Dar al Gani 262, 996, 1042, 1048

Anorthositic regolith breccia

513, 12.31, 801, 0.8 g

Figure 1: Dar al Gani 262 as found in the Libyan desert in 1997 (Bischoff et al., 1998).

Introduction

Dar al Gani (DaG) 262 (Fig. 1) was found in the Libyan desert on March 23, 1997 (Fig. 2). It is partially covered with brown fusion crust but fresh surfaces are gray to dark gray and reveal light colored anorthositic clasts and mineral fragments (Fig. 3). Dar al Gani 996 was found in May 1999 and is paired with 262 on the basis of their similar, yet distinctive, compositions. DaG 1042 was found in the Dar al Gani region near Al Jufrah, Libya in 1999 (Connolly et al., 2007). The 801 g stone is partially fusion crusted, and has feldspathic clasts in a fine grained well lithified matrix. And finally, the 0.8 g DaG 1048 was found in 2001 (Connolly et al., 2008). These four samples have been paired due to their indistinguishable bulk compositions (Korotev et al., 2008). Terrestrial weathering of these samples is evident in calcite and barite found on the outside and along fractures. There are also impact melt veins that criss-cross the samples.

Petrography and Mineralogy

Detailed petrographic studies of DaG 262 have shown that approximately half of the meteorite consists of fine grained constituents (< 100 microns), whereas the other half consists of lithic and mineral clasts and melt veins (Bischoff et al., 1998) Many of the clasts are feldspathic fine grained to microporphyritic crystalline melt breccias. There are significant portions of granulitic lithologies, recrystallized anorthosites and cataclastic anorthosites, and devitrified glasses. Impact melt veins cross cut the entire sample. Mafic crystalline impact melt breccias are rare, and are present in about the same percentage as in QUE 93069 (Bischoff et al., 1998).

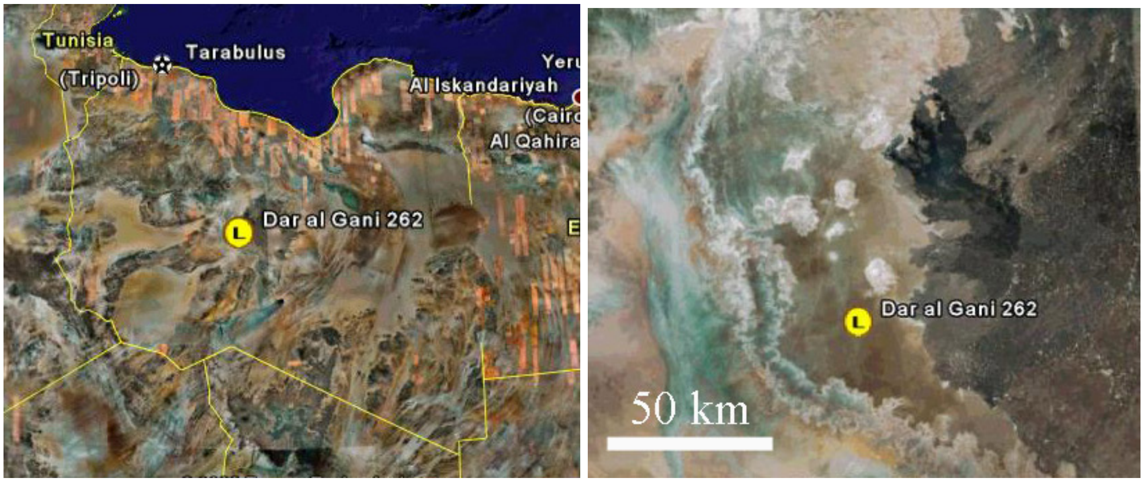

Figure 2: Map of the Dar al Gani region in Libya showing the location of DaG 262.

Figure 3: Cut slab of DaG 996 showing the many feldspathic clasts and mineral fragments. Scale at top has divisions of 1 mm (photo by R. Korotev).

