners in the field. Several methodological revisions were presented and discussed at the conference that impinge on our ability to accurately calculate exposure and burial ages or determine erosion/weathering rates. A significant conversion of ideas has been achieved and a community consensus model for cosmogenic nuclide production on Earth is within reach. Importantly the participants agreed on a modus to discuss and implement future developments into the emerging community consensus model, which will be available via a web-based tool for all users.

The other focus of the conference was to describe the state of the art in the application of the cosmogenic nuclide methodology to Earth Sciences. Highlights were presentations on a novel technique that allows the determination of the timing when a sediment became shielded from cosmic rays (e.g. dating sediments that contain hominid fossils in caves); dating of individual (pre-) historic earthquakes to determine their recurrence rate and magnitude to assess earthquake hazard in a region; or the dating of volcanic eruptions for the assessment of the volcanic risk. Other highlights were presentations that developed how it is possible to determine long-term (averaged over several thousand years) erosion and weathering rates at the scale of a single hillslope to the scale of entire mountain ranges; while others explored the possibility to reconstruct the strength of the Earth's magnetic field in the past, or determine the age of old marine sediments that would otherwise be undatable. One practical drawback of the methodology is that it requires large and expensive infrastructure to accurately measure the few atoms that are produced by cosmic rays in rocks. In the session on accelerator mass spectrometry and analytical methods, i.e. the tools that underpin all applications, recent developments that enable faster and more economical analysis in the future, without sacrificing accuracy, were presented. The conceptual und analytical developments presented at the conference will open new avenues to develop novel applications to the benefit of Earth-surface sciences.

☒ I hereby authorize ESF – and the conference partners to use the information contained in the above section on 'Conference Highlights' in their communication on the scheme.

Scientific Report

Executive Summary

(2 pages max)

The aim of the conference was to provide a forum for methodological development and revision in the field of cosmogenic nuclide methodology; further it was to summarize the state of the art over a wide spectrum of applications, as well as provide an outlook on future developments. These aims have been met.

Methodological revision

Key members of two international research consortia working on the revision of cosmogenic nuclide methodology (CRONUS-EU and CRONUS-Earth; EU-FP6 and NSF-funded, respectively) were present at the conference, as well as the majority of European practitioners in the field and practitioners from Australia & Asia. The methodological revisions presented (revised ^{10}Be half-life; description of albedo effects for thermalized cosmogenic secondary neutrons; new scaling factors to calculate cosmogenic nuclide production rates at any place on the Earth's surface; lowered contribution of muons to ^{10}Be production) have been discussed in detail. A significant conversion of ideas has been achieved and a community consensus model for cosmogenic nuclide production is within reach (pending finalization of model description, programming and evaluation in the review process).

Crucially, a mechanism to evaluate future developments was agreed on: a standing international committee with representatives from N. America (5), Europe (5) and Australia & Asia (2) will be put in place to assess novel developments and whether and how to incorporate new findings in a community model that will be accessible to users through the CRONUS webcalculator. The number of regional representatives correlates with the number of active practitioners in the field in each region.

It was agreed that international meetings of a similar format as this ESF-conference will be organized biennially; to present and discuss new developments and evaluate the decisions/recommendations of the standing committee.

Application of cosmogenic nuclides to Earth Sciences: The state of the art

International leaders in the development and application of cosmogenic nuclide methodology presented keynote lectures on cutting edge applications in the fields of Earth-surface processes (geomorphology, sedimentology, and geochemistry), paleoclimatology, paleoanthropology, paleoseismology, geophysics and natural hazards. Likewise several young researchers presented exiting novel applications in these fields.

Particular highlights were presentations on the novel isochron technique for burial dating; dating of individual (pre-) historic earthquakes and volcanic eruptions; spatially and temporarily resolved hill-slope processes; and the uses of meteoric cosmogenic nuclides in geochemistry, paleoclimatology and geophysics. In the session on accelerator mass spectrometry and analytical methods, i.e. the tools that underpin all applications, recent developments that enable faster and more economical analysis in the future, without sacrificing accuracy, were presented. Together, these conceptual und analytical developments for cosmogenic nuclide applications will open new avenues to develop novel/unique applications in Earth-surface sciences.

Amongst the participants there was a broad consensus that meetings of a similar format as this ESF-conference should be regularly organized to ensure that new developments are presented and discussed in a timely fashion to the benefit of seasoned practitioners, but also novices in the field.

