DRAFT

Luna 16 B1

Basalt

0.062 grams

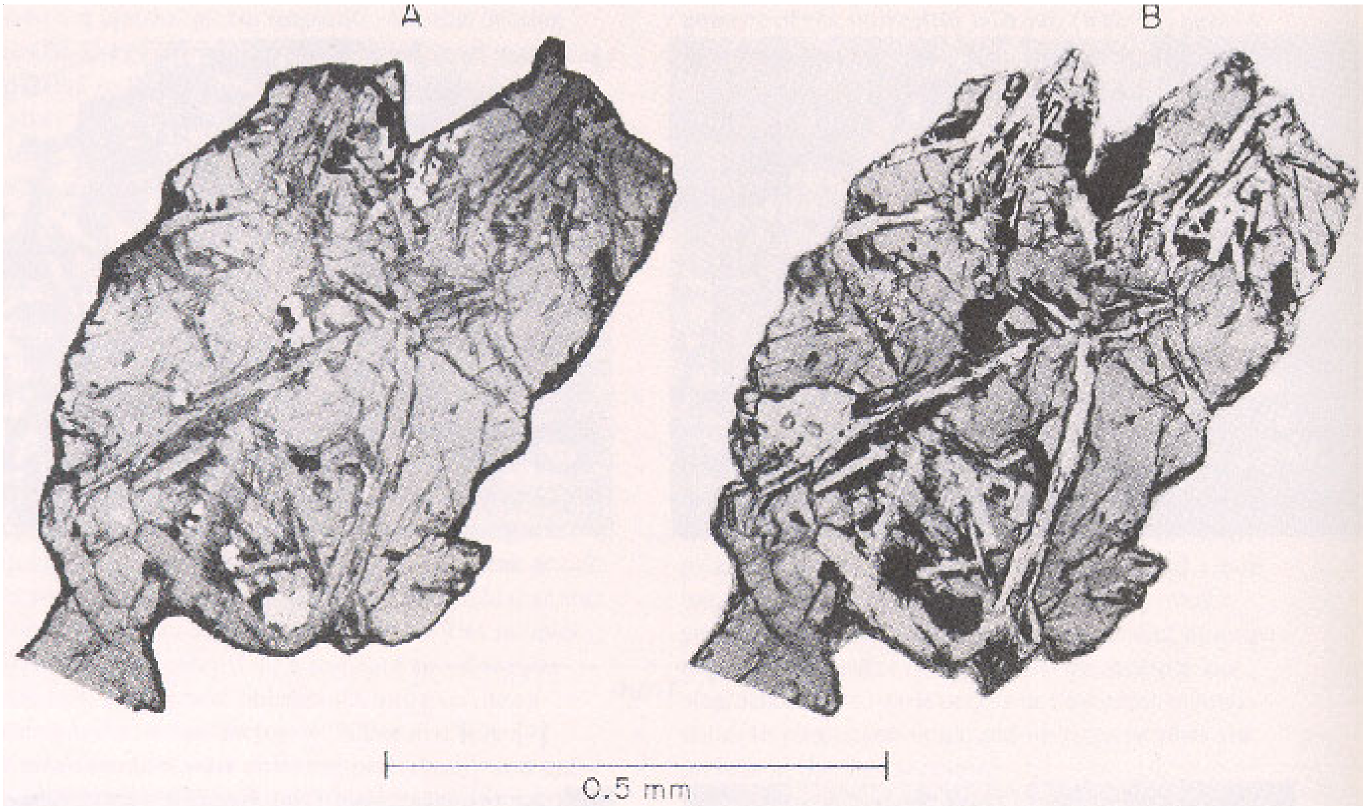

Figure 1: Photo of thin section of basalt fragment B1 from Luna 16 core (from Albee et al. 1972). Dominant pyroxene encloses laths of plagioclase. A is reflected light, B is transmitted light.

Introduction

Luna 16 was, in fact, the third mission to return samples from the Moon (Vinogradov 1971). An unmanned Soviet spacecraft landed in the eastern equatorial portion of the Moon, successfully collected a small core from Mare Fecunditatis and automatically returned it to Earth. The Academy of Science USSR shared these precious samples with various countries and two 1.5 gram aliquots were exchanged with US investigators for representative samples of Apollo 11 and 12. Among these samples was a 62 gram chip of basalt from layer B, apparently typical of Luna 16 basalts. Numerous studies of these samples were published together in volume 13 of Earth Planetary Science Letters (1972).

