Reference List

RBT 04261 – 78.8 grams
RBT 04262 – 205 grams
Enriched Olivine-phryic Shergottite

Figure 1: *ANSMET photo of RBT04262 on ice.*

Figure 2: *Laboratory photographs of two specimens of olivine-phryic basaltic shergottite (McBride et al. 2007). Cube is 1 cm.*

Introduction

These two identical pieces of basaltic shergottite were found together on the ice (figure 1) in Antarctica in 2004, but weren't announced until 2007. The location is termed Roberts Massif. Oxygen isotopes indicate that they are Martian.

The crystallization age of RBT shergottites is 170 m.y. with an exposure to cosmic rays of ~ 2.9 m.y.

Petrography

Brief descriptions of RBT04261 are found in McBride et al. (2007) and Connolly et al. (2007) and a complete description is found in Usii et al. (2010). About half of the exterior surfaces have a brown/black, rough-textured fusion crust. The interiors are soft and tan-grey in color with a sandy texture and low metal content (figure 2). Thin sections show a coarse-grained assemblage of pyroxene, olivine and maskeyenite (grain size about 4 mm)(figure 3). Shock-melt veins and pockets are present.

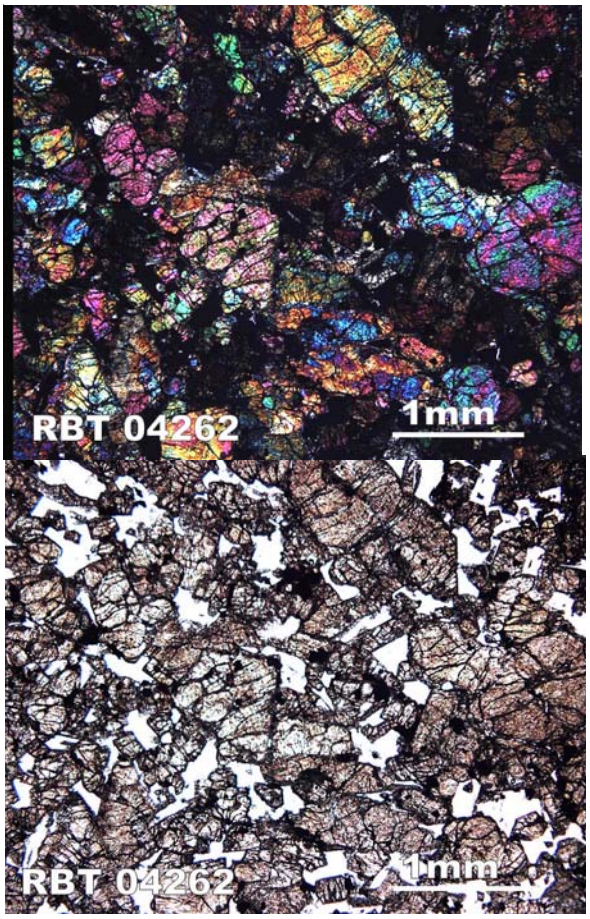

Figure 3: *Thin section photos of RBT04261 (from McBride et al. 2007). Top is crossed polarized; bottom is plane polorized light.*

Mineralogical Mode for RBT04262

	Mikouchi 2008	Usii et al. 2010	
		261	262
Olivine	30 %	42.1	39.4
Pyroxene			
Pigeonite	43	21.5	28
Augite	10	10.7	12.4
Plagioclase	13	20.2	15.9
Chromite	2	1.6	1.5
Ilmenite		0.2	0.2
Phosphate	1	1.8	1.1
Other	1	1.9	1.4

Anand et al. (2008), Dalton et al. (2008), Mikouchi et al. (2008), Mittlefehldt and Herrin (2008), Usii et al. (2008, 2010) and Shearer et al. (2009) have all reported on the petrology of RBT04262. They find these rocks

Summary of Age Data for RBT04262

	Lu-Hf	Sm-Nd	Rb-Sr
Lapan et al. 2008	225 ± 21 m.y.		
Shih et al. 2009		174 ± 14 m.y.	
			167 ± 6 m.y.