Scientific Content of the Conference

(1 page min.)

- *Summary of the conference sessions focusing on the scientific highlights*
- *Assessment of the results and their potential impact on future research or applications*

The scientific program was split in seven thematical sessions spanning the entire field of cosmogenic nuclide methodology. The highlights of individual sessions will be summarised, and an assessment of the impact of the results for the future development of this scientific field provided.

Session 1: Methodological Revision.

Speakers that were representing the two international research consortia that work(ed) on revision of cosmogenic nuclide methodology (CRONUS-EU and CRONUS-Earth; EU-FP6 and NSF-funded, respectively) presented the results of this work. The methodological revision is aimed at deriving accurate scaling factors that allow the calculation of exposure ages at any location of the Earth's surface and near subsurface.

The results of CRONUS-EU indicate that, within current analytical uncertainties, one set of scaling factors should adequately describe cosmic ray flux as relevant to cosmogenic nuclide production on Earth. Notable exceptions are nuclides that have significant production pathways involving thermalized secondary cosmogenic neutrons. Since thermal neutrons are affected by albedo effects at the air/rock interface, which are strongly modulated by the variable moisture content in most environment, in many cases the calculation of accurate production rates will remain impossible in practice for these nuclides (^{36}Cl in Cl-rich rocks and ^{3}He in Li-rich rocks). Another important result presented was the revision of the ^{10}Be half-life; significantly reducing uncertainty and likely to end a decade old debate on the value of that parameter, which is the source of a persistent ambiguity in ^{10}Be data reported in the literature. The results of CRONUS-Earth indicate that presently used scaling factors, which were constructed based on station neutron monitor data, fail to reproduce locally calibrated production rates at high altitude (>3000m) and low latitude (<30º). The probable cause is the (unresolved) increase of multiplicities in the detectors (i.e. counting one event more than once) with decreasing latitude and increasing altitude, due to an increase of the mean energy of secondary neutrons. A new set of scaling factors was presented that relies on neutron monitor data that can resolve neutron energy and is not significantly affected by multiplicities. These new scaling factors can coherently reproduce the global network of local calibration rates at a wide range altitudes and latitudes. It was suggested to generally recommend this new set of scaling factors as the preferred technique to calculate exposure ages (see also *Forward Look*). For subsurface production data was presented that indicate that ^{10}Be production by muons is less than half than was previously assumed. This CRONUS-Earth data set is confirming previous data and interpretation of European scientists, and likely to end the longstanding debate on the importance on muons by reaching agreement.

Session 2: Applications Burial, Depth profiles.

Several applications of burial dating (cave sediments, desert sand) and depth profiles (glacial sediments) were presented. These included the application of novel techniques (e.g. in situ ^{14}C) and novel interpretative approaches (e.g. dune sand burial/transport).The keynote presented results applying a novel isochron technique for burial dating; demonstrating that this new method is uniquely suited to date continental sediments in the age range of several hundred thousand years up to ~ 4 million years. This technique will increase the scope of burial dating, and most importantly provide a means to determine the age of sediment deposits that were previously

impossible to date accurately.

Session 3: exposure applications
Applications of cosmogenic nuclides to exposure dating were presented, covering the fields of paleoseismology, volcanology, and sedimentology. The varied and highly specialized analytical and interpretative approaches were presented in depth by the keynote speakers. However, also the other speakers capably developed their specific, sometimes interdisciplinary approaches. This session highlighted the capability of cosmogenic nuclide methodology to reliably date past earthquakes, volcanic eruptions and rock falls; this to the benefit of scientific understanding of the underlying geological processes and natural hazard assessment.

Session 4: erosion, in-situ
The presentations in this session showcased the current methodological capabilities to quantify erosion and sediment transport using in-situ produced cosmogenic nuclides. The spatial scale covered ranged from outcrop size, over hill-slope, to first to high-order catchments; the temporal scale from annual to glacial periods. Methodological pitfalls (rare large-magnitude events), and limitations (stochastic sediment transport) were discussed; as well as, situations where cosmogenic nuclide methodology permits a robust quantification of Earth-surface processes at a wide range of temporal and spatial scales.

