

OPAL AS A URANIUM-LEAD GEOCHRONOMETER. Yu. Amelin¹, and L. A. Neymark², ¹Department of Earth Sciences, Royal Ontario Museum, Toronto, Ontario M5S 2C6, Canada (yuria@rom.on.ca), ²Mail Stop 963, Pacific Western Technologies, DFC, Denver CO 80225, USA (lneymark@usgs.gov).

Introduction: Records of ancient water flow in arid environments are preserved in precipitated from ground water mineral crusts, composed largely of calcite and amorphous silica (opal and chalcedony). These minerals have been dated by the ¹⁴C and ²³⁰Th/U methods [1]; however these methods are limited to ages ≤ 50 ka and ≤ 500 ka, respectively. The U-Pb system in opal and chalcedony allows dating in the age range from ~ 50 ka to millions of years and older [2,3]. For opals younger than ca. 500 ka it is possible to apply combined U-Pb and ²³⁰Th/U dating to the same materials, thus allowing better evaluation of closed system conditions, determination of initial ²³⁴U/²³⁸U ratios, and examination of continuous vs. episodic growth of opal [4].

Recently, U-Pb dating of opal has been used to study paleohydrology at Yucca Mountain, Nevada, a potential site for high-level radioactive waste repository [3,4]. Further application of this geochronometer requires evaluation of its robustness in a series of experiments with large homogeneous opal samples, some of which may subsequently be used as standard samples. We have selected three large (ca. 1-20 g) opal samples from the mineral collection of the Royal Ontario Museum and studied their U-Pb and ²³⁰Th-U systems.

Samples and methods: Two of the analyzed opal samples are visually homogeneous; one of them (E1989) is clear, another one (M21277) is translucent. The third sample (M21006) comprises a translucent opal matrix with clear opal veins. All three samples show relatively bright green fluorescence in short-wave UV light.

Combined U-Pb and ²³⁰Th/U isotopic determinations [4] were made from single small (1.5-8.1 mg) digestions spiked with a mixed ²⁰⁵Pb-²²⁹Th-²³³U-²³⁶U tracer solution of high isotopic purity. U, Th, and Pb concentrations and ²³⁴U/²³⁸U, ²³⁰Th/²³⁸U, ²⁰⁶Pb/²³⁸U, and ²⁰⁷Pb/²³⁵U ratios were determined simultaneously. Procedure blanks were 1.0-1.5 pg Pb, and about 2 pg ²³⁸U and ²³²Th.

Results: Uranium concentrations vary from 2.2 to 850 ppm, Th from 0.015 to 350 ppb, and common Pb from 7 to 500 ppb. The ²³⁸U/²⁰⁴Pb ratios are from $8.8 \cdot 10^4$ to $2.8 \cdot 10^6$. Variations of U concentrations of 2-4 times are observed in all three samples. In all cases fractions with brighter fluorescence in UV light have higher U concentrations.

Pb isotopic compositions are radiogenic with measured ²⁰⁶Pb/²⁰⁴Pb between 100 and 1000, and ²⁰⁷Pb/²⁰⁴Pb between 20.2 and 62. The ²⁰⁷Pb/²³⁵U ages of two homogeneous opals are 15.3 Ma for E1989 and 2.20 Ma for M21277 and are reproducible between fractions. Errors of ²⁰⁷Pb/²³⁵U ages are between 1.4-5.6% (2σ). The heterogeneous sample M21006 yielded a ²⁰⁷Pb/²³⁵U age of 8.83 ± 0.07 Ma for the matrix, and 2.71 ± 0.02 Ma for the vein.

All fractions have ²⁰⁶Pb/²³⁸U ages slightly older than ²⁰⁷Pb/²³⁵U ages. This reverse discordance may indicate that all studied opals precipitated from water with elevated ²³⁴U/²³⁸U activity ratio. The measured ²³⁰Th/²³⁸U and ²³⁴U/²³⁸U ratios in all fractions are in secular equilibrium, thus suggesting that the U-Th (and presumably U-Pb) isotopic systems have not been disturbed during the last 500 ka.

Discussion: The results of this study, together with previously published data from Yucca Mountain [3,4] and the earlier study by Ludwig et al. [2] suggest that opal is a promising U-Pb and U-series chronometer. Using these methods in combination is essential for both "young" samples with disequilibrium ²³⁰Th/²³⁸U and ²³⁴U/²³⁸U, and "old" ones in secular equilibrium. In the latter case the classical concordia diagram cannot be used as a check for closed system behavior because of unknown initial excess of ²³⁴U.

Ages of "old" opals can be determined from ²⁰⁷Pb/²³⁵U ratios that are not affected by initial uranium isotopic disequilibrium. The ²⁰⁷Pb/²³⁵U ratios are much more sensitive to common Pb correction than the ²⁰⁶Pb/²³⁸U ratios, therefore low analytical blank and finding opals with low common Pb are crucial. One problem that remains to be solved is finding low-U/Pb mineral phases cogenetic with opal, which Pb isotopic composition can be used for the common Pb correction.

The first data from the three large opal samples suggest that some of these or similar samples can be possibly used as interlaboratory standards if U-Pb dating of opal becomes a commonly used technique.

References: [1] Paces J. B. et al. (1996) *GSA Abstr. Progr.* 28(7), A-139. [2] Ludwig K. R. et al. (1980) *EPSL*, 46, 221-232. [3] Neymark L. A. et al. (1998) *Mineral. Mag.* 62a, 1077-1078. [4] Neymark L. A. et al. (1997) *EOS* 46(18), F788.