QUE94281, A GLASSY BASALT-RICH LUNAR METEORITE SIMILAR TO Y-793274.

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QUE94281 [1], the newest basaltic lunar meteorite, is a complex regolith breccia with abundant glass. This glass occurs in a variety of forms and compositions; fusion crust, splash glass coating, glass veins and glass beads. In both mineralogy and composition the breccia is intermediate between highland and mare rocks, but closer to mare samples. It is very similar to lunar meteorite Y-792374 and may be derived from the same site on the Moon.

Samples and Analyses. QUE94281 is a 23 g breccia whose most obvious feature is its thick dark glass coating. In its thickness, vesicularity and delicate structure it looks more like a lunar splash glass than fusion crust. Very thin greenish fusion crust is seen in one area. The interior of the sample consists of one area of massive breccia separated by a thick glass vein from a chaotic mixture of glass and breccia. The vein appears to be continuous with the thick dark glass. We were allocated a thin section (,7), two samples of massive breccia (,14 & 20), a sample of chaotic material (,26), and samples of exterior (,21) and interior glass (,26). We homogenized each of the two breccia samples and distributed splits to D. Bogard and S. Vogt. Split ,20 was analyzed by FMR for Is/FeO. The remaining samples were split for INAA of bulk breccia and glass samples and EMP analyses of glass chips and fused breccia beads. INAA samples will be sent to M. Lipschutz for RNAA after completion of analyses.

Petrography. Our thin section of QUE94281 consists mostly of massive breccia with a thick vein of black glass near one edge and only a small patch of chaotic material. There is a thin rind of light green glass (fusion crust) on one side which shows glass to glass contacts and a single glass bead in the interior of the massive breccia. Clasts in QUE94281 range widely in size, texture and mineral proportions. The larger clasts include devitrified melt rocks, feldspathic granulitic breccias, and a shocked noritic or gabbroic fragment. Smaller clasts are mostly individual grains of blocky pyroxene or plagioclase. No igneous-textured lithic clasts were found with similar pyroxenes. We focused our first stage of microprobe analyses on glasses and did only a qualitative survey of pyroxene compositions which showed that they are augites and pigeonites that range over much of the pyroxene quadrilateral. This suggests a major mare basalt component in the breccia. Glass compositions (except those for the glass bead and a vein in anorthosite) are generally similar to one another and to the bulk breccia, but significant differences in glass composition are observed (10% in Al2O3, FeO & MgO; 20% in Na2O). These are discussed below together with the INAA results for bulk glass chips.

Surface Maturity. Ferromagnetic resonance measurements were taken on a portion of coherent breccia from split ,20. I_S/FeO was calculated using the INAA FeO data. The value of I_S/FeO is 5 units, which is immature for lunar soils and regolith breccias [2]. This is the same as the value for ALHA81005 [3], and between the values of < 0.8 units for MAC88105 [4] and 34 units for QUE93069 [4], the most mature lunar meteorite. FMR results are consistent with petrographic observations in showing that QUE94281 is an immature lunar regolith breccia.

Geochemistry and Internal Variations. Partial INAA and EMP data for QUE94281 samples are reported in Table 1 and compared to data for other brecciated mare meteorites. Major element analyses and some glasses are combinations of INAA and EMP data when the two sets of data were for splits of the same samples and overlap in composition. Other glass analyses are of distinct samples and are not tabulated here. The two bulk breccia samples are similar to each other, but distinct in major element composition. This is consistent with them representing an inhomogeneous breccia with varying proportions of mare and highland components. Surprisingly, the trace elements show less variation in composition than major elements. This suggests that a KREEP component is minimal. Furthermore, the siderophile element content of the breccia is not high for a regolith breccia, supporting its low FMR maturity.

