12064

Ilmenite Basalt

1214.3 grams

Figure 1: Lunar basalt 12064. Sample is 7 cm across. NASA # S70-44454.

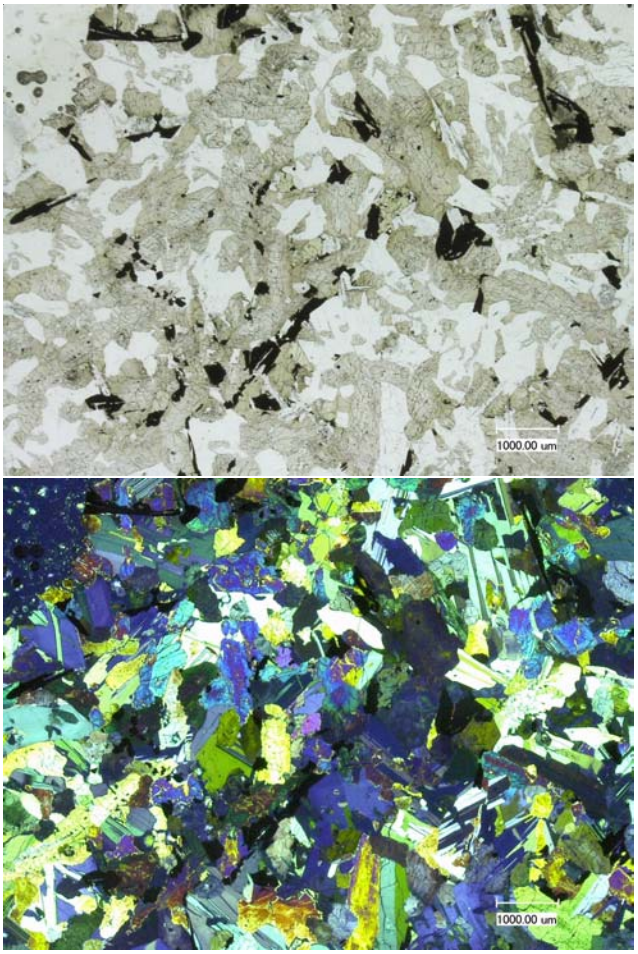


Figure 2a: Photomicrograph of thin section 12064,6 by C Meyer @ 30x.

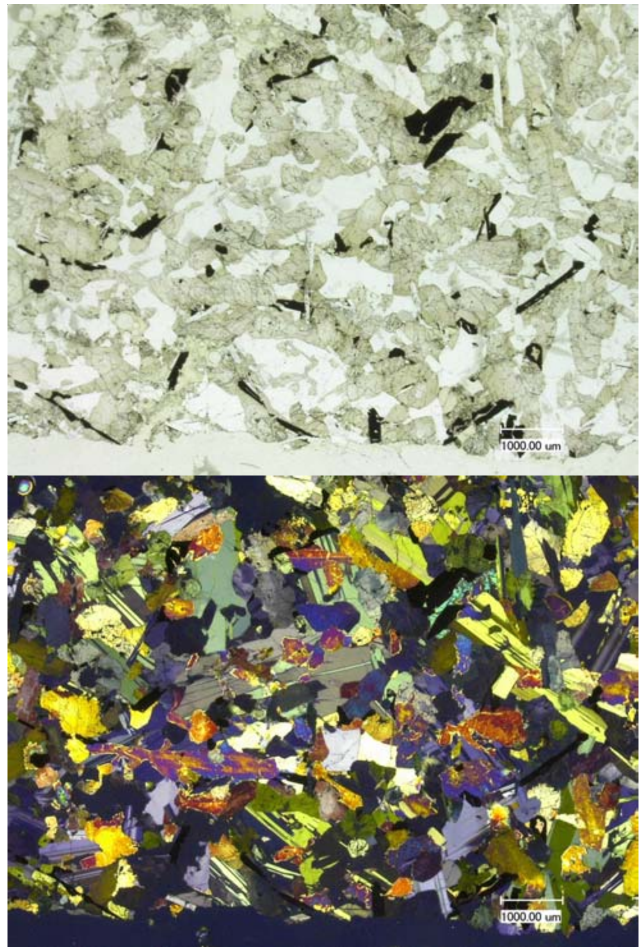


Figure 2b: Photomicrograph of thin section 12064,7 by C Meyer @ 30x (crossed polarizers).

