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Editorial: Oklo and all that…

I well remember the atmosphere when the news broke, or rather seeped through, in the early 1970s. Not in the media, not in the scientific journals, not yet in "Nature" or "Science". And not in the Swiss press at the time—they were busily focussed on another new word in the vocabulary of radioactive waste disposal: "Nagra". No. In the corridors of the Swiss universities the word that was being whispered was "Oklo", by some in awe and excitement, by many others in disbelief or even disdain. Oklo, an obscure uranium mine in Gabon (western Africa), they whispered—fossilized nuclear reactors—uranium gone critical—2 billion years ago—natural transuranic radioisotopes—still in place… proof of the long-term safety of radioactive waste disposal? Fantastic! Impossible!

The first reports appeared in the mid-seventies and were followed by an explosion of interest in the scientific research of a relatively small group of specialists, mainly those working in or with the nuclear energy industry. Numerous technical reports and a number of scientific papers appeared, and with time the unique Oklo phenomenon became known to a larger segment of the geological community. In the early 1990s, a far-ranging, EU-financed, research project was launched, called "Oklo-Natural Analogue, Phase I", and followed by the equally ambitious "Oklo-Natural Analogue, Phase II" later in the decade. A pioneer of Oklo research and one of the leaders of these projects was Prof. Gautier-Lafaye of Strasbourg University (Fig. 1).

The title of this Editorial, however, is "Oklo *and all that*…". Oklo, extremely interesting as a unique geological phenomenon, also set off an avalanche of activity which has hitherto hardly been noticed in academic circles. The Oklo story inspired, in addition to continued study of the phenomenon itself, the development of a whole new branch of applied geoscience, known to its practitioners as "natural analogue research". This harmless-looking term hides a whole spectrum of geoscientific activities, little noticed by earth scientists not involved in problems of radioactive waste disposal. As a bridge between these two worlds, we publish here a selection of papers on the subject, as a Special Theme, to illustrate its wide scope and its intrinsic geological content. The papers originated in the 13th international workshop of the Natural Analogue Working Group (NAWG) which was held in May 2013 at Nagoya University in central Japan. Within this Special Theme, the first paper is a review paper on "natural analogues", in particular their use in advancing knowledge on different aspects of radioactive waste disposal. The aim is to

Fig. 1 Professor Francois Gautier-Lafaye (University of Strasbourg) indicating the contact zone of natural nuclear reactor number 10 to a group of Swiss journalists at the Oklo uranium mine (Gabon) in 1997. Photo courtesy Dr. Matthias D. Knill

contribute to building confidence in the long-term safety of the various systems in development for constructing deep geological repositories. The review paper is followed by six papers treating the application of data from "natural analogues" to the evaluation of the long-term safety of such repositories in different countries (Finland, Germany, Japan, Korea). These in turn are focussed on different aspects of the problem (e.g. corrosion of native metals, stability of bentonite, salt dome development, radionuclide migration).

In spite of having been given a special name, the use of "natural analogue" argumentation is a fundamental and long-standing part of geological methodology, without which the science would hardly have progressed past infancy. It is, in fact, at the heart of Lyell's famous adage—"the present is the key to the past"—considered by some as marking the birth of geology in the early 19th century: the basic principle that that present-day natural processes can be used as "analogues" for those which have taken place throughout Earth history. Today's "natural analogue" specialists, as demonstrated in the papers in the present Special Theme, turn this maxim around—by studying geological phenomena, particularly those analogous to radioactive waste repositories buried deep in the geosphere, information on the long-term behaviour of such artificial systems can be obtained which cannot be acquired in any other way. In this context, the time factor is central, since the aim is to allow projections to be made for inconceivably long time periods into the future, by which time—up to a million years—the radiotoxicity will have subsided to innocuous levels.

"Natural analogues" do not provide a proof or a solution to this intrinsically difficult problem, but they do provide arguments in support or otherwise of the results from laboratory analysis, field experimentation and theoretical study. It is hoped that the papers collected here under this Special Theme will provide insights for our readers into the methods and results of this young line of geoscientific investigation, which, because of the time perspective, is an eminently geological undertaking. The papers present here illustrate the significance of geoscientific research for providing insights and solutions relevant to one of today's most important environmental problems—one for which, because of the long time intervals involved, geoscientists are particularly qualified to address.

Alan Geoffrey Milnes
Chief Editor