Dhofar 925, 960, 961

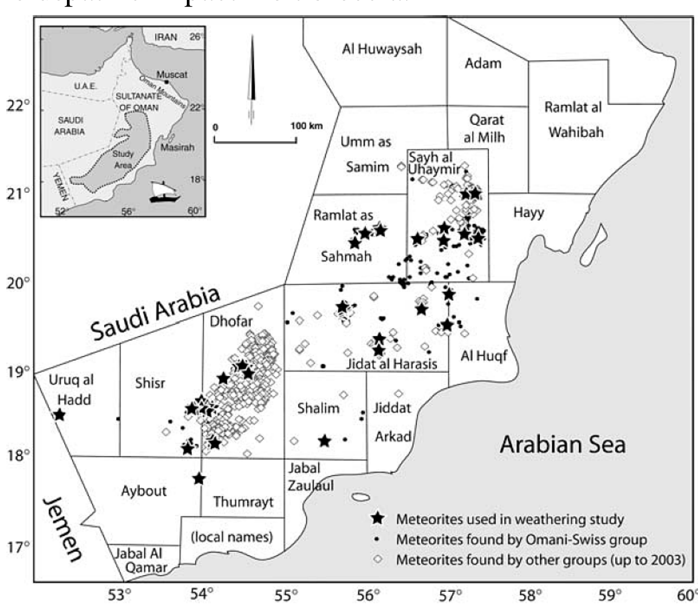
Basalt-bearing anorthositic (polymict) impact melt breccia

49, 35.4, 22.6 g

Figure 1: Cut slab of Dhofar 925 showing feldspathic clasts in a breccia. Black cube is 1 cm.

Introduction

Dhofar 925 (Fig. 1) was found in the Dhofar region of Oman (Figs. 2 and 3) in February, 2003 (Russell et al., 2004). The 49 g stone lacks fusion crust, and contains terrestrial weathering products such as calcite, gypsum, celestite, barite, smectite and Fe hydroxides. In November 2003, Dhofar 960 (35.4 g) and Dhofar 961 (21.6 g) were found nearby (Russell et al., 2005) and on the basis of texture, petrography and mineralogy, all three stones have been paired together as feldspathic impact melt breccia.



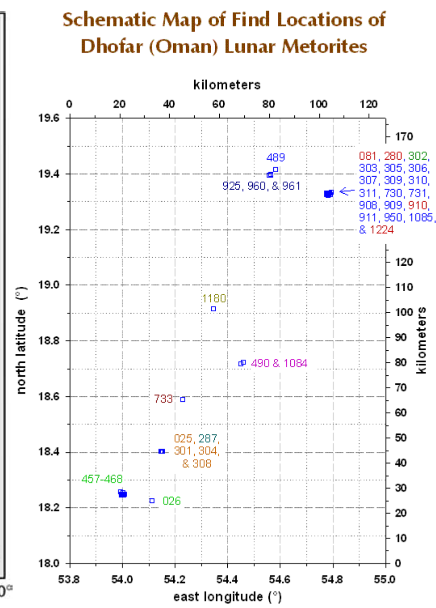


Figure 2 and 3: Location maps of the Dhofar region in Oman (from Al-Kathiri et al., 2005) and the specific coordinates for Dhofar 925, 960 and 961.

Petrography and mineralogy

This meteorite is an impact melt breccia with mineral and lithic clasts in an impact melt rich matrix (Fig. 4). The lithic clasts are granulitic, anorthositic, troctolitic, gabbro-noritic, and noritic. Most of the meteorite is comprised of anorthositic or highlands materials, but it is a polymict breccia that also contains mare basalt, KREEP-related materials, and even granitic material (Russell et al., 2004). Major mineral compositions from each sample overlap completely (Fig. 5). Accessory minerals in these meteorites are numerous and include ulvospinel, Ti-chromite, pleonaste, ilmenite, silica, troilite, FeNi metal, Ba-bearing potassium feldspar, whitlockite, chlorapatite, baddeleyite, zircon, armolcolite, monazite, tranquilityite, and zirconalite (Russell et al., 2004, 2005).

Chemistry

Although Dho 925, 960 and 961 have been classified as a feldspathic impact melt breccia, they have 9 to 13% FeO reflecting, perhaps, up to 40% of a basaltic component in addition to the feldspathic (Korotev, 2006; Korotev et al., 2009b). One of the most distinctive features of this meteorite is the incompatible element enrichment – Sm and La/Yb for Dhofar 960 are very high. And siderophile element concentrations such as Ir are also very high (Fig. 6).

