ION PROBE ANALYSIS OF ZIRCON AND YTTROBETAFITE IN A LUNAR GRANITE:

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Lunar granite clast 14321,1027 is a relatively coarse-grained intergrowth of silica and potassium feldspar with minor zircon, apatite and rare grains of yttrobetafite [1,2,3]. It has been partly melted to yield a glass rich in K_2O. It displays the characteristic V-shaped REE pattern (depleted in the middle-mass REE) of many lunar granites indicating removal of apatite prior to crystallization of the granite [2]. Evidence that this lunar granite may have originally crystallized under relatively oxidizing conditions was presented by Meyer and Yang [3]. To check this hypothesis we have used the ion microprobe method to determine the REE and other elements in two zircons and one grain of yttrobetafite from this lunar granite. These grains were found in grain mount 14321,1613 prepared from the fines left over from processing the granite clast. The zircons from this granite are anomalous in that they have the highest Hf contents of any lunar zircons [4]. They have previously been dated by the $^{207}Pb/^{206}Pb$ method at 3956 +- 21 MY using the SHRIMP I ion microprobe at ANU [5].

Measurements of the REE in the zircons were made on the CAMECA ims-4f ion microprobe at Edinburgh University (funded by the N.E.R.C.), using the methods outlined in Hinton and Upton [6]. Measurements of the Y, Zr, Nb, REE, Hf, Th and U were made by computer controlled peak switching, other elements were recorded manually. Corrections were made for background and the overlap of the $ZrSi^+$ molecular ion interference on the La, Ce and Pr. The surface of the thin section had high concentrations of the light REE, the abundance of these elements decreasing with sputtering time. The light REE were measured only after the count rate for La stabilized (usually after 20-30 minutes recording). The abundances measured for the La and Pr may still be significantly effected by surface effects. Measurement of the yttrobetafite were made with an energy offset of 120eV as the secondary ions generated from this oxide had a much broader energy spread than that normally observed in silicates. Similar high secondary ion energies were observed from terrestrial samarskite [6]. Ion yields relative to Y were determined using NBS 610 glass standard [7].

REE analyses have been made of the two zircon grains previously analyzed by SHRIMP I for U/Th/Pb [8]. Variations observed in the U and Th contents (240-820 for U and 115-270 for Th) were similar to those determined by SHRIMP. As with terrestrial zircons the variations in the abundance of REE follows that of U and Th. The zircons in this granite also had significant Nb contents, consistent with them having crystallized from a melt rich in this element and coexisting with yttrobetafite. The chondrite normalized REE concentrations increase rapidly from La to Lu with positive Ce and negative Eu anomalies (Figure). The large positive Ce anomaly is very similar to those observed in terrestrial granitic rocks. This anomaly has been interpreted by Hinton and Upton as being due to the presence of minor amounts of Ce^{+4} within the melt. If the size of the Ce anomaly is related to the oxygen fugacity, then the lunar zircon analyzed here would appear to have crystallized at oxygen fugacities similar to terrestrial granites. This seems to confirm the apparent oxidizing conditions invoked by Meyer and Yang to explain the presence of tungsten, and possibly Fe^{+3}, in yttrobetafite from the same clast.

Ion probe analyses of small grains of yttrobetafite in TS ,1613 closely resemble previous electron probe analyses of the large grains in TS ,1494 [3]. The REE are extremely high and the pattern is relatively flat, with depletions occurring in the lightest and heaviest REE. Ion probe analyses of the glass are very similar to the results of the bulk rock [1], indicating that the melt forms a reliable average of the bulk rock composition and confirming the V-shaped pattern. Most of the REE in this rock must be present in the apatite and whitlockite which we have not yet analyzed.

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Ion Probe analysis of Zircon, Yttrobetafite and Glass from 14321,1613

element ppm	Zircon average	Yttrobetafite	Glass	Bulk Sample INAA [1]
Y	1742	84500	136	
Zr	493059	4075	911	660
Nb	60	123557	62.5	
Ba	.03	1	2157	2160
La	.13	5420	45	44
Ce	3.5	29125	103	117
Pr	.096	4625	13.5	
Nd	.94	19525	61	58
Sm	2.2	7730	18	15.9
Eu	.06	25	1.7	1.17
Gd	16	7522	27.5	
Tb	9.4	2380	4.6	4.3
Dy	155	20800	34	31.5
Ho	66.6	4585	7.5	8.4
Er	380	14550	21.7	
Tm	96	2480	3.91	
Yb	820	13600	31	32.2
Lu	174	1460	5	5.1
Hf	16027	37	28	13.9
Th	170	27715	14.8	65
U	508	44870	2.8	23.4