GEOCHEMISTRY OF LOS ANGELES, A FERROAN, La- AND Th-RICH BASALT FROM MARS

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We have studied the bulk composition of the Los Angeles basaltic shergottite [1]. The first ever chipping of this meteorite took place on 12/17/99, and our analytical work is not yet complete. However, at this writing we have microprobe fused bead analyses (MFBA) for both stones, and a partially completed INAA for the smaller (2) stone. Our samples were aliquots from powders produced from chips of 350 (stone 1) to 500 (stone 2) mg. INAA (both stones) should be complete before the LPSC. We have also obtained microprobe analyses of fusion crust from both stones. Caveat: available INAA data were mostly obtained 1-2 days before the abstract submission deadline. For long-lived radioisotopes (over half of the elements in our INAA repertoire), these data are still more or less provisional. Obviously, our work on interpretation of these nascent analyses is only at an extremely preliminary stage.

Evidence for martian origin: On top of the mineralogical, textural, and D/H-isotopic evidence [1], we can add that the bulk rock shows characteristically martian values for such ratios as Mn/Fe, Na/Al, and Ga/Al (Fig. 1). In general, the composition is unusually rich in volatile elements, including K, Zn, and the heavy alkalis Rb and Cs, for an achondrite. Siderophile concentrations are low, albeit we can only judge, so far, from early (and thus mild) upper limits for Ni and Ir. The REE pattern lacks any appreciable Eu anomaly, which tends to confirm mineralogical evidence for genesis at a relatively high $f(O_2)$ [1,2].

Los Angeles is unusually coarse grained, for an extraterrestrial basalt, and several lines of evidence suggest that it may be slightly heterogeneous. The modes [1] indicate that stone 2 is richer than stone 1 in late-stage components: K-rich feldspathic glass, apatite, fayalite, silica and ulvöspinel. Our bulk analyses (like the modes) are based on small chips that cannot have been entirely representative, especially for stone 1, which appears coarser grained. Nonetheless, the data (Table 1) do show higher Na, K, P and Ti for stone 2 than for stone 1. For more representative sampling, it may be better to use the natural analogs of the fused beads, i.e., the fusion crusts. As in MFBA, the potential for slight volatilization-loss of Na and K is worrisome; and so, too, is intra-crust heterogeneity (especially for stone 2). However, the fusion crusts agree with the bulk analyses in indicating slightly higher Na, K, P and Ti for stone 2; and go further, by suggesting that stone 2 has a lower *mg* ratio. In Los Angeles, fayalite and silica are largely (entirely?) products of breakdown of former pyroxferroite, so the difference between the two modes tends to confirm a lower *mg* ratio for stone 2. The modes and the bulk analyses also suggest marginally higher Al (maskelynite) in stone 1, but this difference is not confirmed by the fusion crust analyses.

In many respects, Los Angeles is the most geochemically evolved sample yet discovered from Mars. It has lower MgO than any other martian meteorite, and far higher contents of arch incompatible elements such as La than the only two comparably MgO-poor shergottites, EET79001-B and QUE94201; abbreviated E(B) and Q (Fig. 2). The bulk Cr concentration is also low: a factor of 10 lower than in the nearest precedents, Q and E(B). A martian familial resemblance is seen, nonetheless, in features like Ba/La and Hf/Lu (reflecting garnet fractionation at some stage?), both close to 1.5× chondrites, and the absence of any significant Eu anomaly (Fig. 3). Besides light REE, E(B) and Q are also depleted in Ta, Th, and the volatile alkalis compared to Los Angeles. The parent melts of E(B) and Q were probably not dramatically different, in these respects [3,4], so we conclude that despite some mineralogical similarities [1], Los Angeles is not igneously related to either E(B) or Q.

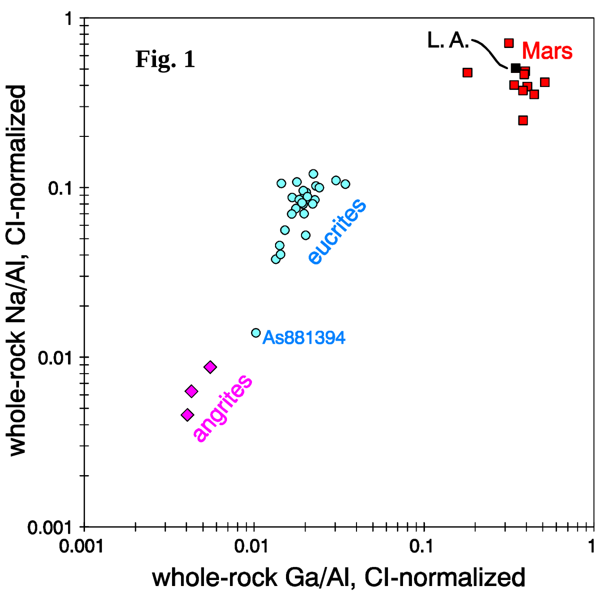
Among basaltic shergottites, the two that most resemble Los Angeles from a trace element perspective are Shergotty (S) and Zagami (Z). The bulk composition of Los Angeles is particularly similar to compositions inferred for the intercumulus melts of S and Z. For major and minor elements, the compositions inferred by Stolper and McSween [5] provide a close match, although still not as ferroan (*mg* = 32 mol%) as Los Angeles (21-24 mol%, at least for stone 2). If Los Angeles is assumed to represent the parent melt of S and/or Z, the magnitude of its enrichment in light REE compared to S and Z (2.6-3.1×) would require that ~2/3 by weight of S and Z formed as accumulated (cumulus) crystals. However, the notion of S and Z as cumulates has since become unfashionable, and a variety of recent estimations of the S and Z intercumulus compositions are lower in late-stage components (Na, K and Ti) and Al, and more magnesian; e.g., *mg* = 41-42 mol% [6].

