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FISSION TRACKS AND URANIUM IN AUSTRALIAN OPALS

By Robert McCorkell

Carleton University, Ottawa 1, Canada

Abstract

An attempt to determine the geological age of four opal specimens by the fission track method has failed, although features believed to be fission tracks were seen in one etched, irradiated specimen. Uranium concentrations of 0·1-11 ppm were measured in the specimens. This uranium was never found to be associated with inclusions. Such concentrations and manner of distribution of uranium in these opals considerably increases the possibility that other hydrous-silica mineraloids may be datable by the fission-track method.

Introduction

In an effort to throw light on the chronology of strata in the Murray Basin of Australia, the National Museum of Victoria forwarded samples of common opal from a paleosol estimated to be of the order of 2,000,000 years old with the request that fission track dating be attempted. This was not successful, but the data obtained are provided. In this *Memoir* the geology of the area is described by Gill, and the mineralogy of the opal by Segnit, Jones and Anderson, thus providing a background for the notes here presented.

Samples

In the Murray Valley region between Mildura and Renmark in Australia an extensive paleosol associated with the Karronda surface has been described. It usually appears in the stratigraphy as a zone of silcrete or silicified sandstone, but where it is formed on clays the silica is in the form of common opal. This was used for implements by the Australian Aboriginals, who scattered it widely through the area. The opal deposits are particularly well developed on the N. bank of the Murray River at Sharp Point on Nampoo Station, between the S. Australian border and Wentworth, where the Darling River joins the Murray. The cliff is about 37 m high, and the palaeosol is near the base. A lacustrine formation, the Blanchetown Clay, forms most of the cliff. The palaeosol is unusual here in that it consists of two horizons associated with thin lenticles of dolomite less than 1 m thick. A sample was provided from each of these lenticles, and to them were added two samples provided by Professor H. B. S. Cooke of Dalhousie University from precious opal sites, as follows:

No. 1. Common opal from upper bed with dolomite in Blanchetown Clay, Nampoo Station, N.S.W.
No. 2. Common opal from the lower bed at the same site.
No. 3. Opal from Coober Pedy, S.A.
No. 4. Opal from Quilpie, Queensland.

Method

Pieces of opal from the above four samples were irradiated for 10 mins. and 2 hours in a flux of $1{\cdot}2 \times 10^{13}$ n/cm^2—sec., and then mounted in epoxy and polished. Unirradiated samples were similarly mounted and polished. In addition, mounts consisting of discs of Lexan pressed against polished surfaces of the opals were irradiated for two hours in order to measure the uranium contents of the opal by the Lexan-overlay method. The mounts containing the opals in these cases contained pieces of glass of known uranium content.

Results

The polished irradiated opals were etched in various ways, but fission tracks were seen in only one case. This was in No. 4, when it was etched 10 seconds with 22 wt. % HF at room temperature. The tracks in this are not uniformly distributed but occur in rounded patches which are found rather infrequently in the clearer parts of the specimens. These pat-

ches are usually a few hundred microns across and contain a few hundred tracks. Although I believe the features are fission tracks they appear rather short and broken and would be difficult to recognize if they occurred singly. They do, however, have a tubular shape and a 3rd dimension and are not found in the unirradiated opal. Within the patches they are randomly oriented and do not radiate. The patches are quite sharply terminated but are not distinguished from their immediate surroundings in any way except in possessing fission tracks. One of these areas of tracks is shown in the plate.

No fission track-like features were found in any of the unirradiated opals.

The Lexan overlays were etched 8 minutes in 6M NaOH at 70°C. The ratio of the track density in the Lexan facing the mineral in the epoxy mount to that in the Lexan facing the standard glass gives the uranium concentration in the mineral:

$$\frac{\rho \text{ in Lexan facing mineral}}{\rho \text{ in Lexan facing glass}} = \frac{[\text{U}] \text{ mineral}}{[\text{U}] \text{ glass}}$$

Where ρ = track density or number of tracks per unit area. The 'background' track density due to uranium in the Lexan itself proved to be negligibly small. In this particular Lexan the tracks proved to be, in general, rather misshapen, perhaps because of strains introduced into it during manufacture. However, because only a ratio of track densities is needed for the uranium measurement, one is free to restrict himself to counting only certain types of track-like features, i.e., those which are well formed and are clearly fission tracks, provided he uses the same criteria in evaluating ρ (sample) and ρ (standard). In this case I counted only those tracks which showed a clear 'head' and 'tail' and were clearly 3-dimensional, i.e., were not surface features.

