APPLICATION OF SHRIMP FOR U-Pb AND U-SERIES DATING OF OPAL

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INTRODUCTION

The recognition of opal's ability to concentrate U, and its applicability for U-Pb dating, has resulted in the increasing use of silica-rich materials in geochronological studies, especially for timing a variety of surface processes (Neymark & Paces 2000, Neymark *et al.* 2000, Ludwig & Paces 2002). Opal often shows significant enrichment in U relative to both Th and Pb. This reduces uncertainties associated with correction for initial Th and Pb, required for the age calculations, making opal particularly suitable for both U-Pb and U-series dating, especially when compared to some other minerals such as carbonates formed by the same processes.

METHOD

Opals are extremely inhomogenous with respect to both U concentration and age. This inhomogeneity is evident on macro- as well as micro-scale and is correlated with the sequence of silica deposition layers. This has resulted in attempts to minimise sample size used in the conventional TIMS (Thermal Ionisation Mass Spectrometry) analysis and the eventually application of the Sensitive High Resolution Ion Micro Probe (SHRIMP) for opal dating.

This abstract discusses the application of SHRIMP to the U-Pb and U-series dating of opals. The important advantages of SHRIMP compared to TIMS is the better spatial resolution (20 μm), resulting in the ability to date one depositional layer at a time on a microscale, and the ability to measure all required isotopes in a single run. In addition, SHRIMP offers a rapid way to analyse opals ranging in age from a few tens of thousands to millions of years. However, as a result of the small sample size, the technique is limited to opals with U concentrations in excess of ca. 50 ppm. Despite this limitation, the method can be used in a range of applications for dating silicified regolith profiles which contain significant quantities of U-rich opal.

There are a number of differences between the U-Pb opal analysis and the procedures developed for more common U-bearing accessory minerals. These differences are related to the relatively young ages of opals as compared to the traditionally analysed minerals such as zircon. The young ages result in the accumulation of relatively small amounts of radiogenic Pb, and are often distorted by incorporation of initial quantities of intermediate products of U-decay. As a result, there is a need to include measurements of these intermediate daughters into the analytical procedure, as well as analysing several isotopes with very small abundance.

SHRIMP RESULTS FOR OLD AND YOUNG OPALS

SHRIMP dating of two opal samples with the ages of ca. 10 Ma and 60-150 kyr has shown internally consistent results indicating that the method is applicable to the dating of relatively old (> 1 Ma) as well as the young (< 300 kyr) silica samples. Examples of dating of opal with intermediate ages are given elsewhere (Paces *et al.* 2003, Neymark *et al.* 2000).

In the > 1 Ma opal sample the $^{230}Th/^{238}U$ activity ratios are equal to one, suggesting that the system is in secular equilibrium. U-Pb systematics is, therefore, the only way to obtain an age of this sample. A relatively precise dating of the sample is still possible since $^{206}Pb/^{204}Pb$ ratios are high, ranging between ca. 200 and several thousand, resulting in the relatively small common Pb contribution. $^{206}Pb/^{238}U$ ages show a contribution of initial ^{234}U where as $^{207}Pb/^{235}U$ ages appear to be unaffected by this kind of problem and the average of these ages are considered as the best estimate of the true age. The average for this sample is 10.4 ± 0.6 Ma (95% confidence). The initial $^{234}U/^{238}U$ activity ratio can be also calculated using measured $^{206}Pb/^{238}U$ ratios and $^{207}Pb/^{235}U$ age. If $^{207}Pb/^{235}U$ ages of individual spot analyses are used in such calculation, the initial $^{234}U/^{238}U$ activity ratio varies from 1.1 ± 2.5 Ma to 6 ± 2.6 Ma, with the exception of two analyses showing negative values of -1.5 ± 5 Ma and -4 ± 4 Ma, and all analyses giving an average of 3 ± 2 Ma.

The young sample shows that the ^{234}U and ^{230}Th systems are not in equilibrium, making ^{230}Th-based ages most appropriate for dating. The relatively young age makes $^{207}Pb/^{235}U$ ages extremely imprecise. ^{230}Th-based ages vary systematically from about 150 kyr in the center of the vein to about 60 kyr near the contact (Figure 1). Considering that $^{232}Th/^{238}U$ ratios are very low (upper limit is 10^{-5}), most of ^{208}Pb is common. The

relatively high $^{208}Pb/^{206}Pb$ ratio, varying between ca. 1 and 2 for most of analytical spots, suggests a large proportion of common Pb in this sample. In fact, the fraction of common Pb calculated on the basis of $^{208}Pb/^{206}Pb$ ratios varies from 70% to 100%. This high proportion of common Pb makes correction very sensitive to any uncertainties in assumed initial composition as well as to even minor analytical problems, such as observing a few extra counts or a slight off-center position of one of Pb isotopes. As a result, $^{206}Pb/^{238}U$ ages are more likely to be meaningless.