Sample B1 (62 mg), from the 15-28 cm depth zone of the Luna 16 core, was selected for dating and gave an age of 3.45 b.y. Thin section studies showed it to be a fragment of mare basalt (figure 1).

Petrography

Photographs of Luna 16 basalt particles are found in Ivanov et al. (1973). Luna sample B-1 is a fine-grained

Mineralogical Mode of Luna 16 basalts

	B1 Albee	G37 Steele	G36 Hollister	(norm) Vinogradov
Olivine	tr.	15	17.3	
Pyroxene	50 %	30	45.5	(50)
Plagioclase	40	50	33.5	(40)
Ilmenite	7	6	3.7	(7)

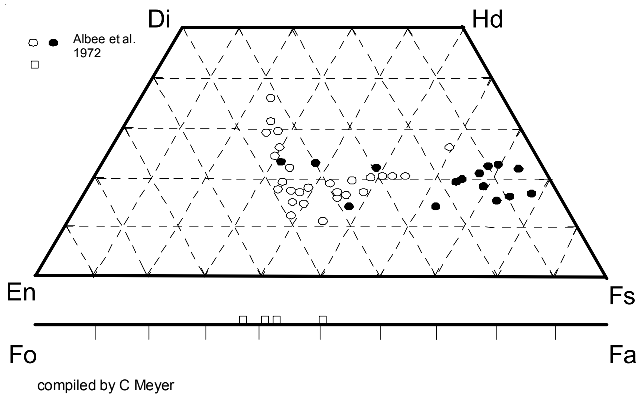

Figure 2: Pyroxene composition for Luna 16 basalt B1 (replotted from Albee et al. 1972).

ophitic basalt composed of 50% clinopyroxene, 40% plagioclase, 7 % ilmenite and minor ulvöspinel, olivine, troilite, mesostasis and other minor phases (Albee et al. 1972). The fragment was covered with an irregular, thin, vitreous-appearing "glaze" with numerous zap pits on all sides, but the basaltic texture was apparent. Plagioclase on the outside seemed to appear shocked (Albee et al. 1972). It was noted that one side of the 2 mm particle (B1) seemed to have been a vug wall.

Additional fragments of basalt from the Luna 16 core were studied by Grieve et al. (1972), Bence et al. (1972), Hollister and Kulick (1972), Steele and Smith (1972) and Cimbalnikova et al. (1977).

Chemistry

Albee et al. (1972) determined the major element composition by broad-beam-electron-microprobe and a few trace elements by isotope dilution mass spectroscopy on the small fragment B1, showing it to be representative of basalts from Luna 16 (table 1). Fragment B1 and other Luna 16 basalts appear to have relatively high Ti (figure 3).

The rare-earth-element pattern for the Luna 16 soil matches that of the basalt rather closely (figure 4), indicating that the KREEP component is restricted to the Apollo samples.

Radiogenic age dating

Papanastassiou et al. (1972) and Huneke et al. (1972) have dated basalt fragment B1 and obtained concordant ages (table).

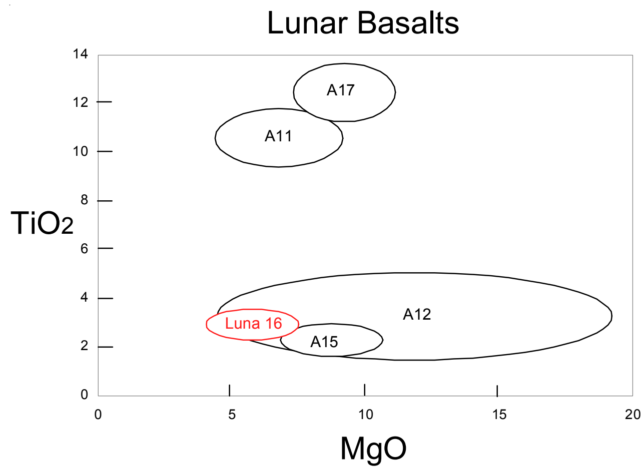

Figure 3: Composition of basalts from Luna 16 comparded with other sites.

