Calcalong Creek

Basalt-bearing anorthositic regolith breccia

19 g

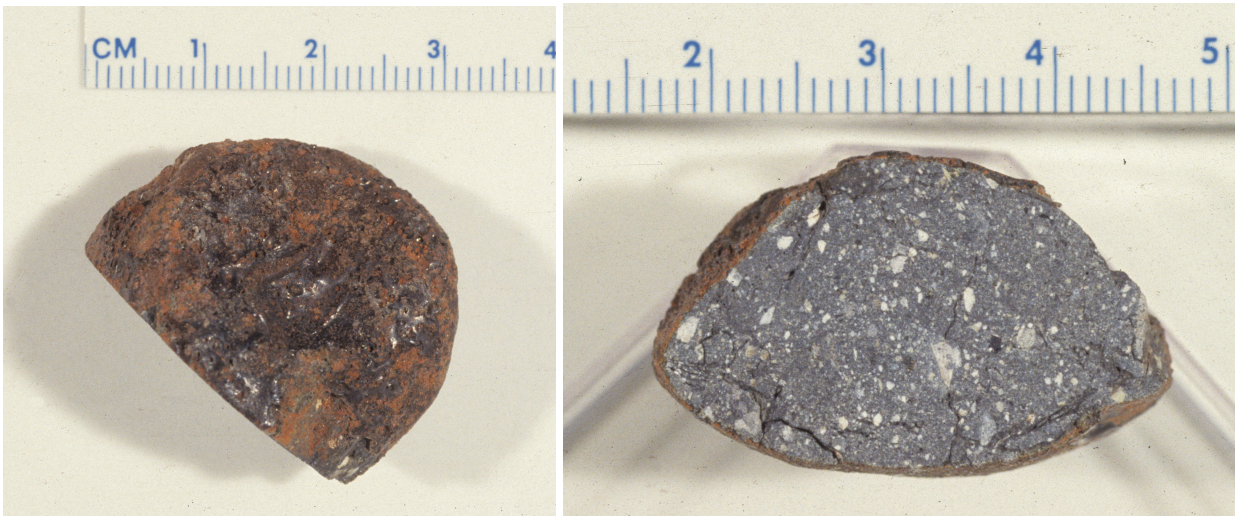

Figure 1: Left: Exterior photo of Calcalong Creek showing the shiny fusion crust as well as some rusty regions from terrestrial weathering. Right: Interior photo of Calcalong Creek showing many clasts and mineral fragments. In both images is shown a 4 cm scale bar. Photos courtesy of D. Hill.

Introduction

Calcalong Creek (Fig. 1) was found in 1990 in the Nullarbor Plain of South Australia (Fig. 2). This ~ 3 cm, 19 g single stone was 100% fusion crusted, and was the first recognized lunar meteorite from a desert locality. In hand sample it is clearly a polymict breccia with sub mm clasts welded by a glassy vesicular matrix (Fig. 3).