Glass compositions are generally similar to the breccia composition, but significant variations are observed among glasses both in bulk samples and in thin section. As might be expected, the clear glass sphere and vein in anorthosite are very different from the other samples (they are much more aluminous, 23-25% Al2O3). The frothy green glass (fr-gl) was found lapping onto massive glass (ma-gl) in hand specimen 26 and fusion crust in thin section It is more mafic, ferroan and more similar to the bulk breccia than is the massive glass. The frothy glass could represent the fusion crust of the bulk breccia. The massive glass is more similar to the vein glass (re-gl) and exterior glass (ex-gl). Although these glasses vary somewhat in composition, they are more feldspathic and magnesian in composition than the frothy glass or bulk breccia. Furthermore, the massive, vein and exterior glasses all have a factor of three higher trace siderophile element contents (Co, Ni, Ir) than the bulk breccia, together with lower Fe and higher mg'. This cannot be due to increases in metal or even silicate inclusions, but suggests that they may be melts of a different, and possibly more mature lunar regolith. The as yet unanalyzed lithic portion of the chaotic material may represent that regolith. The combination of hand specimen, petrographic and geochemical observations suggest that the dark glass coat and vein, and perhaps massive glass, are pre-existing lunar splash glass and not fusion crust, and that the frothy glass may be fusion crust from the bulk breccia.

Table 1. Major and trace element concentrations determined in lunar meteorites by INAA and EMP.

Sample	Q94281	Q94281	Q94281	Q94281	Q94281	Q94281	Y793274	E87521	E87521
Split	14 brec	20 brec	21 ex gl	26 ma-gl	26 fr-gl	26 re-gl	avg	avg lt	avg br
SiO2	47.2	46.5		46.8	46.6		47.7	46	47.95
TiO2	0.68	0.69		0.59	0.62		0.61	0.54	0.97
Al2O3	15.6	17.2		17.6	16.8		15.9	14.9	13.3
FeO	15.38	13.68	11.89	13.05	13.7	12.43	14.23	16.1	18.7
MgO	8.56	8.1		9.5	8.4		9.17	9.83	6.8
CaO	12.2	12.5	12.9	12.6	12	12.4	12.1	11.2	11.6
Na2O	0.367	0.394	0.469	0.446	0.393	0.419	0.4	0.32	0.42
K2O	0.056	0.058	0.07	0.08	0.06	0.07	0.083	0.035	0.07
mg'	50	51		56	52		54	52	39
Sc	35.7	31.1	23.19	26.8	30.4	27.1	32.4	29.1	42.3
Cr	1965	1760	1727	2043	1467	2187	2023	2180	1670
Co	45.3	41.6	52.5	58	41	49.5	42.8	49.9	48.0
Ni	129	117	480	560	170	400	100	35	37
La	6.47	6.41	6.94	6.87	7.75	7.48	6.11	4.13	8.2
Sm	3.25	3.16	3.3	3.29	3.31	3.23	2.83	2.05	3.77
Eu	0.821	0.864	0.901	0.843	0.82	0.809	0.88	0.65	0.98
Yb	2.53	2.43	2.52	2.53	2.63	2.58	2.43	1.72	3.02
Hf	2.49	2.53	2.47	2.53	2.55	2.56	2.42	1.69	2.75
Th	0.85	0.85	1.1	1.61	1.27	1.09	0.89	0.51	0.97
Ir	3.9	2.7	15.8	15		14.7	4.6		0.31
Au	2.5		3.2	3.6			2.77		

External Relationships. Comparison of the QUE94281 breccia to other lunar meteorites shows that it is very similar in bulk and mineral composition to Y-793274 [5]and somewhat similar to the light portion of EET87521 [6], yet distinct from the typical or dark portions of that basaltic breccia [7]. QUE94281 and Y-293274 are both regolith breccias dominated by a coarse-grained mare basalt component, while EET87521 is a polymict mare breccia consisting of brecciated ferroan and magnesian basalts [5-8]. QUE94281 and Y-793274 appear to be samples of the same regolith, but probably not samples of the same breccia as shown by their differences in glass composition. Exposure histories on separated rock and glass from QUE94281 are needed to confirm this suggestion. Evaluation of the nature and relative proportions of mare and highland components in QUE94281 and Y-793274 and possible relationship with basalts from EET87521 awaits completion of our quantitative microprobe analyses of clasts in QUE94281.

References. [1] Score R. et al. (1995) Ant. Met. News. 18 (2). [2] Morris R.V. (1978) PLPSC9, 2287. [3] Morris R.V. (1983) GRL 10, 807. [4] Lindstrom M.M. et al . (1995) LPSC XXVI, 849. [5] Takeda H. et al. (1991) and following papers, NIPR 4, 12. [6] Lindstrom M.M. et al. (1991) LPSC XXII, 817. [7] Warren P.H. & Kallemeyn G.W. (1989) GCA 53, 3323 [8] Warren P.H. (1994) Icarus 111, 338.