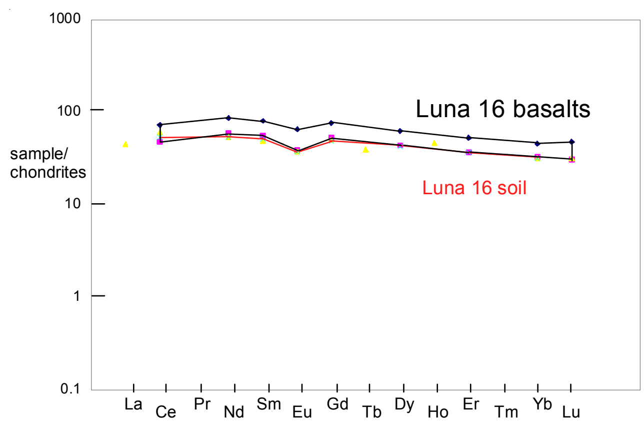

Figure 4: Normalized rare-earth-element composition diagrams for Luna 16 basalts. Data from table 1 (Philpotts et al. 1972, Jerome et al. 1972). Luna 16 soil from Hubbard et al. (1972) matches basalts rather well!

Cosmogenic isotopes and exposure ages

Huneke et al. (1972) determined an exposure age of 475 m.y. by ^{38}Ar.

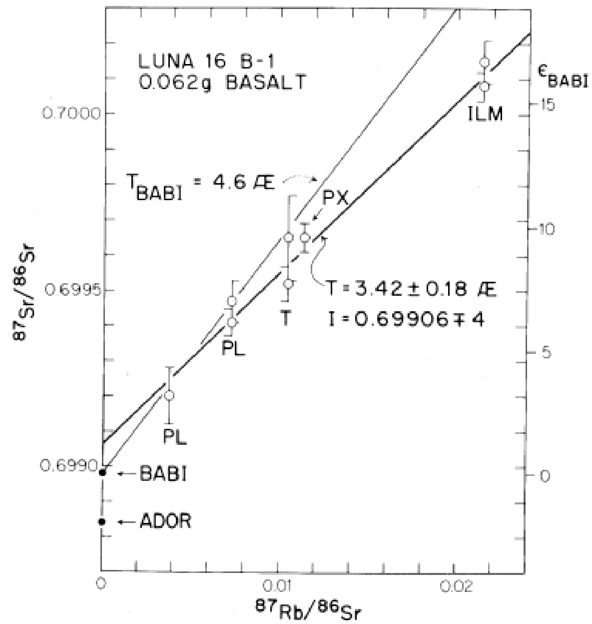

Figure 5: Rb-Sr isochron diagram for basalt fragment B1 from Luna 16 (from Papanastassiou et al. 1972).

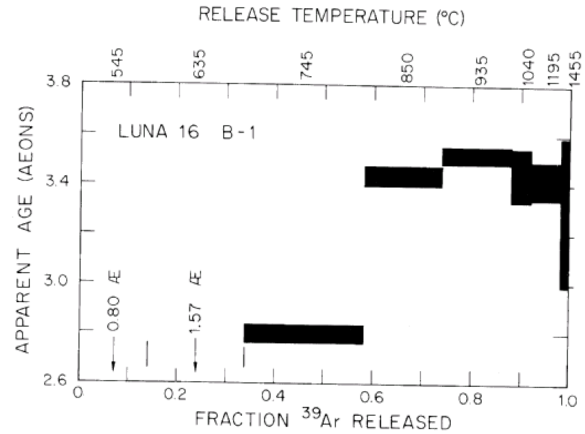

Figure 6: Argon plateau age for basalt fragment B1 (from Huneke et al. 1972).

Summary of Age Data for Luna 16 basalt B1

	Ar/Ar	Rb/Sr
Huneke et al. 1972	3.45 ± 0.04 b.y.	
Papanastassiou et al. 1972		3.42 ± 0.18