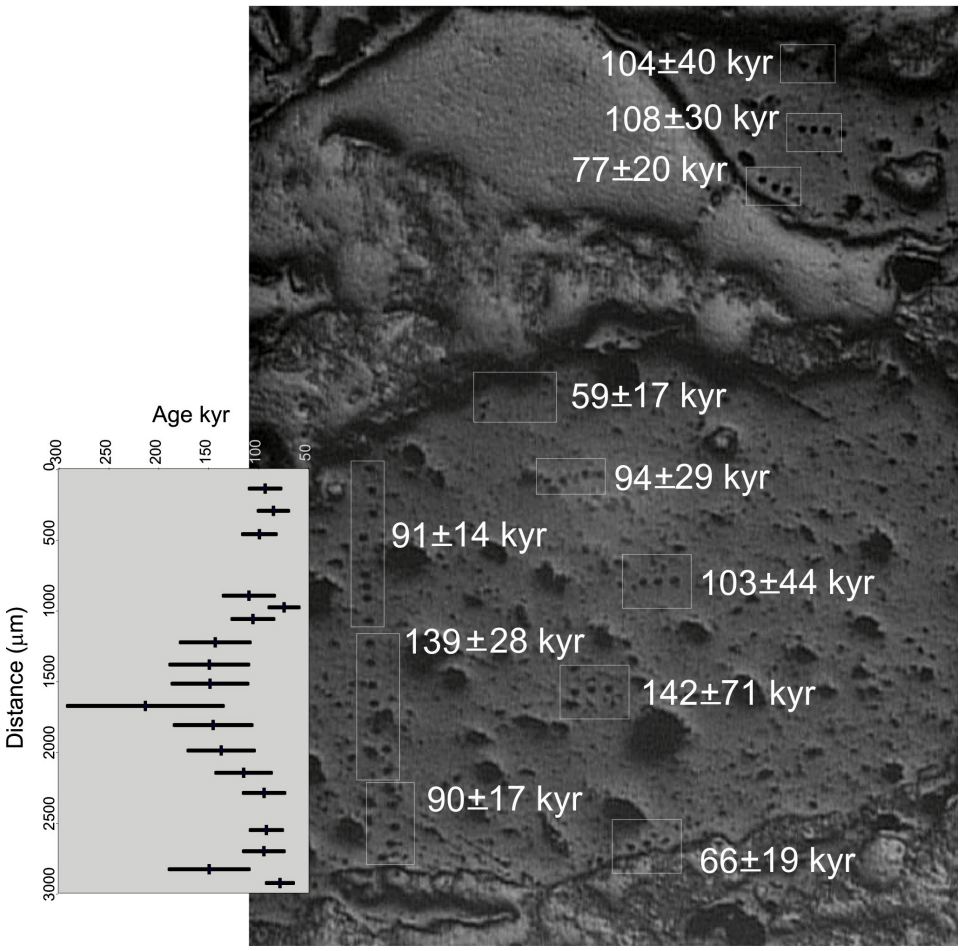

Figure 1: Optical microscope image of the young opal vein showing a range of ^{230}Th ages from 60 Ma to 140 Ma.

The wide distribution of silica-bearing minerals in regolith profiles, combined with the very limited age data-set, makes the area of application of SHRIMP-based opal dating virtually unlimited. The accumulation of opal age data in the future will increase the understanding of the temporal distribution of silica within the weathering profile.

REFERENCES

LUDWIG K.R. & PACES S.B. 2002. Uranium-series dating of pedogenic silica and carbonate, Grates Flats, Nevada. *Geochimica et Cosmochimica Acta* **66**, 487-506.

NEYMARK L.A., AMELIN YU.A. & PACES J.B. 2000. ^{206}Pb–^{230}Th–^{234}U–^{238}U and ^{207}Pb–^{235}U geochronology of Quaternary opal, Yucca Mountain, Nevada. *Geochimica et Cosmochimica Acta* **64(17)**, 2913-2928.

NEYMARK L.A., AMELIN YU.A., PACES J.B. & PETERMAN Z.E. 2002. U-Pb ages of secondary silica at Yucca Mountain, Nevada: implications for the paleohydrology of the unsaturated zone. *Applied Geochemistry* **17(6)**, 709-734

NEYMARK L.A. & PACES J.B. 2000. Consequences of slow growth for $^{230Th}/U$ dating of Quaternary opals, Yucca Mountain, NV, USA. *Chemical Geology* **164**, 143-160.

PACES J.B., NEYMARK L.A., JOSEPH L., WOODEN J.L. & PERSING H.M. in press. Improved spatial resolution for U-series dating of opal at Yucca Mountain, Nevada, USA, using ion-microprobe and microdigestion methods. *Geochimica et Cosmochimica Acta*.