# ANALYTICAL AND EXPERIMENTAL ACTINIDE PARTITIONING IN NATURAL

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SUMMARY: U distributions between olivine, plagioclase, and glass were measured in terrestrial mid-ocean ridge basalts (MORB). U and Th partitioning experiments are being run using natural basalt starting materials. The results from the MORBs suggest surprisingly high U partition coefficients (D_U) for olivine and plagioclase. The experimental results indicate that $D_U^{cpx/liq}$ in a natural basalt is 2-3 times higher than those previously measured for the Di_2-Ab-An system [1].

Because actinides exhibit similar geochemical behavior and, more importantly, are highly incompatible, relatively little fractionation of U and Th is expected in planetary igneous processes. There is a strong coherence for U and Th in igneous rocks and chondrites [2], and during planetary differentiation actinide elements are highly concentrated in the crust of the Earth, Moon, and Venus. However, significant fractionation of U and Th can occur. There are well documented internal fractionations in ordinary chondrites (e.g. [3,4]), in CAIs [5], and in terrestrial basalts [6]. The magnitude of this fractionation in terrestrial volcanic rocks is perhaps best revealed by [238]U-[230]Th disequilibrium. [230]Th/[238]U enrichments as high as 60% have been observed in MORBs [7]. Significant Th/U enhancements are also observed in Apollo 17 mare basalts (e.g. [8]). An understanding of these fractionations is important because: A) U-Th fractionations may provide unique clues to planetary melting processes. Some workers believe that [230]Th disequilibrium can only be produced by very small degrees of partial melting [9]. B) In principle whole-planet U, Th, and K concentrations can be obtained by combining relative abundances from crustal samples with the average global heat flux (e.g. [2]). In the next 10 years orbiting gamma ray spectrometers (Mars Observer, Lunar Geophysical Orbiter) will obtain important new data for U, Th, and K for the Moon and Mars, but a better understanding of actinide fractionation mechanisms is required.

U PARTITIONING IN MORB: Because U and Th partition Ds are low (<0.05 for major phases), and yet fractionations high in some cases, it is possible that non-equilibrium crystal-liquid partitioning processes (surface adsorption, defect partitioning, inclusions, etc.), which may not occur in laboratory experiments, are important. To test for such effects, U distributions were determined by fission track radiography in polished sections of three fresh
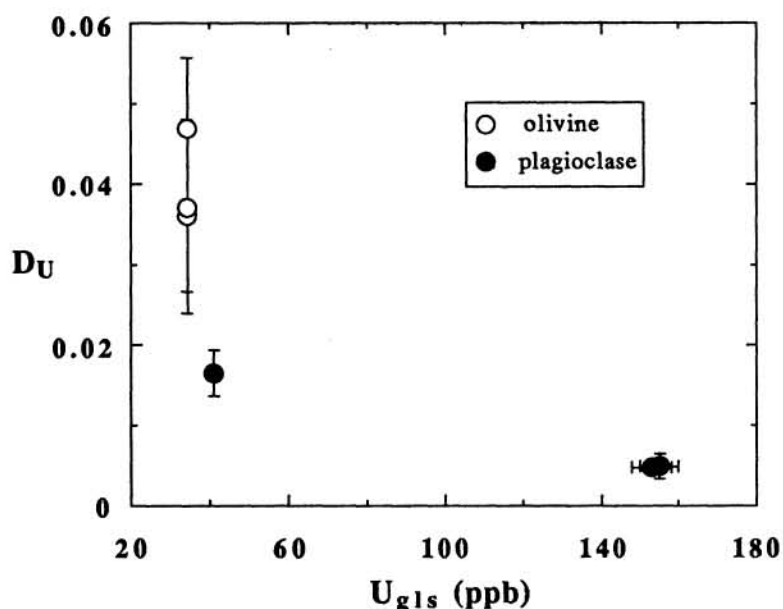
MORB glasses containing phenocrysts of plagioclase, olivine and trace Cr-spinel (CY21-1, E. Pac. Rise [10]; AG22-9-2, S.W. Indian Ridge [11]; TT152-21, Juan de Fuca Ridge [12]).

The glass in all samples was analyzed at two or more points in the sample and determined to be homogeneous to within counting statistics (±4%). Partition coefficients for three olivine crystals from AG22-9-2, two plagioclase crystals from TT152-21, and one plagioclase from CY21-1 are plotted against U concentration in the glass in the Figure. Although statistically significant, U concentrations

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in the crystals are extremely low and, conservatively, the D_Us should be considered upper limits at present. However, we have no basis for rejecting the data, and measured background U concentration in the mica detector is 0.1 ppb, well below the crystals. Appropriate blank data are not yet available, but polishing contamination from the surrounding glass should be less than 0.001 times the glass value (i.e. apparent D_U <0.001). The values for olivine are systematically higher than those for plagioclase. Even if the plagioclase values are taken as blanks, $D_U^{ol/liq}$ is at least 0.02-0.04, high enough for olivine to be a significant source of U in the upper mantle. These values are a factor of 10 lower than a value of 0.40 for olivine determined by fission track radiography in a Mid-Atlantic Ridge tholeiite [13]. However, the olivine U concentration reported that work (160 ppb) is 100 times greater than ours, suggesting that the MAR sample may have experienced post-emplacement alteration.

EXPERIMENTAL U PARTITIONING: The degree to which crystal-liquid separation fractionates U and Th depends on both the absolute Ds and on the difference between Ds for U and Th. A wide range of absolute and relative Ds for natural samples can be found in the literature, with lower values obtained in laboratory experiments using relatively simple compositions. Previous experiments, run in a synthetic Di_2-Ab-An system, give $D_U^{cpx/liq}$ =0.005 (1 atm, fO_2 =QFM [1]) and 0.017 (20 Kbar, $fO_2 \approx$ WM [14]). To investigate the effects of composition, U and Th partitioning experiments are being run with natural basalt starting materials. Preliminary results for U are given here. The initial starting composition was a natural alkali basalt [15] "fortified" with 10 wt% $CaSiO_3$ to make diopsidic clinopyroxene the liquidus phase at 1 atm. This was then thoroughly mixed, glassed, crushed, and spiked with 50 ppm ^{235}U and ^{230}Th, then re-glassed and crushed. Experiments were run at 1 atm, and details are given in [1]. U concentrations were determined by fission track radiography.

The initial results for U at the QFM oxygen buffer show that $D_U^{cpx/liq}$ =0.014, almost 3 times greater than that for the Di_2-Ab-An system at the same fO_2. In addition to the compositional difference, the basalt run (T_{liq}=1200°C) was 70°C lower than the Di_2-Ab-An (T_{liq}=1270°C) run, but it would be surprising if this temperature change alone would produce such a large change in D. It is more likely that the composition has a large affect on $D_U^{cpx/liq}$. Based on the data of [16], 90% of the U is present as U^{+5} in the Di_2-Ab-An melt. The presence of multivalent Fe, Cr, and Mn in the basalt melt may increase U^{+4}/U^{+5} relative to the synthetic system where U is the only multivalent element, although Schreiber et al. [17] concluded that Fe^{+2} does not reduce U^{+5} to U^{+4} in the Fo-An-Di and Fo-An-Si systems. Another possibility is that the presence of various cations in the natural system may provide more options for coupled substitutions involving U in the pyroxene.

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