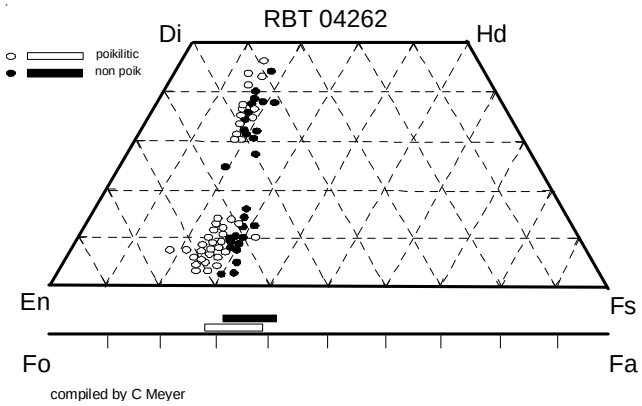

Figure 4a: *Olivine and pyroxene composition diagram (redrwawn from Mikouchi et al. 2008).*

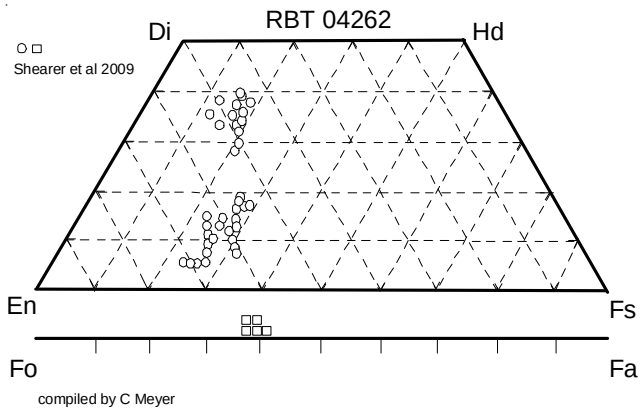

Figure4b: *Mafic mineral compositions were also reported by Shearer et al. (2009)*

are made up of two distinct regions: a poikilitic region defined by large (5 mm) low-Ca pyroxene oikocrysts including small olivine chadocrysts, chromites and melt inclusions and a non-poikilitic region with intergrown maskelynite, olivine, pyroxene, phosphates, chromite, ilmenite and sulfides. Anand et al. consider RBT04262 to be an olivine cumulate and, indeed, *"ghosts"* have been reported in P scans of olivine (Beckett et al. 2008). Papike et al. (2009) have compared these various shergottites, and confirmed the earlier mineral chemistry.

Mineralogy

Olivine: Usii et al. (2010) noted that the poikilitic areas had olivine that was "distinctly higher in forsterite content" (Fo_{60-70}) than the olivine in the non-poikilitic areas (Fo_{57-62}). Beckett et al. (2008) illustrated rather strange phosphorous zoning in olivine from RBT.

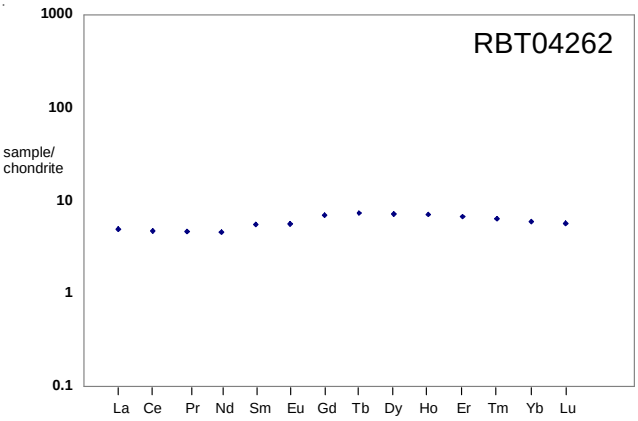

Figure 5: *Normalized rare-earth-element diagram for RBT04262 (data from Anand et al. 2008).*

Pyroxene: Low-calcium pyroxene oikocrysts are abundant (Mikouchi et al. 2008; Anand et al. 2008; Usii et al. 2010). They are rimmed by high-calcium pyroxene approaching augite in composition (figure 4 a,b).