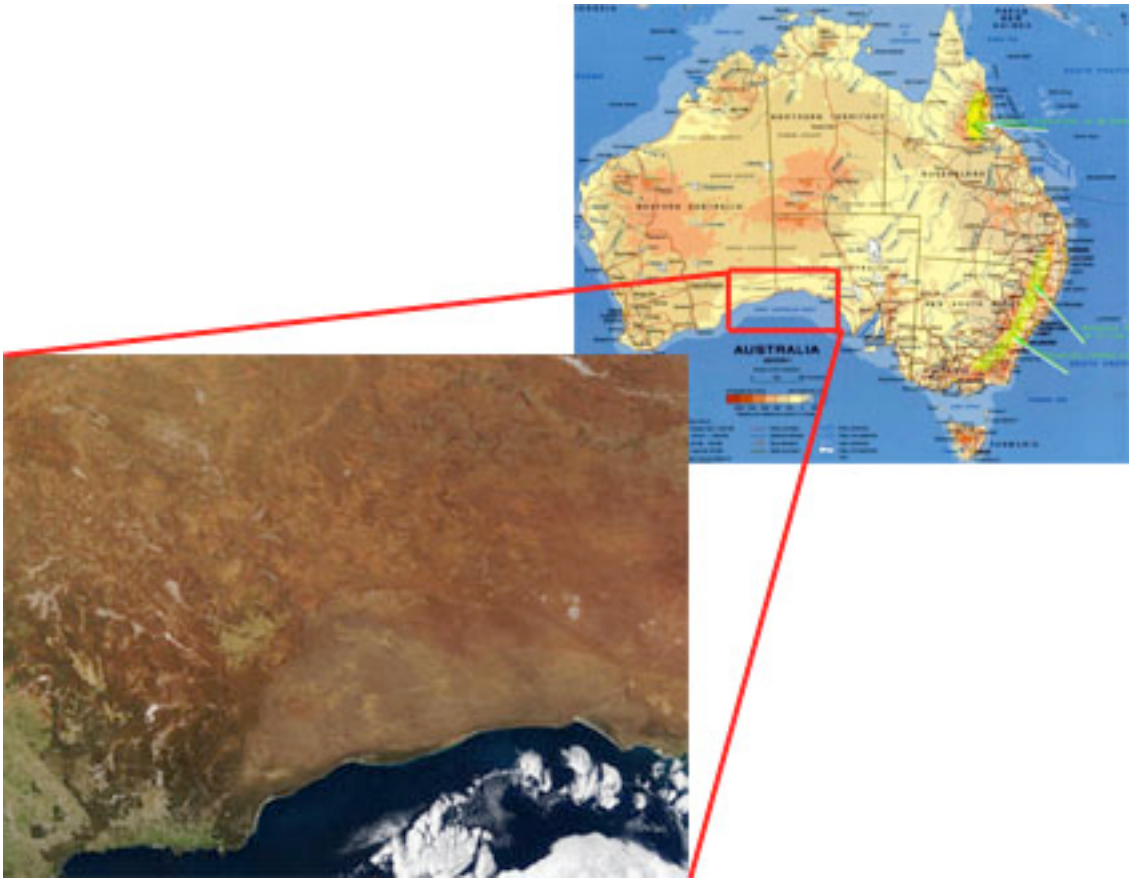

Figure 2: Location of the Nullarbor Plain in South Australia, where Calcalong Creek and many other meteorites have been found in the desert (Bevan et al., 2002).

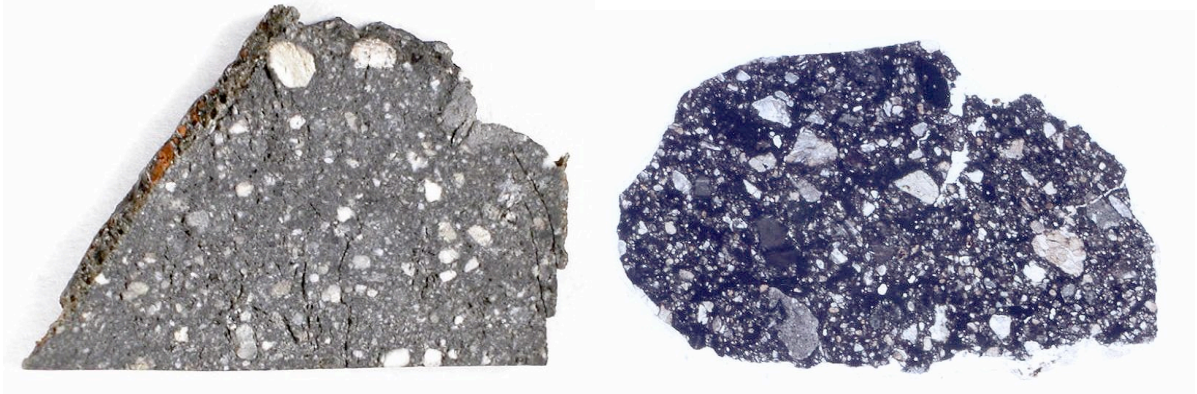

Figure 3: A small slab (left) and thin section (right) of Calcalong Creek illustrating the sizes of the small clasts and the preponderance of matrix.

