Galena generations in the Oklo natural fission reactors, Gabon

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The Palaeoproterozoic Francevillian sedimentary basin, in SE Gabon (Equatorial Africa), hosts a number of natural fission reactors. These are found within a uranium mineralisation situated between two sedimentary formations in the Franceville series. The reactors were first discovered in the Oklo mine in 1972. The fission reactions have subsequently been dated to 1980 ± 0.05 Ma (Ruffenach, 1978), and were in operation for several hundred thousand years (Hagemann, 1975). The reactors have been investigated intensively since their discovery, partly due to the excellent opportunity to study the behaviour of radioelements in a natural environment as a natural analogue for a high-level radioactive waste repository. A recent review of the studies is given by Gauthier-Lafaye *et al.* (1996).

So far, 18 reactor zones have been identified. There are important geological and physical differences between the zones, but typical reactor zones are *c.* 10 m in diameter and 50 centimetres thick. The cores of the reactors consist of highly concentrated uranium ore (up to 80% uraninite) in a clay mineral matrix (mainly illite and chlorite).

The main goal of this study is to investigate how the uraninite has responded to the fission reactions and subsequent hydrothermal and geological events; the cooling of the reactors after operation, the intrusion of a dolerite dyke and recent uplift of the basin. Galena, composed of radiogenic lead from uraninite, is a good indicator of uraninite lead loss, and is used to try to date the events of lead mobility.

Sampling and analytical methods

One drill core (Pix 3) from reactor zone 16, which has not been studied in detail previously, was sampled. The investigated drill core is 5 m long, and 9 thin sections have been made from different parts. Three of the thin sections are from the core of the reactor, one is from the hydrothermal clay halo surrounding the reactor core, and the remaining are from the surrounding sandstone with different relations to veinlets of quartz, clay and calcite.

Optical microscopy and SEM/EDS were used for textural and mineralogical studies with the aim to obtain a relative chronology of crystallisation. SIMS U and Pb isotope analyses were made using the Cameca ims1270 at the NORDSIM facility in Stockholm.

The SIMS analyses were concentrated on galena in different textural positions within the reactor core. The primary ion beam spot size was 5 μm for good spatial resolution.

Results

Galena is found in all sizes ranging from mm-sized anhedral crystals in the clay mineral matrix to micro-inclusions, with sizes around 10 μm, within the uraninite. The uraninite is more or less altered, which is seen as low reflectance patches in the optical microscope. EDS analyses reveal a significant concentration of Si and loss of Pb in the altered parts of uraninite. Outside the reactor core, uraninite is found mainly associated with organic matter in the sandstone and clay veins.

Optical and electron microscopy of thin sections occasionally reveal a clear relative chronology of crystallisation, indicating at least three different episodes of galena formation. Secondary uranium minerals are observed, indicating at least one episode of uranium mobility after primary uraninite crystallisation.

SIMS results provide a distribution pattern for Pb isotope ratios in galena (Fig. 1). Large, mm-sized galena in the clay mineral matrix of the reactor core display a peak around a $^{207}Pb/^{206}Pb$ ratio of 0.15, while smaller crystals (*c.* 10 μm) spread from ca 0.09 to 0.23, with a peak around 0.12.

Model ages were calculated assuming total lead loss from the uraninites at the time of the fission reactions at 1980 Ma. The peak around 0.15 gives a single stage lead evolution model age of around 700 Ma. This is approximately the age of the dolerite dyke intrusion, which is assumed to be the main event affecting the deposit after cessation of the fission reactions. The range of Pb isotope ratios, with

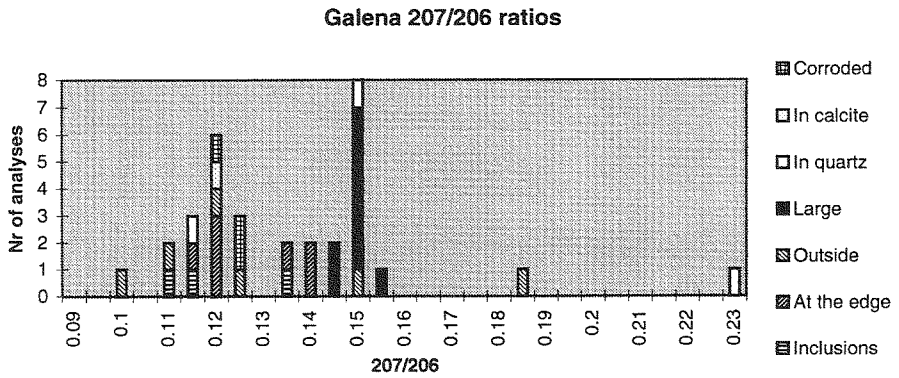

FIG. 1. $^{207}Pb/^{206}Pb$ isotopes of galenas. Corroded = corroded galena, In calcite = galena in calcite veins, In quartz = galena as inclusions in quartz, Large = mm-sized galena in clay, Outside = small galena in clay, At the edge = galena at the edge of uraninite, Inclusions = galena as inclusions in uraninite.

a concentration around 0.12, indicate a more complex history for the U-Pb system than the simple, single stage model adopted in earlier work.

In combination with relative chronology, a preliminary conclusion is that there has been at least one episode of uranium mobility after the fission reactions, and that there are three or more galena generations. These are composed of lead exsolved from uraninite at different times and mixed in different proportions.

References

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