XV. Los Angeles

Basalt, 698 grams
2 pieces (so far)

Figure XV-1: *Photograph of Los Angeles, stone 1, illustrating calichi and fusion crust (courtesy of Bob Verish, photographer Ron Baalke).*

Introduction

Bob Verish found two stones, with attached fusion crust, weighing 452.6 g (figure XV-1) and 245.4 g (figure XV-2) respectively, while he was cleaning out a box of rocks in his backyard (in Los Angeles, California). He took them to UCLA where he learned they were from Mars! The specimens may have been collected ~20 years ago, somewhere in the Mojave Desert (Grossman 2000).

Petrography

Los Angeles has a coarse-grained (2-4 mm), basaltic texture and mineralogy closely resembling that of QUE94201 and the coarse-grained portions of Zagami (Rubin *et al.* 2000; Mikouchi 2001). Xirouchakis *et al*. (2002) describe the texture of Los Angeles as that of a microgabbro, dominated by relatively large anhedral to subhedral grains of pyroxene (2 mm) and subhedral to euhedral plagioclase. Xirouchakis *et al.* (2002) provide a detailed crystallization history, including a discussion of the T – pO_2 trend.

Rather dramatic patches of two-phase and three-phase symplectite occur in the Fe-rich Los Angeles meteorite (usually adjacent to merrillite). Approximately 5-10% of the sample consists of ~50-200 micron-sized, patches of a fine-grained vermicular to micrographic intergrowth of fayalite, hedenbergite and silica that (at first) appears to be the breakdown product of metastable "pyroxferroite" (Rubin *et al*. 2000; Aramovich *et al.* 2001, 2002). However, Xirouchakis

Figure XV-2: Photograph of Los Angeles, stone 2, illustrating fusion crust (courtsey of Bob Verish, photographer Ron Baalke).

et al. (2002) argue that the complex, fine-grained, late-stage, fayalite-hedenbergite intergrowths are a natural occurrence of the slow crystallization history.

Photomicrographs of thin sections illustrated in Mikouchi (2001) and Greenwood *et al*. (2001), best illustrates the interior texture. Photos of bulk samples can also be seen at http://www.jpl.nasa.gov/snc/la.html.

The samples appear to have some calichi attached (Rubin), and may have been collected from a "dry" lake bed. However, the interior of the samples appears to be unweathered.

Mineral Chemistry

Pyroxene: Pyroxenes in Los Angeles are present as low-Ca pigeonite and high-Ca augite, zoned to become relatively Fe-rich (figure XV-3). $En_{50}Wo_{10}$ and $En_{40}Wo_{33}$ zoned to $En_{5}Wo_{15}$. Wadhwa *et al*. (2001) have determined the REE contents of pyroxenes. Pyroxenes exhibit relatively thick (0.7 to 4 micron) exsolution, indicating slow cooling (Warren *et al*. 2000; Mikouchi 2001; Xirouchakis *et al*. 2002).

"Pyroxferroite": Rubin *et al.* (2000) and Aramovich *et al.* (2002) have studied the low-pressure, breakdown

Modal Mineralogy	**Rubin *et al.* (2000)**	**Mikouchi (2001)**	**Xirouchakis *et al.* (2002)**
Plagioclase (maskelynite)	43%	45	53.9 ± 3.2
Pyroxene	38	41.6	40.9 ± 2.8
silica	5	2.7	1.7
fayalite	4	1.9	
K-rich felsic glass	2	3.7	
Ca-phosphate	3	2.3	1
pyrrhotite	0.7		
oxides	3	1.7	1
fusion crust			1.5

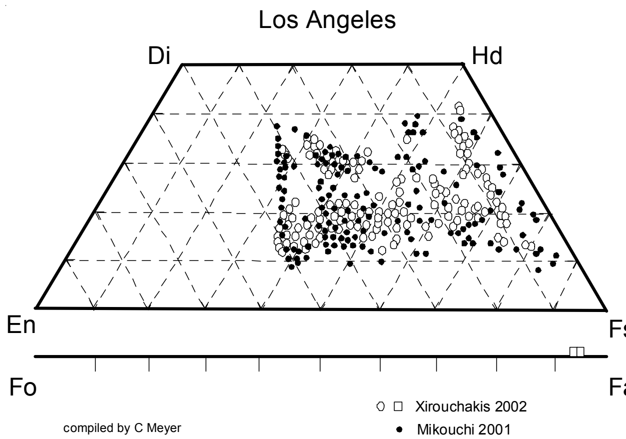

***Figure XV-3**: Pyroxene and olivine composition diagram for Los Angeles (data replotted from Mikouchi 2001 and Xirouchakis et al. 2002).*

