Reference List

Dhofar 378 – 15 grams
Dhofar unnamed – 209 grams
Enriched Basaltic Shergottite

Figure 1: Photo of piece of Dhofar 378 (found on internet).

Introduction

Ikeda *et al*. (2002) first reported another Martian meteorite (Dho378) from Oman (*found in an area near Dho019*). Dho378 is somewhat similar to Los Angeles, except that the plagioclase has been shocked to Plag-glass, instead of maskelynite (Ikeda *et al*. 2006). Dreibus *et al*. (2002) found that Dho378 is enriched in Na, Sr and feldspar compared with other shergottites. There are unconfirmed reports of a larger piece of same meteorite, and, indeed, Dho378 has a freshly broken surface (figure 1).

An age of formation of Dho378 of 157 m.y. has been determined. Ar/Ar data indicate a major shock event at about 141 m.y., and finally it was sent into space ~ 3 m.y. ago.

Petrography

Dho378 is reported to have *"a doleritic or microgabbroic texture, and grain sizes of the main minerals about 1 mm"* (Ikeda *et al*. 2002). It has a fresh black fusion crust on one side and has been highly shocked.

Modal Mineralogy foe Dhofar 378

	Ikeda *et al.* (2006)
Pyroxene	49.3%
Plagioclase (glass)	43.5
Opaques	2
Phosphates	1.4
Fayalite	tr.
Silica	tr.
Sulfide	0.6
Mesostasis	3.2

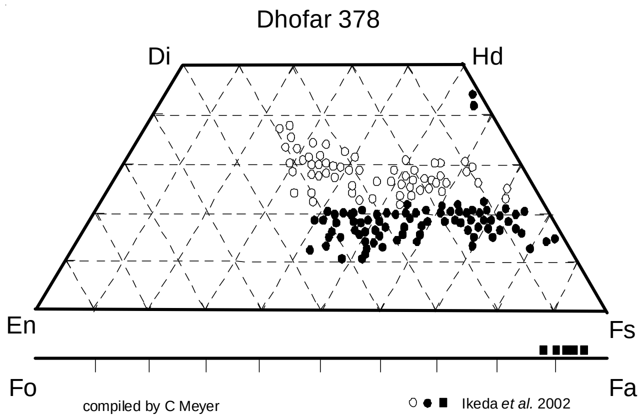

Figure 2: *Pyroxene and olivine composition diagram for Dhofar 378 (replotted from Ikeda et al. 2002).*

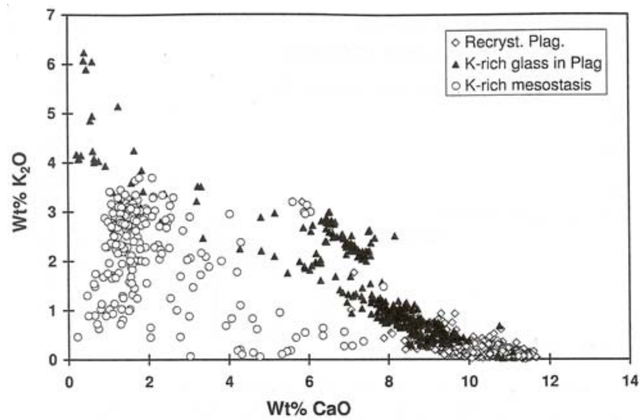

Figure 3: *Composition of feldspar-rich glasses in Dho378 (Park et al. 2008).*

Dho378 is a basaltic shergottite made up of about equal amounts of clionpyroxene and plagioclase (now glass) with minor mesostasis including alkalai feldspar, silica, K-rich glass, Ca-phosphates and regions of heddenbergite, pyroxferroite, fayalite and pyrrhotite (Ikeda *et al.* 2006). Note that it is the most feldspathic of the Martian meteorites.

Vesicular shock-melt veins are common, sometimes cutting through pyroxene and Plag-glass grains. No reports of high-pressure phases can be found.

