ZIRCON SATURATION AND REE PARTITION COEFFICIENTS IN LUNAR BASALTS AND GRANITES, J.E. Dickinson, P.C. Hess and M.J. Rutherford, Dept. of Geological Sciences, Brown University, Providence RI 02912

Last year we reported preliminary results for the liquidus surface of zircon in late stage lunar basalts and granites (1). This year completed results for zircon saturation over a range of temperatures from 1070°C-1400°C and partition coefficients for La, Sm, and Ho are reported.

Experiments were done by adding crystalline ZrO₂ to the immiscible basaltic and granitic liquids produced by fractional crystallization of KREEP basalt 14310 (2). After the saturation surface was determined, REE K_D's were found by adding the oxides to a zircon saturated 50 wt% Hi-Si/50 wt% Lo-Si mixture, held at 1135°C for 24 hrs. The ppm Zr required for zircon saturation and the REE K_D's were determined by microprobe analyses of the coexisting liquids and crystals.

The results of the zircon saturation experiments are shown in Fig. 1. Zircon saturation is reached at 9000 ppm Zr in the basaltic liquid at 1070°C. At this same temperature, a coexisting immiscible granitic liquid required 5000 ppm Zr for zircon saturation. From 1070°C to about 1200°C the concentration of Zr required for saturation in both compositions is relatively temperature independent. Above 1200°C, a strong temperature dependence is indicated, being stronger in the basaltic than the granitic composition.

REE K_D's determined for zircon and coexisting Hi-Si and Lo-Si immiscible liquids are shown in Fig. 2a & b. K_D zircon/Lo-Si liquid for La, Sm, and Ho are 0.1, 0.5, and 3.0 respectively. The corresponding zircon/Hi-Si liquid K_D's are 0.3, 1.0, and 7.0. Fig. 2a shows this information presented as a plot of wt% REE in zircon vs. wt% REE in liquid. The constancy of the K_D's in the Hi-Si and Lo-Si liquids over a range of bulk compositions suggests that Henry's law is obeyed over these compositional ranges. Fig. 2b illustrates the strong light to heavy REE fractionation that would result from zircon crystallization.

It is obvious from the high concentration of Zr required for saturation that zircon will not be a liquidus phase for any reported lunar composition. However, since the magma ocean is presumed to have undergone fractional crystallization, it is possible to have a range of melt compositions with different initial Zr concentrations, depending on the amount of crystallization that occurred before magma segregation. For example, 70017 has 200 ppm Zr (3), 14310-1200 ppm Zr (4), 15382-1170 ppm Zr (4), 12012 (5) felsite-1800 ppm Zr and 12013 black breccia groundmass-1855 ppm Zr. Fig. 3 shows results of calculations assuming initial Zr concentrations, Co^Zr, of 20, 200, 1000, and 2000 ppm Zr.
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Other boundary conditions are that 1. the bulk distribution coefficient, $D_{Zr}$, equals zero, 2. zircon saturation is reached at 10,000 ppm Zr in the basaltic composition and 5600 ppm Zr in the granitic composition, and 3. after separation, each body of liquid undergoes equilibrium crystallization. These boundary conditions will provide an upper limit on the possible effects of zircon crystallization. Given these initial constraints, zircon saturation is reached after 99.8, 98, 90, and 80% crystallization, respectively, for a basaltic composition. The silica-rich felsite of 12013, would reach zircon saturation after about 70% crystallization.

Fig. 3 also illustrates that for $CoZr$ less than 1000 ppm Zr, liquid immiscibility will occur before zircon saturation. The concentration of Zr in each liquid will be determined by the two-liquid $K_D$ and the ratio of the two liquids which will, in turn, be functions of the temperature and composition of the liquid just prior to contacting the two-liquid solvus. Both the fact that the bulk composition of the liquid prior to immiscibility has nearly the same SiO$_2$ content as the immiscible basalt composition and the fact that immiscible granites are very SiO$_2$ rich and comprise less than 20% of an experimental charge (6) require the liquid line of descent to intercept the solvus at some point down the Fe-rich limb. This suggests that it is possible for some liquids in the range $CoZr = 560$-1000 ppm to become zircon saturated simultaneously with the onset of immiscibility, but this is very dependent on the ratio of the Hi-Si to Lo-Si liquids. For compositions with $CoZr$ less than 560 ppm, liquid immiscibility will occur first and only after further and different degrees of crystallization will zircon saturation take place.

For $CoZr$ greater than 1000 ppm Zr, zircon saturation will occur before the onset of immiscibility. The high zircon/Ho $K_D$ suggests the possibility of modification of REE pattern of the liquid prior to immiscibility as a result of zircon crystallization. Using $CoZr = 2000$ ppm Zr, saturation is reached after 80% crystallization and 0.2% zircon will have crystallized at the onset of immiscibility. If 50% plagioclase, 45% pyroxene, and 5% ilmenite were crystallizing prior to zircon saturation, $D_{REE}$ for La, Sm, and Ho would be about .09, .09, and .11 respectively. Using the above zircon $K_D$'s and adding .2% zircon, changes $D_{REE}$ by .1, 1 and 5%. These differences are hardly significant in that the individual mineral/REE $K_D$'s that go into determining $D_{REE}$ are not known to an accuracy of ±5%. Even the wing-shaped REE pattern of the 12013 felsite (5) can not be partially explained by zircon crystallization because of its low modal abundance (<.1%). Therefore, we conclude that zircon crystallization will not influence, to any resolvable degree, the...
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(3) Garg and Ehmann (1976) PLSC 7th, p. 3397.
(5) Quick, et al. (1977) PLSC 8th, p. 2153.