Table 1. Chemical composition of Luna 16 Basalts

reference	*Vinogradov 71*		*Albee 1972*		*Jerome 72*		*Grieve 72*			*Keil 72*		*Philpotts 72*			*Jakes 72*	
weight			B1		L16-19		G38					A29	G27		glasses	
SiO2 %	43.8		45.5	a			45.17	43.36	44.2	46.6	a				44.57	f
TiO2	4.9		4.04	a	3.6	d	2.9	4.37	2.48	6.1	a				2.62	f
Al2O3	13.65		13.95	a	15.3	d	16.98	15.13	16.45	15.7	a				15.92	f
FeO	19.35		17.77	a	15.8	d	13.21	17.48	13.67	17.2	a					
MnO	0.2		0.26	a	0.21	d	0.22	0.27	0.2	0.28	a				14.43	f
MgO	7.05		5.95	a	9.28	d	4.02	4.97	4.3	3.7	a				9.01	f
CaO	10.4		11.96	a	11.5	d	13.32	12.77	12.65	11.3	a				11.86	f
Na2O	0.33		0.63	a	0.34	d	0.69	0.7	0.69	0.46	a				0.32	f
K2O	0.15		0.21	a	0.2	d	0.17	0.17	0.21	0.24	a	0.123	0.17	e	0.09	f
P2O5			0.15	a						0.12	a					
S %																
sum																
Sc ppm	20	c			50.2	d										
V	42.5				97	d										
Cr					1990	d										
Co	29				30.9	d										
Ni	147															
Cu	13															
Zn	26															
Ga	1.2															
Ge ppb																
As																
Se																
Rb			1.58	b								2.1	1.5	e		
Sr	445		436.6	b								303	468	e		
Y	58															
Zr																
Nb																
Mo																
Ru																
Rh																
Pd ppb																
Ag ppb																
Cd ppb																
In ppb																
Sn ppb																
Sb ppb																
Te ppb																
Cs ppm	0.75		0.054	b												
Ba			218	b	360	d						215	230	e		
La	7.7				10.7	d										
Ce	24.6				37.2	d						29	44	e		
Pr	4.8															
Nd	25				24.7	d						27.4	39.4	e		
Sm	7.1				7.2	d						8.23	11.9	e		
Eu	1.2				2.15	d						2.2	3.7	e		
Gd	4.8				10	d						10.4	15.2	e		
Tb	0.9				1.44	d										
Dy	5.2											10.7	15.2	e		
Ho	2				2.6	d										
Er	5											5.95	8.43	e		
Tm	0.4				0.75	d										
Yb	3.6				5.23	d						5.4	7.53	e		
Lu	0.3				0.78	d						0.75	1.18	e		
Hf	0.3				6.32	d										
Ta																
W ppb					17	d										
Re ppb																
Os ppb																
Ir ppb																
Pt ppb																
Au ppb					1.7	d										
Th ppm					1.06	d										
U ppm			0.3	b												

technique (a) e-probe, (b) idms, (c) ms and es, (d) , (e) idms, (f) eprobe

Table 1b. Chemical composition of Luna 16 Basalts and Soil

reference	Cimalnikova 77		Helmke 72			Hubbard 72	Philpotts		
weight	ave of 11		A-31	C-29		L16 soil	soil	soil	
SiO2 %						44			(b)
TiO2	4.6	(a)				3.3			(b)
Al2O3	11	(a)				16			(b)
FeO	22.6	(a)				16			(b)
MnO	0.28	(a)				0.23			(b)
MgO	7.1	(a)				8.3			(b)
CaO	10.7	(a)				12.1			(b)
Na2O	0.5	(a)				0.42			(b)
K2O	0.2	(a)				0.1			(b)
P2O5									
S %									
sum									
Sc ppm	75	(a)	26	54	(a)				
V	76	(a)							
Cr			1900	2050	(a)				
Co	29	(a)	21	14	(a)				
Ni									
Cu									
Zn									
Ga			4.3	3.6	(a)				
Ge ppb									
As									
Se									
Rb						1.87	1.85	1.9	(c)
Sr	744	(a)				295	244	271	(c)
Y									
Zr							224	227	(c)
Nb									
Mo									
Ru									
Rh									
Pd ppb									
Ag ppb									
Cd ppb									
In ppb									
Sn ppb									
Sb ppb									
Te ppb									
Cs ppm									
Ba	371	(a)	203	243	(a)	171	169	172	(c)
La	18	(a)	12	19.4	(a)				
Ce	65	(a)	30	66	(a)	32.6	31.2	32.5	(c)
Pr									
Nd	61	(a)				24.7	26.4	26.3	(c)
Sm	15	(a)	8.1	16	(a)	7.65	7.98	8.18	(c)
Eu	4.4	(a)	2.04	4.04	(a)	2.11	2.16	2.22	(c)
Gd				17	(a)	9.57	10.5	10.5	(c)
Tb	2.7	(a)		3.1	(a)				
Dy	22.5	(a)	8.8	17.9	(a)	10.4	10.1	10.4	(c)
Ho	4	(a)	2.1	3.9	(a)				
Er				12	(a)	5.88	5.78	5.87	(c)
Tm	2.4	(a)							
Yb	9	(a)	5.2	10.9	(a)	5.26	5.45	5.44	(c)
Lu	1.4	(a)	0.69	1.51	(a)		0.822	0.841	(c)
Hf	12	(a)	0.46	1.3	(a)			5.88	(c)
Ta									
W ppb									
Re ppb									
Os ppb									
Ir ppb									
Pt ppb									
Au ppb									
Th ppm	1.3	(a)							
U ppm	1	(a)							

technique (a) INAA, (b) XRF new, (c) Idms