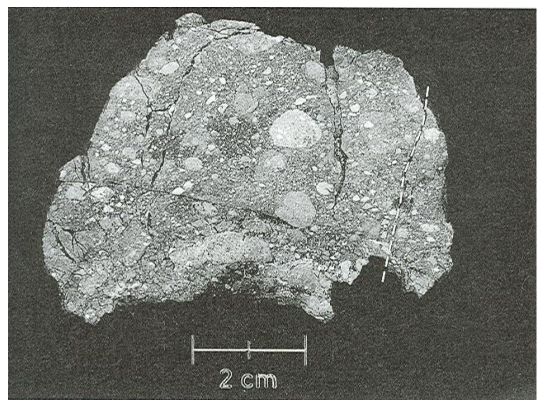

Figure 4: Thin section of DaG 262 showing abundant light colored anorthositic fragments in a fine grained matrix (from Bischoff et al., 1998).

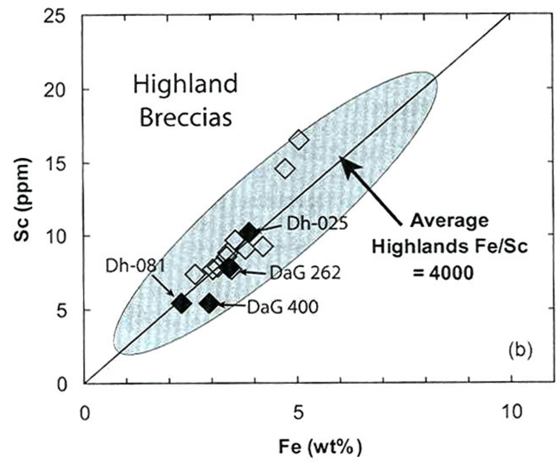

Figure 5a) Sc vs. Fe for DaG 262 compared to other highland breccias and the average highlands Fe/Sc ratio of 4000 (from Cahill et al., 2004).

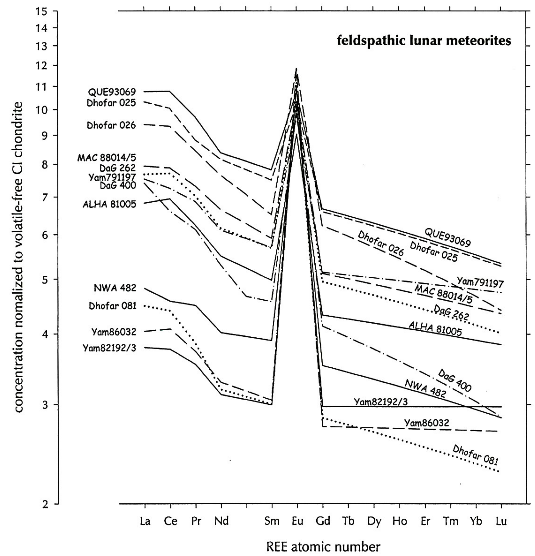

Figure 6: Rare earth element pattern for DaG 262 compared to other lunar feldspathic meteorites (from Korotev et al., 2003).

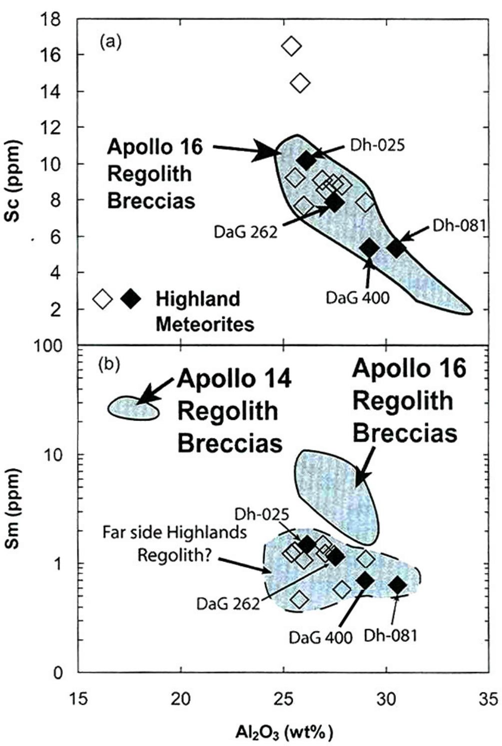

Fig. 5b: Sc and Sm vs. Al_2O_3 for DaG 262 compared to other lunar highlands meteorites, Apollo 15 and 14 regolith breccias (modified from Cahill et al., 2004).