Plagioclase: The plagioclase in RBT shergottites has been converted to maskelynite by shock. It has a range of composition from An_{56} to An_{22} and is more sodic than is found in the other olivine-phyric shergottites (Usii et al.). Some maskelynite in RBT is also potassic ($An_{15}Ab_{64}Or_{21}$).

Opaques: Al-rich chromites have two distinct trends in RBT shergottites (see Usii et al. 2010). The chromites in the mafic poikilitic regions vary from Chr_{52} to Chr_{77}, while the chromites in the non-poikilitic regions vary from Ulv_{2} to Ulv_{37}.

Phosphate: The phosphate in RBT04262 is merrillite (Usii et al.). It contains most of the REE.

Chemistry

The chemical composition of RBT04262 has been reported by Anand et al. (2008). The REE pattern is essentially flat, like that of Shergotty, but lower (figure 5). Walker et al. (2009) and Brandon et al. (2012) have reported data on the highly siderophile element contents (Ir = 1.8 ppb).

Table 1. Chemical composition of RBT 04262.

reference	Anand2008	
weight		
SiO2 %	47.6	(a)
TiO2	0.43	(a)
Al2O3	3.32	(a)
FeO	20.6	(a)
MnO	0.53	(a)
MgO	21.6	(a)
CaO	5.66	(a)
Na2O	0.59	(a)
K2O	0.08	(a)
P2O5	0.39	(a)
S %	0.17	(b)
sum		
Sc ppm	31	(b)
V	218	(b)
Cr	7152	(b)
Co	63	(b)
Ni	291	(b)
Cu	6.6	(b)
Zn	74	(b)
Ga	8.2	(b)
Ge ppb		
As		
Se		
Rb	4	(b)
Sr	22.2	(b)
Y	9.3	(b)
Zr	23	(b)
Nb		
Mo	0.4	(b)
Ru		
Rh		
Pd ppb		
Ag ppb		
Cd ppb	42	(b)
In ppb		
Sn ppb	110	(b)
Sb ppb	83	(b)
Te ppb		
Cs ppm	0.29	(b)
Ba	12.8	(b)
La	1.15	(b)
Ce	2.81	(b)
Pr	0.414	(b)
Nd	2.07	(b)
Sm	0.81	(b)
Eu	0.314	(b)
Gd	1.36	(b)
Tb	0.26	(b)
Dy	1.75	(b)
Ho	0.4	(b)
Er	1.07	(b)
Tm	0.155	(b)
Yb	0.96	(b)
Lu	0.145	(b)
Hf	0.97	(b)
Ta		
W ppb	380	(b)
Re ppb		
Os ppb		
Ir ppb		
Pt ppb		
Au ppb		
Th ppm	0.257	(b)
U ppm	0.058	(b)
technique:	*(a) ICP-AES, (b) ICP-MS*	