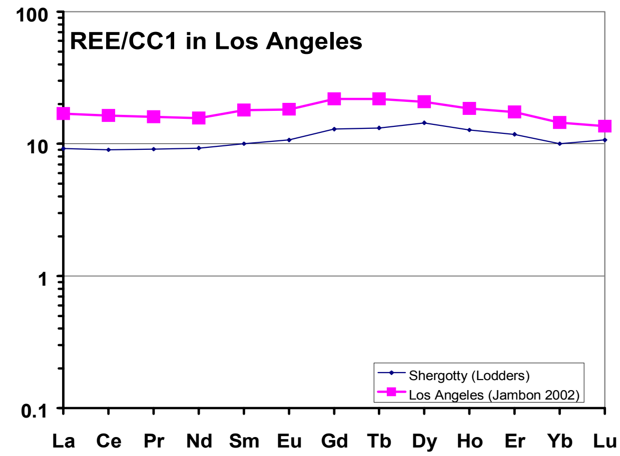

***Figure XV-4**: Rare earth element diagram for Los Angeles compared with that of Shergotty (data from Jambon et al. 2002 and Lodders 1998)*

products (symplectite ?) of inferred metastable "pyroxferroite" in Los Angeles. These regions of symplectite generally surround large grains of merrillite.

Feldspar: The high content (~50%) of maskelynite ($An_{41}Or_4$ to $An_{58}Or_1$) in Los Angeles makes it unique among Martian meteorites. A few grains show normal core to rim chemical zoning, but many grains are reversed zoned, Ca-rich near the pyroxene (Mikouchi 2000). A few grains of plagioclase are still birefringent, indicating that Los Angeles was less shocked than Shergotty.

Phosphates: Mikouchi (2001) and Xirouchakis *et al.* (2002) have determined the composition of the phosphates. Wadhwa *et al.* (2001) have determined the trace element contents of apatite and whitlockite (merrillite). Aramovich *et al.* (2002) find that the co-crystallization of merrillite and pyroxene depletes the Ca and Mg content of the pyroxene leading to metastable "pyroxferroite" (now symplectite).

Silica: Large grains (up to 1 mm) of silica are found in Los Angeles (Mikouchi 2001). Fine-grained intergrowths of silica and fayalite or hedenbergite are also observed.

Oxides: Ulvöspinel is the dominant opaque phase in Los Angeles (Mikouchi 2001). Xirouchakis *et al.* (2002) give an analysis of titano-magnetite. Ilmenite exsolution is found in the ulvöspinel – titano-magnetite.

Pyrrhotite: Rubin *et al.* (2000), Mikouchi (2001) and Xirouchakis *et al.* (2002) all report trace pyrrhotite – usually as "blebs" within the oxides.

Olivine: Fayalite (Fo_5) is found intergrown with other phases in symplectite and as thin (5 to 15 micron) rims on titano-magnetite.

Carbonates: Graham *et al.* (2000) studied the carbonates on surfaces of Los Angeles.

Whole-rock Composition

The chemical composition of both pieces of the Los Angeles meteorite was first reported by Rubin *et al.* (2000) (see also GSA data repository item #2000107). Los Angeles is more differentiated than other Martian basalts (table XV-1). It has higher Fe/Mg ratio and higher trace element content. The REE pattern is flat, similar to that of Shergotty and Zagami, and unlike that of QUE94201 (figure XV-4). Jambon *et al.* (2002) have also carefully determined the chemical composition of Los Angeles.

Radiogenic Isotopes

Nyquist *et al.* (2000) have dated Los Angeles by Rb-Sr at 165 ± 11 Ma (figure XV-5). Nyquist *et al.* (2001) also reported a Sm-Nd age of 172 ± 8 Ma.

Cosmogenic Isotopes and Exposure Ages

Terribilini *et al.* (2000) and Eugster *et al.* (2002) calculated exposure ages of 3.1 ± 0.7 and 3.35 ± 0.7 Ma, respectively, from ^{81}Kr measurements of Los

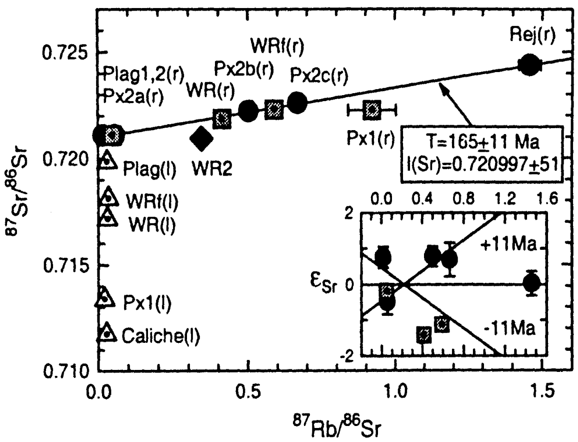

Figure XV-5: Rb-Sr internal mineral isochron plot for Los Angeles (from Nyquist et al. 2000).