Petrography and mineralogy

Calcalong Creek is comprised mainly of dark glassy matrix (Fig. 3), but contains a variety of clast types and mineral fragments, dominated by highlands lithologies, such as anorthosites, gabbroic anorthosite, spinel troctolite, and KREEP basalt (Marvin and Holmberg, 1992; Hill and Boynton, 2003). In addition, many of the mineral fragments are similar in composition to Fe-rich basalt material (fayalite, pyroxferrite, ferro-hedenbergite, ferro-augite, silica and troilite). X-ray maps show the modal mineralogy to be 26% plagioclase, 60% pyroxene, 2% olivine, < 1% of k-spar,

ilmenite, whitlockite, troilite, and chromite, and 11% vesicles (Hill and Boynton, 2003).

Chemistry

Four small bulk splits and several individual clasts of Calcalong Creek have been analyzed (Table 1; Hill and Boynton, 2003). Major element compositional characteristics of Calcalong Creek are similar to other mingled breccias in that it has intermediate values of FeO and TiO_2 (Fig. 4). Other major and trace element characteristics also point toward a mixed or mingled origin for Calcalong Creek. For example, Sm, Th and Al_2O_3 characteristics of the bulk and clast samples show it is intermediate between mare, highlands, and KREEP end members (Fig. 5). Similarly, Eu, Ga, Al, Na, Ca, and Mg# diagrams show that many of the clasts are of highlands nature, but that the bulk composition is more intermediate (Fig. 6). Clast F of the Hill and Boynton (2003) study is clearly KREEP-like (Fig. 6). Rare earth elements and incompatible elements are high in the bulk sample analyses, and it also exhibits a negative Eu anomaly (Figs 7 and 8). On the other hand, Calcalong Creek REE concentrations are not as high as SaU169 or KREEP samples. Finally, siderophile element concentrations are high in Calcalong Creek, with Re and Os close to chondritic levels, and Ir, Ni, Co and Au between 0.01 and 0.1 chondritic values consistent with mature regolith (Fig. 9).

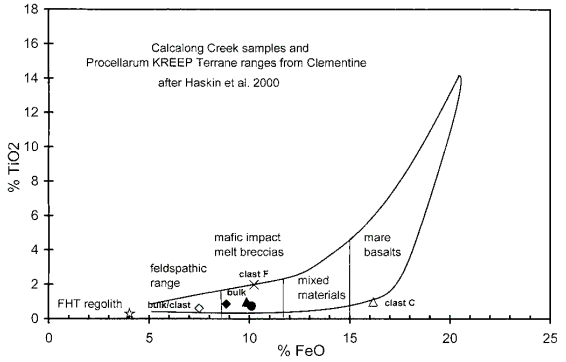

Figure 4: FeO vs. TiO_2 for bulk and clast analyses from the study of Hill and Boynton (2003).

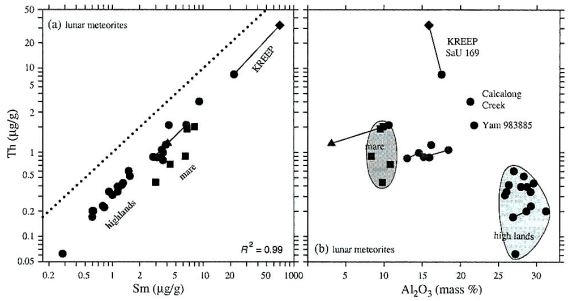

Figure 5: Th-Sm-Al_2O_3 systematics of Calcalong Creek compared to mare, highlands, and KREEP samples (from Korotev, 2005).