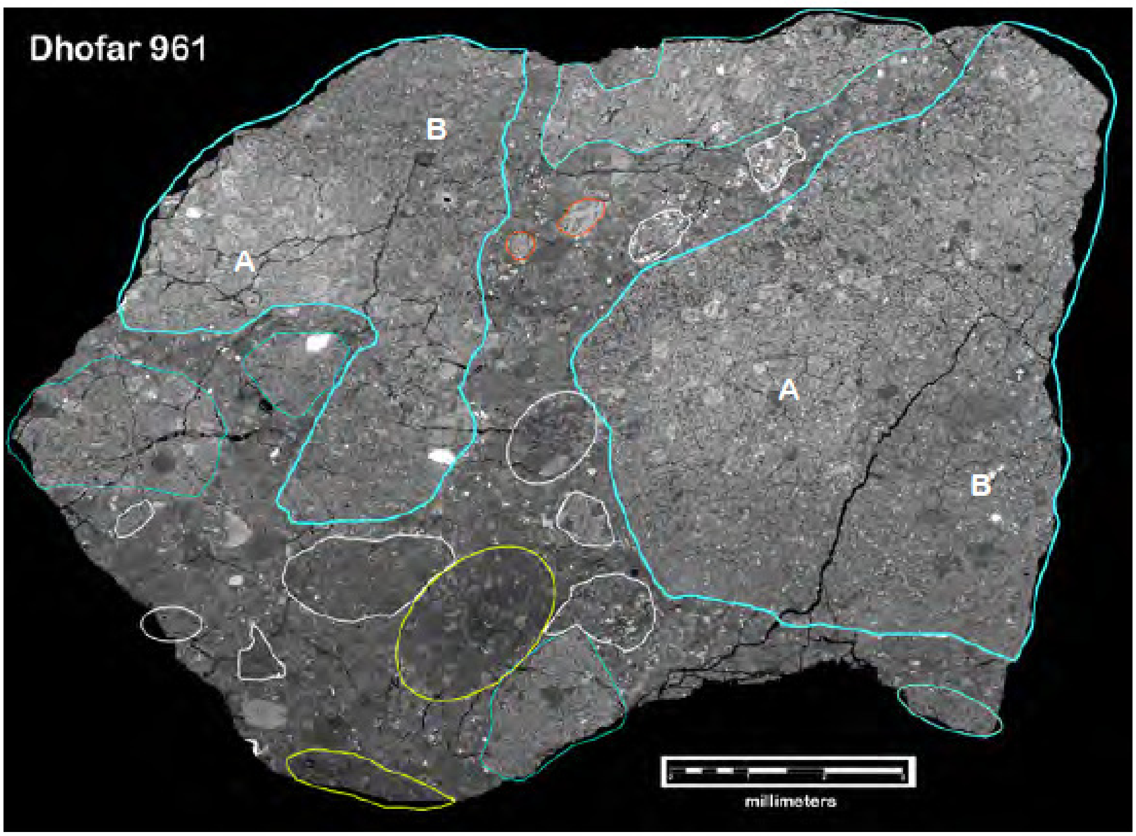


Figure 4: Backscattered-electron image with main lithic clasts outlined. Blue surrounds the prominent mafic impact-melt clast lithologies. Other lithic clasts include granulite (yellow), less mafic impact-melt breccias (white), and small, rounded aluminous basalt clasts (orange). Two bright spots at left-center are Fe-Ni metal. Scale bar is 3 mm (image from Jolliff et al., 2008).

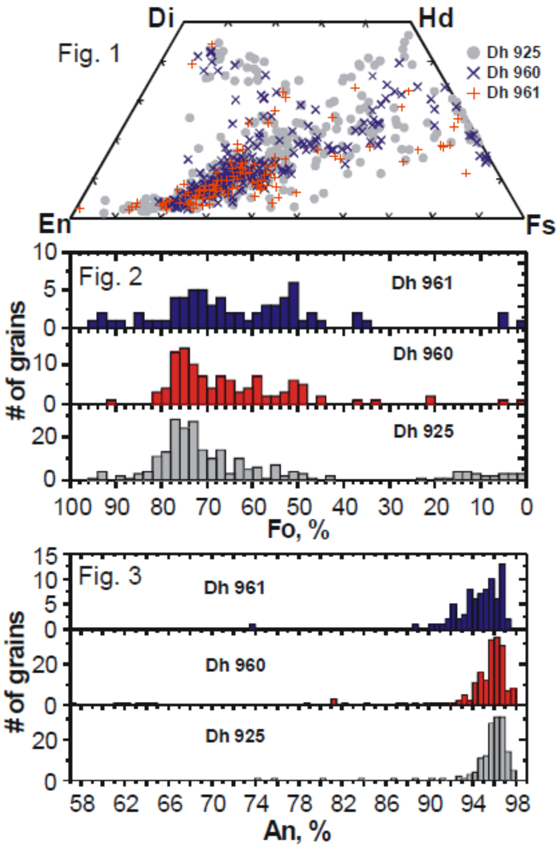


Figure 5: Pyroxene, olivine and plagioclase feldspar compositions from Dho 925, 960, and 961 (from Demidova et al., 2005).