Session 5: AMS, analytical methods
Presentations in this session described the history and current state of the art in accelerator mass spectrometry (AMS). Recent developments of low-energy AMS were presented. Low-energy AMS has a huge potential, since it allows accurate but also economical analysis of isotopes, that were previously exclusively in the realm of large-facility high-energy AMS.
Results of the performance tests of a new AMS-facility in Europe, which is dedicated to the use for cosmogenic nuclide analysis in Earth-sciences, were presented. This facility should become fully operational in the course of next year. Another focus of the session were presentations on analytical methodology on novel nuclide-target material pairs (^{14}C in quartz; ^{10}Be in chert), which should serve to expand the applicability of cosmogenic nuclide methodology to a wider range of lithologies and shorter time scales in the near future.

Session 6: Erosion, meteoric
This session focussed on the recent renaissance of the application of meteoric cosmogenic nuclides (those produced in the atmosphere, rather than in-situ in rocks) to Earth Surface sciences. The underlying systematics, and their recent refinements, were explored in detail. The presentation on the use of the ^{10}Be/^{9}Be ratio as a regional/global weathering tracer delivered a pioneering conceptual and methodological development with far reaching impact in the Earth-Sciences, and left many senior participants awed.

Session 7: meteroic
This session covered state of the art applications of meteoric cosmogenic nuclides to paleoclimatology and paleomagnetics. These included detailed reconstructions of past magnetic field-strengths from marine sediments covering several hundred thousand years, the use of remaining ^{10}Be-activity to date otherwise undatable marine sediments of up to 14 million year old, and the reconstruction of mixing of marine waterbodies in the Arctic Ocean. These applications demonstrated the versatility and uniqueness of information that can be garnered from meteoric cosmogenic nuclides in lacustrine and marine sediment records as well as in marine water samples.

Forward Look

(1 page min.)

- *Assessment of the results*
- *Contribution to the future direction of the field – identification of issues in the 5-10 years & timeframe*
- *Identification of emerging topics*

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Crucially, a mechanism to evaluate future developments was agreed on: a standing international committee with representatives from America (5), Europe (5) and Australia & Asia (2) will be put in place to assess novel developments and whether and how to incorporate new findings in a community model that will be accessible to users through the CRONUS webcalculator. The number of regional representatives correlates with the number of active practitioners in the field in each region.

The emergence of a community consensus, and the decision on a mechanism to incorporate novel developments/insights into a community consensus model in the future, is a result that the chairs may have hoped for; but is much more than was expected. The meeting was the first of its kind, where a large number of practitioners from both sides of the Atlantic sat together and earnestly tried to hash out their differences, and largely succeeded in this. As such the ESF-conference has already had a large impact on the field. A critical issue will be to maintain the dialogue, i.e. maintain inclusive meetings at regular intervals (biennial meetings were decided at the conference); finding funding will be crucial but is uncertain. Continuing hands-on scientific work on questions that arise/remain from/after the CRONUS-initiatives (such as increasing the number and regional spread of calibration sites) can be maintained by national/regional funding over the time-scale of five to ten years; it is the funding to maintain community consensus from a likely cacophony of emergent data/opinions that is uncertain.

Methodological developments

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The conference had an important function in dissemination of concepts and ideas, their permeation into the field would otherwise be slower (e.g. the isochron technique was first published three years ago, but slipped the attention of most practitioners; it appeared in a journal not widely read in the field). Other than lingering methodological uncertainties (see Methodological revision) the applications do not have any issues that could not be solved by the ingenuity of the mind. Once the methodological revision is complete, and production rates can be calculated accurately, there will be novel applications that depend on this improved accuracy.
An (re-)emerging field is the use of meteoric cosmogenic nuclides in the Earth Surface sciences; amongst others the use of the $^{10}Be/^{9}Be$ ratio as a regional/global weathering tracer will probably find wide application.

- Is there a need for a foresight-type initiative?

The methodology itself does not need a foresight-type initiative. Some of the applications, such as the assessment of the sustainable use of soil-resources, do merit a foresight-type initiative

Atmosphere and Infrastructure

- *The reaction of the participants to the location and the organization, including networking, and any other relevant comments*

The participants were exceedingly content with the location and the smooth logistical organization of the event. The location worked perfectly well to support crucial aims of the conference, i.e. enable formal and informal discussions between seasoned practitioners and young scientists. Networking, to establish scientific collaboration or to make the next steps in a scientific career was prolific. Staff at the venue was competent, friendly and always supportive.

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Not applicable

Date & Author: 9.10.2011, Prof. Tibor Dunai