Mineral Chemistry

Pyroxene: Pyroxene shows undulatory extinction and mosaicism due to shock (Mikouchi and McKay 2006). Subcalcic clinopyroxene is exsolved and chemically zoned (figure 2). The Fe/(Mg+Fe) ratio varies from 0.4 to 0.9 (Ikeda *et al.* 2002). Both Fe-rich hedenbergite and pyroxferroite are present.

Plagioclase: Plagioclase (An_{33-53}) has been shock-melted to glass, which has re-crystallized at the rims (Ikeda *et al.* 2006). Large plagioclase areas (probably several grains) up to 2 x 3 mm in size contain vesicles (~500 microns) with "dirty halos" around them.

Opaques: Titanomagnetite includes ilmenite lamellae (Ikeda *et al.* 2006).

Phosphates: Both whitlockite (merrillite) and minor apatite are present in the mesostasis of some thin sections. Compositions have been determined by Ikeda *et al.* (2006).

Calcite: Calcite occurs as a weathering product (Ikeda *et al.* 2006).

Silica: Both quartz and tridymite have been identified by Raman spectra (Ikeda et al. 2006).

Pyroxferroite: Small grains of pyroxferroite have been identified by Raman spectra (Ikeda *et al*. 2006). In Dho378 it has apparently formed as a secondary phase after the shock event.

Glass: Park et al. (2008) determined that there were multiple, shock-produced glasses, in Dho378 (figure 3).

Whole-rock Composition

Dreibus *et al*. (2002) and Ikeda *et al*. (2006) have analyzed Dho 378 (table 1). It has a REE pattern indicating it is an "enriched" shergottites. They explain a slight positive Eu anomaly as due to high plagioclase/ whitlockite ratio in the small split they analyzed (figure 4). They note that Dho378 is "weakly contaminated with terrestrial U and K", as is the case for all Martian meteorites collected from "hot desert" sites.

Radiometric Age Dating

Nyquist *et al.* (2006) determined a crystallization age of 157 ± 24 m.y. by the Sm-Nd isochron method (figure 5). Park and Bogard (2006) studied the isotopic release of Ar from plagioclase and concluded that a major shock event occurred at ~ 143 m.y. ago (figure 6). Park et al. (2008) revised this to 141 m.y. The Rb-Sr isotopic system is highly disturbed by terrestrial contamination (calichi). However, the initial Sr isotopic ratio was found to be like that of Los Angeles (Nyquist *et al.* 2006).

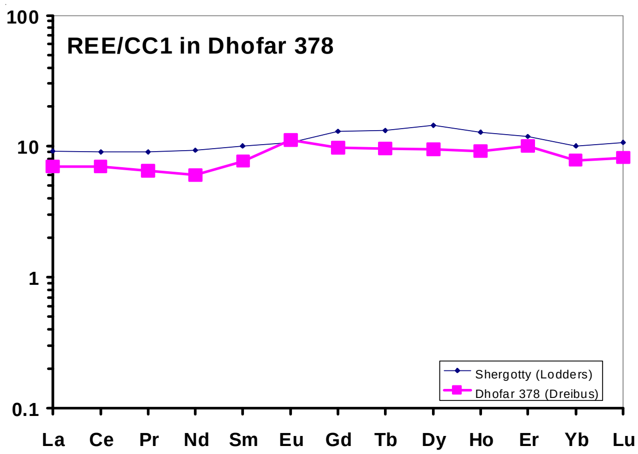

***Figure 4**: Rare earth element diagram for Dhofar 378 compared with Shergotty (data from Dreibus et al. 2002 and Lodders 1998).*

Other Isotopes

The oxygen isotope composition, determined by Mayeda and Clayton and reported by Ikeda *et al.* (2002), is $\delta^{18}O$ = + 4.46 ‰ and $\delta^{17}O$ = + 2.52 ‰, indicating that this meteorite is Martian. Rumble and Irving (2009) have also reported oxygen isotopes.

Processing

There are no reports on how this sample has been recovered, nor processed. Clearly it deserves better study.