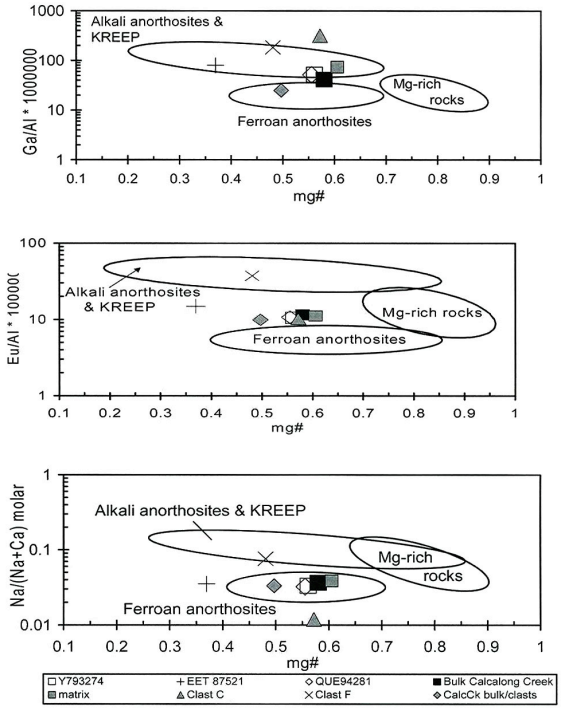

Figure 6: Eu, Ga, Al, Na, Ca and Mg# characteristics of Calcalong Creek bulk and clasts compared to mare, highlands, and KREEP samples (from Hill and Boynton, 2003).

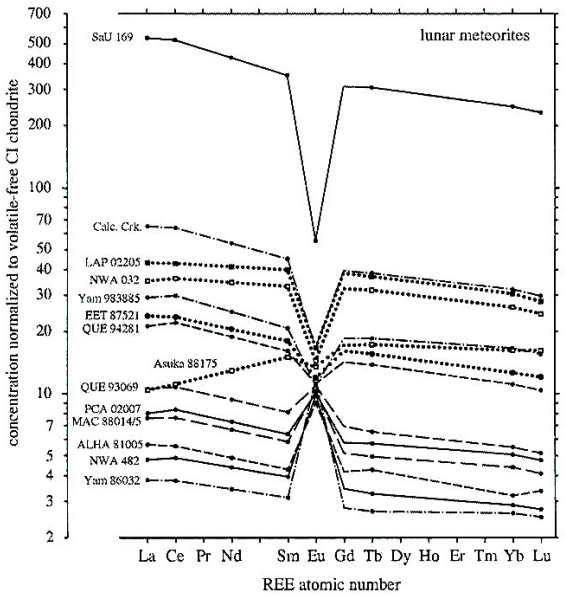

Figure 7: Rare earth element characteristics of Calcalong Creek compared to other feldspathic lunar meteorites (from Korotev, 2005).

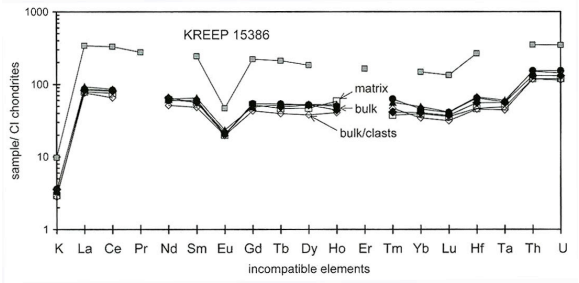

Figure 8: Incompatible lithophile elements of Calcalong Creek bulk and clasts compared to KREEP sample 15386 (from Hill and Boynton, 2003).

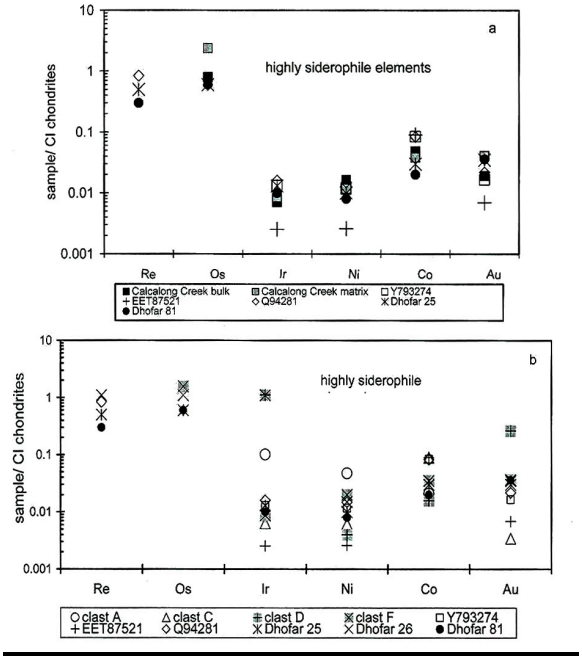

Figure 9: Siderophile elements of Calcalong Creek bulk and clasts compared to several other lunar meteorites (from Hill and Boynton, 2003).