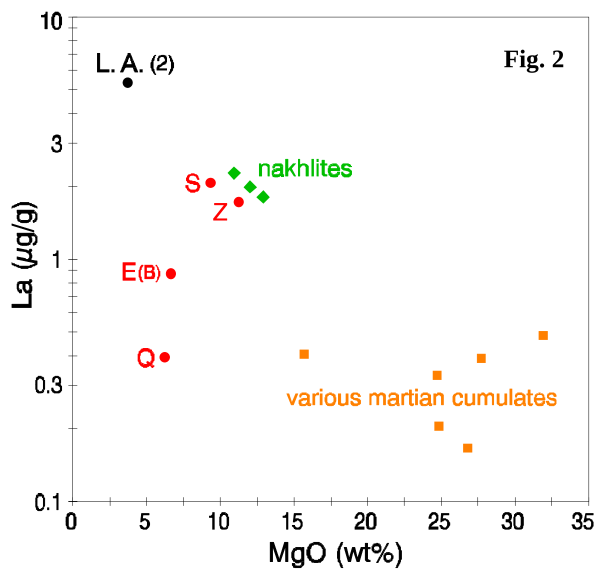
In any event, Los Angeles seems unlikely to have formed as a primary partial melt from a plausibly heterogeneous mantle that elsewhere generated magmas as MgO- and Cr-rich as the parents of S, Z, and the cumulate martian meteorites. Its final genesis as part of a large flow or small, shallow intrusion was more likely preceded by an episode of fractional crystallization and/or assimilation of older crustal matter. The major element composition is relatively close to that of the globally wind-stirred martian soil and to the "soil-free rock" extrapolated from Pathfinder data [7]. Still, the match between the meteorites, collectively or individually, and the global soil is rather poor. For example, suitably low-mafic (low [Mg+Fe]/Si) meteorites consistently have higher Ca/Si than the soil. Evidently the soil has been affected by differential loss of Ca to a large global reservoir of high-Ca/Si sediments (carbonates) [8], and/or the meteorites are providing a very selective sampling of the martian crust.

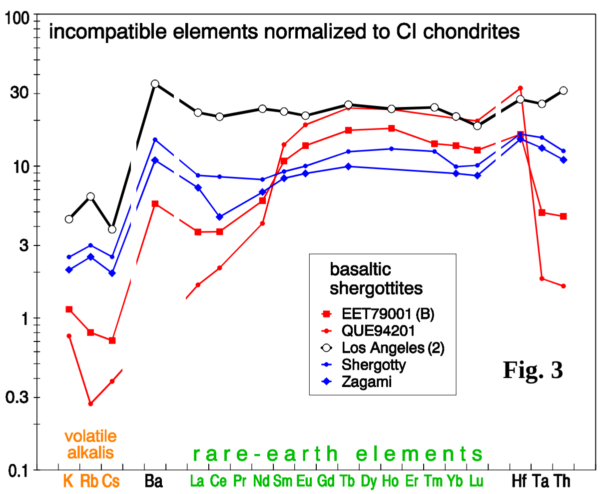
Table 1. Compositional data for bulk Los Angeles and its fusion crust; oxides in wt%, others (a few of which are highly preliminary) in µg/g. FeO* = total iron reported as FeO; actually a minor proportion is Fe_2O_3.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	Sc	TiO_2	V	Cr_2O_3	MnO	FeO*	Co	sum	*mg*
LA1 fusion crust	1.86	5.11	9.70	48.3	1.08	0.15	10.32	--	0.92	--	0.046	0.52	21.5	--	99.48	29.8
LA2 fusion crust	2.02	3.53	9.46	47.7	1.26	0.19	9.64	--	1.29	--	0.020	0.57	24.2	--	99.80	20.6
LA1/LA2	0.92	1.45	1.03	1.01	0.85	0.76	1.07	--	0.72	--	*2*	0.91	0.89	--		
LA1 (MFBA only)	*1.7*	3.53	11.72	49.1	0.66	*0.16*	10.08	--	1.24	--	0.027	0.48	20.5	--	99.20	23.5
LA2 (INAA+MFBA)	2.17	3.73	10.55	48.5	1.50	0.30	9.90	46	1.35	202	0.014	0.49	21.4	33	99.87	23.7

Ni	Zn	Ga	Rb	Sr	Zr	Cs	Ba	La	Ce	Nd	Sm	Eu	Tb	Ho	Yb	Lu	Hf	Ta	Th
<30	*110*	22	*14*	*<80*	*90*	*700*	*80*	5.3	*13*	*10.9*	3.4	1.2	*0.9*	*1.3*	3.37	0.45	3.3	0.41	0.91







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