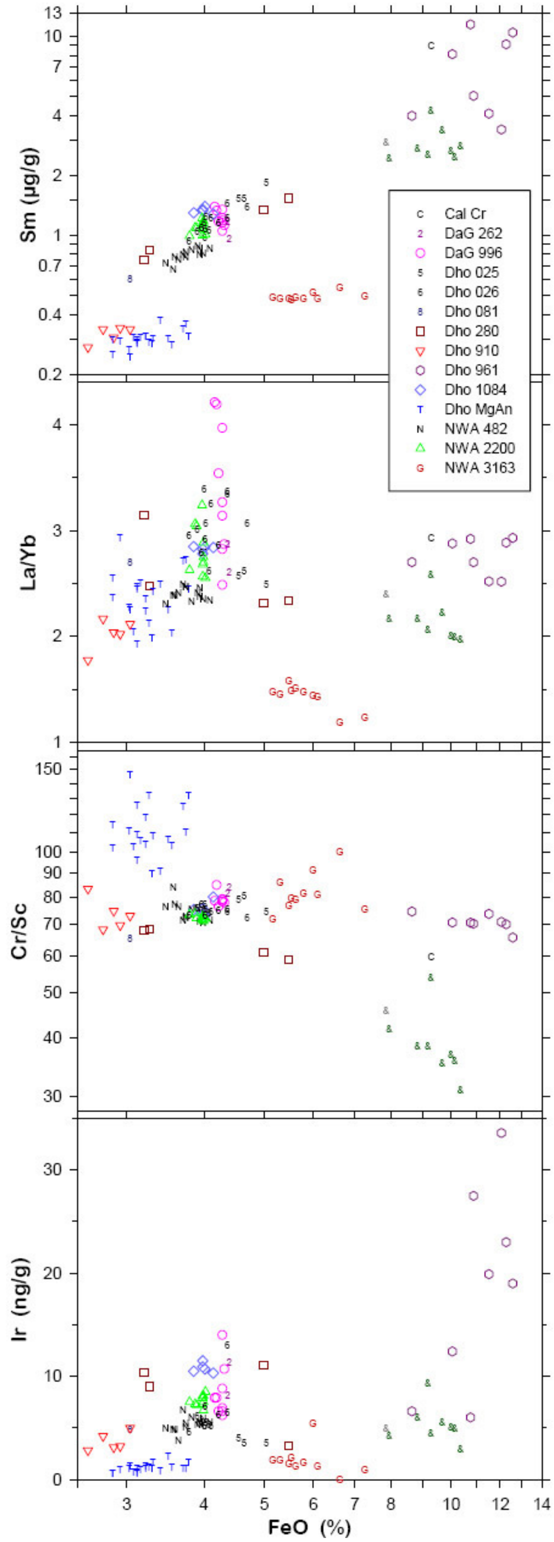
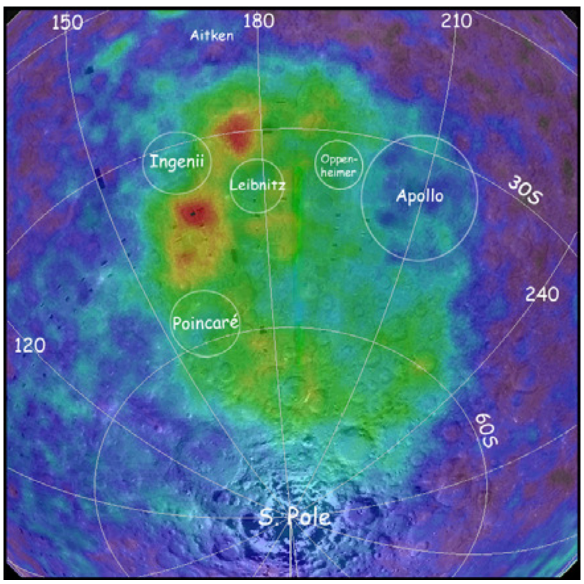


Figure 6: FeO vs. Sm, La/Yb, Cr/Sc, and Ir for a large number of lunar meteorites, including Dhofar 961 (open purple circles; from Korotev, 2006).