Radiometric age dating

No studies are known yet.

Cosmogenic isotope studies

Calcalong Creek has a relatively old lunar exposure age of ~ 3.0 Ma (Nishiizumi et al., 1992, 1995; Swindle et al., 1995). As for other lunar meteorites it has a short transit time (200 Ka), and a young terrestrial age (< 30 Ka; Nishiizumi et al., 1992, 1995; Swindle et al., 1995).

Table 1a. Chemical composition of Calcalong Creek

reference	1	1	1	1	1	1
sample	bulk	bulk	bulk	bulk	bulk/clasts	matrix
weight	18.9	6.1	38.8	avg	3	0.3
method	e	e	e	e	e	e
SiO_2 %						
TiO_2	0.719	0.964	0.833	0.817	0.604	
Al_2O_3	21.17	20.26	21.55	20.83	21.94	19.77
FeO	10.1	9.86	8.84	9.69	7.49	10.98
MnO	0.15	0.14	0.12	0.14	0.11	0.16
MgO		6.47	8.12	7.11	4.15	9.45
CaO	13.73	13.1	13.57	13.31	14.07	13.05
Na_2O	0.48	0.49	0.49	0.49	0.46	0.51
K_2O	0.25	0.23	0.24	0.24	0.19	0.2
P_2O_5						
S %						
sum						
Sc ppm	22.49	21.6	17.68	21.24	15.66	24.88
V	54	65	48	55.3	47	85
Cr	1301	1146	1099	1170	835	1752
Co	25.11	23.97	26.9	24.82	19.55	28.3
Ni	273	159	202	180	129	151
Cu						
Zn		5.68	7.2		4.4	5.7
Ga			4.7	4.7	2.9	7.7
Ge						
As		0.22	0.12			0.192
Se						
Rb	10.1	9	7.7	9.37	6.1	7.29
Sr	141	150.4	153	149.2	160	129
Y						
Zr	250	375	187	354	212	236
Nb						
Mo	1.83	1.72		1.79	1.7	0.94
Ru						
Rh						
Pd ppb						
Ag ppb						
Cd ppb						
In ppb						
Sn ppb						
Sb ppb						
Te ppb						

Cs ppm	0.37	0.37	0.44	0.367	0.281	0.33
Ba	224	271	241	257	153	215
La	21.09	22.63	20.23	21.83	18.7	19.3
Ce	53	54.6	51.6	54.1	41.7	48.3
Pr						
Nd	28.3	29.7	30.7	29.5	24.27	29.3
Sm	9.3	10.02	8.71	9.55	7.41	8.71
Eu	1.199	1.356	1.282	1.303	1.146	1.162
Gd	11	10		10.5	8.8	10.7
Tb	2.01	1.946	1.83	1.941	1.483	1.735
Dy	13.23	13.4	13.2	13.28	9.64	11.9
Ho	2.83	2.96	2.49	2.67	2.31	3.3
Er						
Tm	1.6	1.45	1.06	1.407	1.19	0.96
Yb	7.52	8.1	6.69	7.5	5.69	6.5
Lu	1.036	1.05	0.945	1.024	0.796	0.911
Hf	7.69	7.93	6.58	7.15	5.39	5.5
Ta	0.966	1.015	0.95	0.991	0.752	0.824
W ppb	550	800	460	554	660	720
Re ppb						
Os ppb		400	160	200	1200	
Ir ppb	3	3	6	3	4	3
Pt ppb						
Au ppb	3	2	6	3	5.9	2
Th ppm	4.4	4.303	3.76	4.28	3.36	3.39
U ppm	1.24	1.15	1.06	1.18	0.92	0.966

technique (a) ICP-AES, (b) ICP-MS, (c) IDMS, (d) Ar, (e) INAA

Table 1b. Light and/or volatile elements for Calcalong Creek

Li ppm						
Be						
C						
S						
F ppm						
Cl						
Br	0.566	1.67		0.829	0.42	0.22
I						
Pb ppm						
Hg ppb						
Tl						
Bi						

1) Hill and Boynton (2003)