Angeles. Nishiizumi *et al.* (2000) determined a ^{10}Be exposure age of 3.0 ± 0.4 Ma and ^{21}Ne exposure age of 3.0 ± 0.2 Ma. Nishiizumi *et al*. (2000) also report the ^{36}Cl and ^{26}Al concentrations.

Magnetics

The Los Angeles meteorite appears odd magnetically (Rochette *et al*. 2001). Saturation magnetization (M_s) is as high as 1.2 Am^2/kg (*one must be careful not to magnetize a sample from Mars with a hand magnet*).

Other Isotopes

Garrison and Bogard (2000, 2001) have studied the noble gases extracted from Los Angeles and found isotopic evidence for Martian "interior" component, but little "atmospheric" in the sub-sample that they studied. Busemann and Eugster (2002) show that substantial, fractionated, terrestrial air is adsorbed on weathered meteorites from desert regions, including Los Angeles.

Rubin *et al.* (2000) reported the oxygen isotopes in bulk Los Angeles $\delta^{18}O$ = +4.53‰, $\delta^{17}O$ = +2.53‰ and $\Delta^{17}O$ = +0.17‰.

Processing

About 30 grams of the Los Angeles meteorite is at UCLA, 30 grams at Arizona State, 19 grams at the Smithsonian and about 11 grams remains with the finder. Mikouchi credits UCLA for the loan of the thin section he studied. Xirouchakis *et al.* credit the American Museum of Natural History for a piece (5103) of stone 1.

Table XV-1. Composition of Los Angeles.

reference	Rubin 2000	Rubin 2000		Jambon 2002		Ikeda 2002		
weight	352 mg	207 mg				fusion crust		
SiO2	49.1	48.6	(a)			48.3	47.4	(d)
TiO2	1.3	1.43	(a)	1.12	(b)	0.92	1.29	(d)
Al2O3	11.2	10.4	(a)	10.86	(b)	9.7	9.46	(d)
FeO	21.2	21.4	(a)	21.07	(b)	21.5	24.2	(d)
MnO	0.45	0.47	(a)	0.46	(b)	0.52	0.57	(d)
CaO	9.95	9.89	(a)	9.92	(b)	10.32	9.64	(d)
MgO	3.53	3.74	(a)	3.91	(b)	5.11	3.53	(d)
Na2O	2.22	2.13	(a)	2.24	(b)	1.86	2.02	(d)
K2O	0.24	0.31	(a)	0.36	(b)	0.15	0.19	(d)
P2O5	0.66	1.49	(a)			1.08	1.26	(d)
sum	**99.85**	**99.86**				**99.46**	**99.56**	
Li ppm				5.03	(c)			
Be				0.54	(c)			
Sc	39	46	(a)	41.3	(c)			
Cr	95	104	(a)	219	(b)			
Co	28	34	(a)	29.2	(c)			
Ni	20	25	(a)	32	(c)			
Cu				22.6	(c)			
Zn	90	90	(a)	62.3	(c)			
Ga	24	22	(a)	22.09	(c)			
Rb	11	14	(a)	12	(c)			
Sr				81	(c)			
Y				29.39	(c)			
Zr				79.6	(c)			
Nb				4.99	(c)			
Cs ppm	0.54	0.77	(a)	0.88	(c)			
Ba				46.8	(c)			
La	3.1	5.1	(a)	3.97	(c)			
Ce				9.84	(c)			
Pr				1.43	(c)			
Nd				7.07	(c)			
Sm	1.94	3.4	(a)	2.64	(c)			
Eu	0.86	1.3	(a)	1.02	(c)			
Gd				4.28	(c)			
Tb	0.63	0.93	(a)	0.792	(c)			
Dy				5.04	(c)			
Ho				1.03	(c)			
Er				2.76	(c)			
Tm								
Yb	2.21	3.1	(a)	2.35	(c)			
Lu	0.33	0.43	(a)	0.331	(c)			
Hf	3.7	3.7	(a)	2.19	(c)			
Ta	0.44	0.43	(a)	0.28	(c)			
W ppb				660	(c)			
IIr ppb	<2	<2	(a)					
Th ppm	0.7	0.92	(a)	0.57	(c)			
U ppm				0.12	(c)			

technique: (a) INAA, b) ICP/AES, c) ICP-MS, d) elec. Probe