References for Dho378

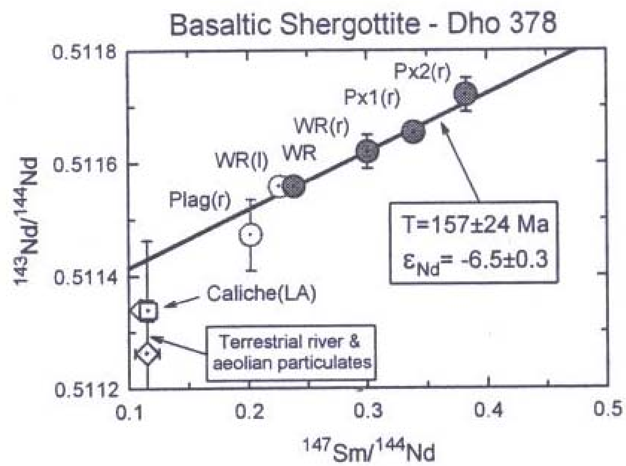

***Figure 5:** Sm-Nd isochron diagram for Dhofar 378 (from Nyquist et al. 2006).*

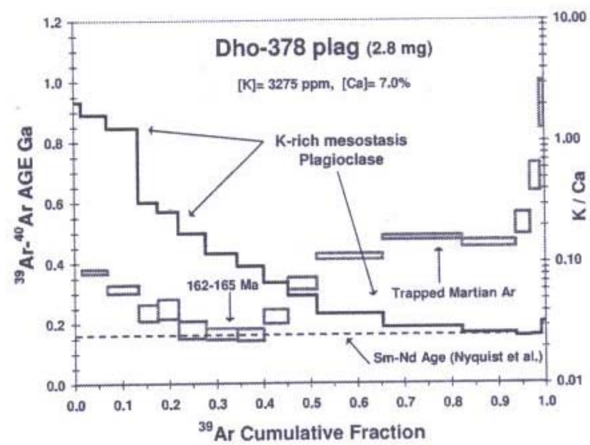

***Figure 6:** Ar plateau diagram for Dhofar 378 (but without the plateau)(from Park and Bogard 2006).*

Table 1: Composition Dhofar 378

reference	Dreibus2002		Ikeda 2002		Ikeda2006		Ikeda2006	
weight			fusion crust		550 mg		97 mg	
SiO2			48.08	(b)	49.88	(c)	*49*	(d)
TiO2			1.18	(b)	0.98	(c)	*1*	
Al2O3			9.5	(b)	10.08	(c)	15.8	
FeO	15.65	(a)	21.11	(b)	19.94	(c)	15.66	
MnO	0.38	(a)	0.55	(b)	0.48	(c)	0.38	
CaO	10.46	(a)	9.76	(b)	10.32	(c)	10.45	
MgO			5.35	(b)	5.66	(c)		
Na2O	2.6	(a)	2.31	(b)	1.98	(c)	2.64	
K2O	0.2	(a)	0.15	(b)	0.17	(c)	0.2	
P2O5			0.9	(b)	0.7	(c)	1.2	
sum			98.89		100.23	(c)		
Li ppm								
Be								
F								
S								
Cl								
Sc	43.7	(a)						
V								
Cr	260	(a)			274	(c)		
Co	29.3	(a)						
Ni	<40	(a)						
Cu								
Zn	77	(a)						
Ga	23.6	(a)						
Ge								
As								
Se								
Br	0.89	(a)						
Rb								
Sr	*120*	(a)						
Y								
Zr								
Nb								
Mo								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb								
Sb ppb								
Te ppb								
Cs ppm	0.4	(a)						
Ba	33	(a)						
La	1.64	(a)						
Ce	4.17	(a)						
Pr								
Nd	2.7	(a)						
Sm	1.13	(a)						
Eu	0.627	(a)						
Gd	1.9	(a)						
Tb	0.35	(a)						
Dy	2.3	(a)						
Ho	0.51	(a)						
Er								
Tm								
Yb	1.27	(a)						
Lu	0.2	(a)						
Hf	1.49	(a)						
Ta	0.14	(a)						
W ppb								
Re ppb								
Os ppb								
Ir ppb	<6	(a)						
Au ppb	7.7	(a)						
Tl ppb								
Bi ppb								
Th ppm	0.3	(a)						
U ppm	0.1	(a)						

technique: (a) INAA; (b) elec. Probe, (c) XRF, (d) INAA