The following data on uranium concentrations and distributions were obtained:

No. 1. In a mount composed of many grains 1-3 mm in diameter the uranium concentration is uniform within a grain but variably by factors of 2-4 between grains. Some concentrations in ppm measured on randomly selected grains are

0·15	0·11	0·07
0·32	0·08	

No. 2. Concentration high, so that tracks in Lexan overlay overlap somewhat and are difficult to count. The uranium concentration is estimated to be 11 ppm, and appears to be very uniform.

No. 3. Concentration uniform over a distance of 5 mm or more: 0·11 ppm.

No. 4. Overlay shows many serpentining, ribbon-like, uranium-rich bands, usually ~ 100 microns wide but variable. Within these bands the uranium concentration is fairly uniform. The edges of the bands are sharp. The uranium concentration between these bands is unmeasurably low, and hence, probably $< 0{\cdot}03$ ppm. Uranium concentrations measured at randomly chosen points in the uranium-rich bands are, in ppm:

0·57	0·49	0·09
1·59	0·60	0·52

The uncertainties in the measured uranium concentrations vary somewhat, but are never more than ± 15% except, perhaps, for No. 2.

The second illustration in the plate shows a portion of the overlay from Opal No. 4.

Interpretation

Probably fossil tracks in the more uranium-rich opals were not seen because the texture, grain boundaries, obscure them. In addition, the specimens from the Murray River cliffs generally develop a thick encrustation during etching, and become dark during irradiation. Samples 3 and 4 do not darken in the reactor.

It is interesting that, in the Lexan overlay, no group of radiating fission tracks has been seen. All of these opals must me free of uranium-rich inclusions, although rarely a small enrichment of uranium along grain boundaries was seen in opal No. 1. The uranium in them must have precipitated from solution with the major consitituents; it was not incorporated into the opal as detrital grains, or precipitated with inclusions of minor constituents such as oxides. This is a fact that must be related in some

manner to the way in which opal forms. Uranium-rich inclusions are common in other minerals, micas for example. In those micas which have been affected by groundwater, these seem to have formed when uranium from the groundwater precipitated on, or with, grains of opaque minerals, oxides or organic material in the mica. Micas from the interior of unaltered rocks also frequently contain uranium-rich inclusions around which the well-known pleochroic haloes are sometime seen. These may be the usual accessory minerals which form with the major minerals. However, I have noticed that they seem to be more common in micas from meta-sediments than in micas from igneous rocks. I suspect that this may be because, in the original sediments, the uranium was already in the form of detrital grains and any that precipitated from the sea water may have done so on grains of $Fe(HO)_3$, MnO_2, or clays. Apparently, in this respect at least, there is a great difference between the environment in which marine sediments form and that in which opal forms.

Although I have not succeeded in dating this opal, the results have not been as negative as might have been anticipated. It has been shown that opal contains concentrations of uranium which would make fission track dating possible, and even simple, if other factors were favourable, and this uranium is not associated with inclusions. Since this is so for these opals, it is probably so for opals in general, and for other hydrous-silica mineraloids. (Quartz, on the other hand, has uranium concentrations so low that it could not be dated by the fission track method even if its age were similar to that of the earth.) This considerably raises the chances that, among the great variety of these mineraloids, some will prove to be datable. One should look for types in which the grain boundaries are not prominent under the microscope at powers of $\sim$ 400X, and do not become so on etching with hydrofluoric acid.

Explanation of Plate 31

Upper—Features which are believed to be fission tracks in neutron-irradiated, etched Opal No. 4.

Lower—Etched fission tracks in the Lexan overlay of Opal No. 4, showing uranium-rich bands in uranium-free matrix.