Precise Pb-Pb dating of Precambrian zircon using thermal extraction-condensation (TEC) and ^{202,205}Pb double spike

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Method

Demonstrating reproducibility of Pb isotopic ratios in zircon is sufficient for accurate dating of Precambrian samples without the need for isotope dilution and U analysis, which require total dissolution of sample and chemical processing to remove Zr. The Kober [1,2] and Davis [3] methods of thermal extraction of Pb are simple but both provide relatively inefficient ionization and neither is amenable to double Pb isotope spiking, which limits the accuracy of ages that they can provide. We have experimented with a modification of Kober method that overcomes these limitations. Zircon is folded into a 0.03 in x 0.0005 in Re filament and thermally pre-treated at about 1450C for 30-45 min in vacuum to evaporate disturbed Pb from chemically altered domains. A condensation surface is then exposed to the sample and the zircon is heated at 1600C over 15 min to totally evaporate Pb. The condensation surface consists of either a 0.25 in wide Re ribbon (thermally cleaned using high current in a carbon coating chamber) or the inside of a 3 ml Savillex vial. Condensation of common Pb from the posts of the filament is prevented by the use of blinders welded to the posts of the evaporation filament. Operations are carried out inside a bell jar normally used for filament outgassing. Deposited silica from the zircon is subsequently removed using HF, by swabbing the Re surface using a pipette or open fluxing in the vial. The recovered Pb in the solution is dried, converted to HCl and spiked with ET2535 ^{202,205}Pb-^{233,235}U spike, then loaded onto a conventional Re filament with phosphoric acid and silica gel for conventional TIMS analysis. The vial condensator is more convenient than the wide filament but it produces relatively high blanks probably because of partial melting of a thin teflon surface layer by the hot silica. The Re condensator gives negligible blank but is less efficient for collecting Pb.

Results

The TEC method has been tested on two Precambrian zircon populations from northwest Ontario previously dated by conventional methods. One of them is from the Marmion tonalite which has a conventional U-Pb age of 3002.6 ± 1.5 Ma [4]. Four fractions of it gave an average TEC age with 2 standard deviation of 3001.9 ± 0.6 Ma. The other one consists of two zircon fractions from a rhyolite at Nevison Lake (conventional age of 2998.6 ± 0.8 Ma) with a TEC age of 2998.5 ± 0.4 Ma.

[1] Kober (1986) *Contrib. Min.& Petr.* **Vol. 93**, 482-490. [2] Kober (1987) *Contrib. Min.& Petr.* **Vol. 96**, 63-71.[3] Davis (2008) *Geol.* **Vol. 36**, 383-386.[4] Tomlinson et al. (2003) *Contrib. Min.& Petr.* **Vol. 144,** 684–702.

Noble gas and radionulcides study of chondrules from Dhajala and Bjurbole chondrites

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Chondrules were formed ~ 2-3 Myr after the formation of CAIs (the first solid condensates of solar system) and then accreted into large bodies with fine-grain matrix material [e.g.,1]. Chondrules might experience excess exposure to energetic solar particles and cosmic rays before their compaction. To investigate such pre-compaction exposure, cosmogenic noble gas isotopes and radionuclides were studied for individual chondrules from Dhajala and Bjurböle.

Separated individual chondrules from Bjurböle (L/LL4) and Dhajala (H3.8) meteorites were crushed to small and uniform grain size and then divided into three aliquots for composition, radionuclide and noble gas analyses. To calculate production rates of cosmogenic nuclides, major element compositions of the samples were determined by a Thermo Electron Corporation iCAP 6000 series mass spectrometer. Measurements of ^{10}Be, ^{26}Al, and ^{36}Cl were performed by AMS at Primelab, Purdue University. He, Ne and Ar measurements were carried out using noble gas mass spectrometry at Washington University in St. Louis. The cosmic ray exposure age of Bjurböle (> 8 Myr, [2]) is greater than five half-lives for all the radionuclides measured, indicating that the production rate is equal to the activity of the sample. The production rates of ^{10}Be, ^{26}Al, and ^{36}Cl were calculated based on irradiation depth using the model suggested by [3]. Estimates for the pre-atmospheric size of Bjurböle are ~ 400kg with a density of 2.28 g cm^{-3} [4]. Assuming a spherical shape, the pre-atmospheric radius of Bjurböle is ~ 35 cm. From radionuclide analysis, we find the Bjurböle samples were located from 2-5 cm inside the parent body. For Dhajala (CRE age ~ 4 Myr, [5]), ^{36}Cl and ^{26}Al activity is at the saturation point. Based on ^{26}Al, the most likely size and location of the sample is 70 cm inside a 120 cm body. At this depth, the ^{10}Be activity is saturated and the minimum CRE age is 6.8 Myr. The noble gases in chondrules are dominated by cosmogenic component however a detectable amount of trapped gases are also present. We are initially using the ^{22}Ne/^{21}Ne as a depth indicator, allowing us to calculate production rates of ^{3}He, ^{21}Ne and ^{38}Ar [6]. An alternative method is to deduce the irradiation depth based on radionuclide activity [3]. ^{3}He, ^{21}Ne and ^{38}Ar CRE ages suggest that chondrule D#10C from Dhajala and chondrule BC06C from Bjurböle were exposed to cosmic rays longer than the host matrix. The remainder of the chondrules show CRE ages similar to matrix. The excess exposure duration is within the range of earlier reports [2, 5]. Radionuclide data in this study were used to find size and depth profile of the samples; future radionuclide data will be used to quantify recent exposure history with the goal of elucidating pre-compaction exposure from the total exposure history.

[1] Kita et al. (2005) Chondrites & the protoplanet. Disk, ASP conf. series, 341, 558-587. [2] Polnau et al. (2001) *Geochim. Cosmochim. Acta* **65,** 1849-1866. [3] Leya et al. (2001) *Meteor. Planet. Sci* **36,** 1547-1561. [4] Flynn (2004) Earth Moon and Planets **95,** 361-374. [5] Eugster et al. (2007) *Meteor. Planet. Sci* **42,** 1351-1371. [6] Eugster and Michel (1995) *Geochim. Cosmochim. Acta* **59,** 177-199.