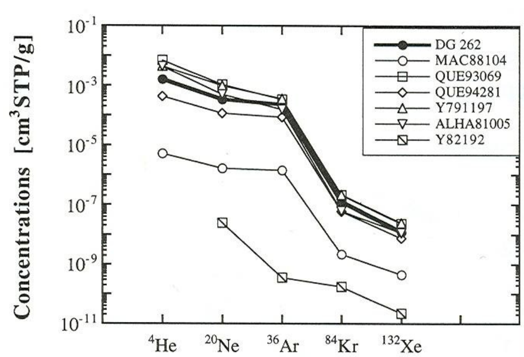

Figure 7: Noble gas isotopes for DaG 262 showing high concentrations relative to many other feldspathic lunar meteorites, indicating it originated from a mature regolith (Bischoff et al. (1998).

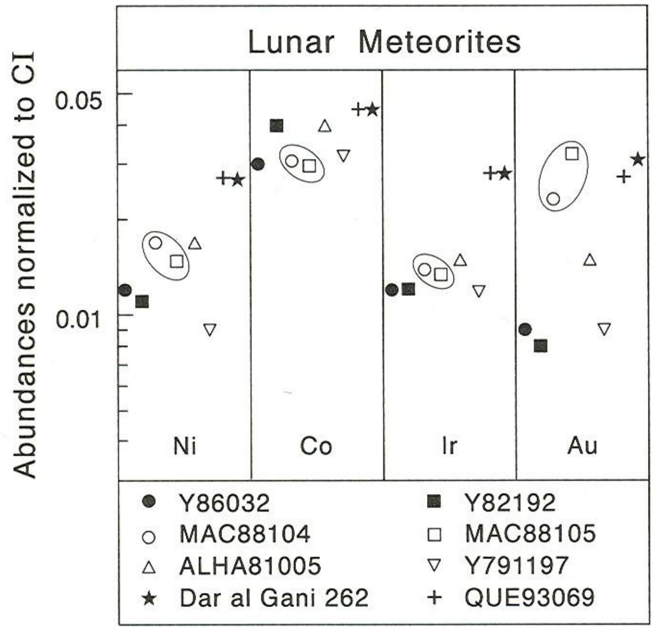

Figure 8: siderophile elements for DaG 262 showing high concentrations relative to many other feldspathic lunar meteorites, and similar to those in QUE 93069 (Bischoff et al. (1998)

DaG 1042 is an anorthositic or feldspathic regolith breccia with "typical lunar highland breccia clasts (with feldspathic crystalline melt breccias, granulitic lithologies, cataclastic anorthosites) embedded in a well-lithified matrix" (Connolly et al., 2007). Granulitic clasts consist of dominant plagioclase ($An_{95.4–96.7}$) with orthopyroxene ($Wo_3Fs_{19}En_{78}$, Fe# = 0.19), clinopyroxene ($Wo_{8–12}Fs_{26–28}$ $En_{62–64}$, Fe# = 0.28–0.30; $Wo_{44}Fs_9En_{47}$, Fe# = 0.15–0.16), olivine ($Fo_{65–69,81–84}$), ilmenite, and Ti-rich chromite ($Chr_{45}Hc_{19}Usp_{36}$). Isolated mineral fragments are plagioclase, co-existing augite and pigeonite, and olivine with ranges of compositions similar to those in the above clasts. Anorthositic impact glasses occur both as glass veins and spherules (see Connolly et al., 2007).

Chemistry

DaG 262 has low FeO (~4.5 wt%) and high Al_2O_3 (~27 wt%) as expected for a feldspathic highlands breccia (Fig. 5 and Table 1). Whereas DaG 262 has Fe and Sc contents very similar to highlands breccias (Fig. 5), it has lower Sm/Al_2O_3 ratios, as observed in many other highlands meteorites, indicating a different composition of the far-side highlands regolith from that of the Apollo 16 and 14 regolith breccias (Fig. 10; Korotev et al., 2003; Cahill et al., 2004). Ba and Sr contents are variable presumably due to non-uniform distribution of terrestrial weathering products (Korotev et al., 2003; Bischoff et al., 1998; Floss and Crozaz, 2001). Rare earth element compositions of DaG 262 show a typical positive Eu anomaly, and enrichment of LREE compared to HREE (Fig. 6). Noble gases measured in 5 subsamples from DaG 400 show that this meteorite has high concentrations of solar noble gases, comparable to those measured in QUE 93069 and ALHA81005, and indicating derivation from a mature regolith (Fig. 7). Siderophile elements are also high in DaG 262, and similar to those in QUE 93069 (Fig. 8). Chemical analyses of Dag 996 show that it is almost identical in composition to DaG 262 (Korotev, 2006).