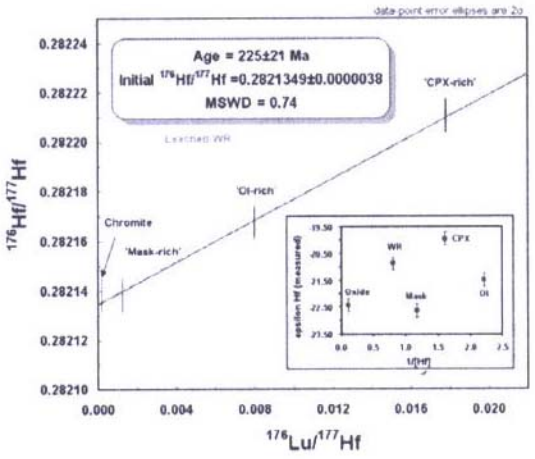

Figure 6: *Lu-Hf isochron diagram for RBT04262 (Lapan et al. 2008).*

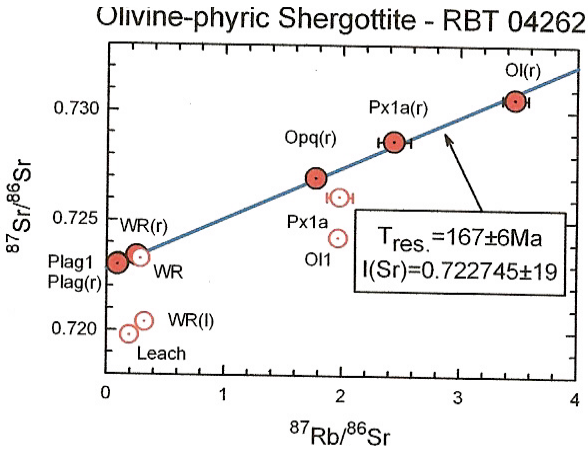

Figure 7: *Rb-Sr isochron for RBT 04262 (from Shih et al. 2009).*

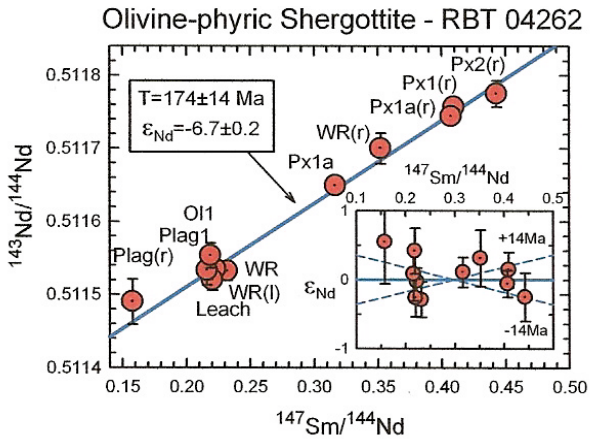

Figure 8: *Sm-Nd isochron for RBT 04262 (from Shih et al. 2009).*

Radiogenic age dating

RBT04262 was dated by the Lu-Hf technique with an age of 225 ± 21 m.y. (Lapan et al. 2008)(figure 6). However, Shih et al. (2009) reported significantly younger ages (174 ± 14 m.y. by Sm-Nd and 167 ± 6 m.y. by Rb/Sr)(figures 7 and 8).

Niihara (2011, 2012) used U/Pb, Pb/Pb ion probe techniques to date small (<5 micron) baddeleyite grains @ ~ 235 m.y.

Cosmic ray induced radiochemistry

Nishiizumi and Chaffee (2010) reported a ^{10}Be exposure age of 3.0 ± 0.6 m.y. for RBT04261 and 2.0 ± 0.5 m.y. for RBT04262. They calculate a terrestrial age of 710 ± 60 k.y. from ^{36}Cl. Nagao and Park (2008) reported an average cosmic ray exposure age of 2.3 ± 0.6 m.y. from rare gas measurements.

Other Studies

Oxygen isotopes are reported by McBride et al. (2007) and Anand et al. (2008). Sulfur isotopes are reported by Franz et al. (2008). Xenon isotopes and halogen contents have been reported by Cartwright et al. (2008, 2009). Cartwright et al. (2010) reported an exhaustive study of all the minerals in RBT and other shergottites, *without concluding age data!*

Cartwright et al. (2010) found that while some minerals contain excess ^{129}Xe, other minerals contain excess ^{40}Ar, suggesting different sources.

References for RBT04261 and 262.