Dhofar 961, is moderately rich in Sm, and has lower Eu/Sm than Apollo samples at the same Sm concentration (Korotev et al., 2009b). This difference indicates that the carrier of rare earth elements is not KREEP, as known from the Apollo missions. This, coupled with the mafic character of its melt-breccia lithic clasts, Dho 961 is similar in composition to a broadly mafic region such as the interior of SPA and distinctly different from the feldspathic highlands. Compositional differences from Apollo impact-melt groups point to a provenance that different from the Procellarum KREEP Terrane. The SPA basin has several "hot spots" where Th concentrations reach 5 ppm and it has a broad "background" of about 2 ppm (Fig. 7 and 8, Jolliff et al., 2008, 2009); the range of Th concentrations in the SPA region is similar to compositons of lithic clasts from the different Dhofar 961 subsamples. Therefore, Jolliff et al. (2009) and Korotev et al. (2009b) argue that on the basis of present knowledge from remote sensing, Dhofar 961 is a lunar meteorite that is most likely to have originated from South Pole-Aitken basin on the lunar far side.



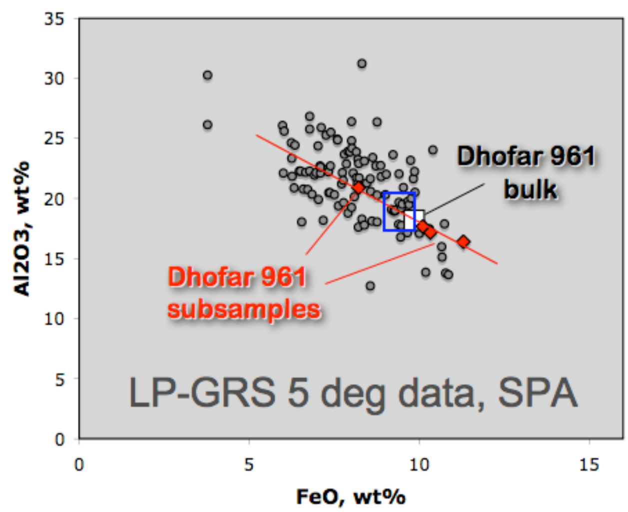


Figure 7: Thorium concentrations in the South Pole-Aitken Basin from the Lunar Prospector gamma-ray spectrometer. An area with suitable Th and FeO corresponding to Dhofar 961 shown by the dashed white boundary (from Jolliff et al., 2008).

Figure 8: FeO and Al2O3 contents of Dhofar 961 bulk and subsplits compared to the Lunar Prospector GRS data for the region near the South Pole Aitken basin (from Jolliff et al., 2009).

Radiogenic age dating

No work has been reported yet.

Cosmogenic isotopes and exposure ages

No work has been reported yet.

Table 1a:Chemical composition of Dho 925, 960, 961

reference	1	1	1	1	2
weight	20-60	51	20-60	239	1000
technique	i	e	i	e	a,h,i
	925	925	961	961	925
SiO_2 %	45.1		45.9		45.4
TiO_2	0.35		0.63		0.27
Al_2O_3	22.7		17.7		22
FeO	7.41		11.14		8.77
MnO	0.11		0.16		0.11
MgO	9		10.31		8.02
CaO	14.2		12.65		13.7
Na_2O	0.33		0.37		0.35
K_2O	0.07		0.1		0.06
P_2O_5	0.08		0.23		
S %					
sum	99.6		99.4		98.7
Sc ppm		16.6		27.8	24.8
V					
Cr		1350		1985	1302
Co		31.4		54.7	36.6
Ni		344		642	170
Cu					
Zn					
Ga					
Ge					
As		0.39		0.69	
Se		0.23		0.7	
Rb		<3		<10	
Sr		373		1180	630
Y					
Zr		62		215	90
Nb					
Mo					
Ru					
Rh					
Pd ppb					
Ag ppb					
Cd ppb					
In ppb					
Sn ppb					
Sb ppb					
Te ppb					
Cs ppm		0.09		0.22	

Ba	93	320	105
La	4.04	15.4	3
Ce	10.35	40	6.5
Pr			
Nd	6.8	23.2	3.7
Sm	1.91	6.9	1.4
Eu	0.704	0.815	0.49
Gd			
Tb	0.428	1.439	0.36
Dy			
Ho			
Er			
Tm			
Yb	1.82	5.48	1.61
Lu	0.252	0.762	0.3
Hf	1.61	5.39	0.72
Ta	0.23	0.61	1.1
W ppb			
Re ppb			
Os ppb			
Ir ppb	18.3	18.3	22.6
Pt ppb			
Au ppb	18.6	12	8
Th ppm	0.94	2.86	0.93
U ppm	0.45	0.98	1.14

technique (a) ICP-AES, (b) ICP-MS, (c) IDMS, (d) Ar, (e) INAA, (f) RNAA (g) SSMS, (h) XRF, (i) EMPA

Table 1b. Light and/or volatile elements for Dho 925, 960, 961

Li ppm		
Be		
C		
S		
F ppm		
Cl		
Br	0.4	0.56
I		
Pb ppm		
Hg ppb		
Tl		
Bi		

References: 1) Korotev et al. (2009b); 2) Demidova et al. (2007)