Table 1: Chemical composition of DaG 262, 996, 1042

reference	1	1	2	2	2	3	3	4
weight	126	231	120	105.6	123.07	46.9	12.9	204
method	e	e	g	e	e	e	d	e
SiO_2 %	44.28	44.28	44.24				43.8	
TiO_2	0.25	0.18	0.22				0.2	
Al_2O_3	27.96	27.39	27.24				28.4	
FeO	4.52	4.32	4.58	4.30	4.49	4.38	4.47	4.31
MnO	0.06	0.06	0.06	0.06	0.07		0.06	
MgO	5.37	5.32	5.21				5.5	
CaO	16.37	17.35	16.90	15.39	17.07	16.70	17.1	
Na_2O	0.35	0.33	0.33	0.33	0.33	0.35	0.35	0.342
K_2O	0.07	0.10	0.10	0.05	0.06	0.05	0.052	
P_2O_5			0.057				0.06	
S %								
sum								
Sc ppm	8.4	8		7.7	7.99	7.67		7.69
V	10	26	26					
Cr	660	620	648	630	639	640	547	643
Co	22.2	17.9			22	20.1		
Ni	230	186		230	310	242		294
Cu								
Zn				40	33			
Ga	4.4	4.3		3.8	4.7			
Ge								
As	<1	0.21		0.3	0.53	0.56		
Se				<0.5	<0.4			
Rb				<2	<3	<3		
Sr	176	209		220	270	202		
Y								
Zr	37	<30		38	30	27		
Nb								
Mo				0.9	0.87			
Ru								
Rh								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb								
Sn ppb								
Sb ppb	<70	41				20		
Te ppb								
Cs ppm	<0.120	<0.120		0.08	0.15	0.049		
Ba	240	117		190	390	150		
La	2.65	2.25		2.3	2.57	2.21		

Ce	6.6	5.3		7.7	6.8	5.83		
Pr								
Nd	4.2	3.3		4.5	3.2	3.2		
Sm	1.22	1.01		1.2	1.09	1.015		1.12
Eu	0.86	0.74		0.74	0.725	0.749		0.738
Gd				1.2				
Tb	0.25	0.21		0.23	0.24	0.206		
Dy	1.81	1.5		2	1.5			
Ho	0.37	0.26		0.3	0.3			
Er								
Tm								
Yb	1	0.79		0.9	0.93	0.82		
Lu	0.143	0.11		0.12	0.13	0.1212		
Hf	0.87	0.78		0.83	0.87	0.738		
Ta	0.13	0.114		0.1	0.11	0.099		
W ppb						<1000		
Re ppb								
Os ppb								
Ir ppb	10.4	9.8		11	13	10.5		
Pt ppb								
Au ppb	7	4.6		5	3.8	62		
Th ppm	0.38	0.38		0.4	0.46	0.364		0.45
U ppm	0.069	0.16		0.16	0.26	0.181		

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

Table 1b. Light and/or volatile elements for DaG 262 and 996

Li ppm						
Be						
C						
S						
F ppm						
Cl						370
Br	5.5	3.4			0.8	1.22
I						
Pb ppm						
Hg ppb						
Tl						
Bi						

References: 1) Warren et al. (2005); 2) Bischoff et al. (1998); 3) Korotev et al. (2003); 4) Korotev et al. (2008)

Radiometric age dating

Ar-Ar studies of Fernandes et al. (2000) yielded ages between 1.7 and 3.0 Ga on several different impact melt clasts. Similarly, Cohen et al. (2005) obtained impact melt clasts ages of 2.4 and 3.5 Ga. Clearly, this meteorite has experienced a number of different impact and/or resetting events, making a simple interpretation very difficult.

Cosmogenic exposure ages

Cosmogenic exposure age dating of DaG 262 has yielded terrestrial ages of 80 Ka, ejection ages of 150 Ka, and Earth-Moon transit times of ~ 80 Ka (Nishiizumi et al., 2004). In addition noble gas studies have led Eugster et al. (2000) to deduce a long residence time at shallow depths.