Introduction

12064 is an angular rock believed to be the one described by the astronauts as a "square rock" collected near the Surveyor spacecraft (figure 1). It is a coarse-grained ilmenite basalt that is 3.2 b.y. old.

Petrography

Klein et al. (1971) and McGee et al. (1977) describe 12064 as "a coarse-grained subophitic basalt characterized by anhedral pyroxene crystals (0.4 to 2.0 mm) intergrown with plagioclase anhedra (0.8 – 1 mm) and rare subhedral plagioclase tablets (0.2 – 1 mm)." The rather coarse-grained mesostasis of 12064 is characterized by intergrowths of fayalite, heddenbergite, and glass - also containing K-spar, whitlockite, apatite and two Zr-rich phases (Kushiro et al. 1971). Photomicrographs of representative thin sections are illustrated in figures 2 a,b,c,d.

Mineralogy

Olivine: 12064 contains trace fayalite (Kushiro et al. 1971).

Pyroxene: The clinopyroxene in 12064 shows pronounced optical zoning from light tan at the center to dark brown border zones at the edge (Klein et al. 1971). The composition of pyroxenes in 12064 are plotted in figure 3.

Pyroxferroite: Klein et al. (1971) remarked: "Pyroxferroite occurs sporadically as distinctly yellowish, transparent areas next to clinopyroxene. When the clinopyroxene and pyroxferroite coexist a clear and sharp optical contact is visible between them. The pyroxferroite shows a very limited range of composition, with FeO contents between 44 and 44.8 wt. % and CaO ranging from 5.9 to 6.8 %. The TiO_2

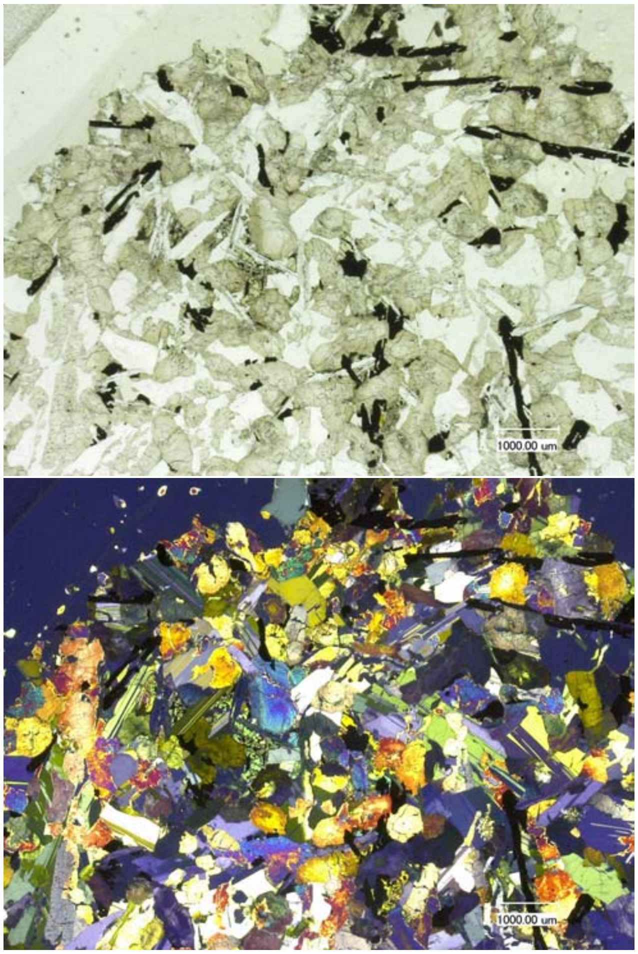


Figure 2c: Photomicrograph of thin section 12064,8 by C Meyer @ 30x.

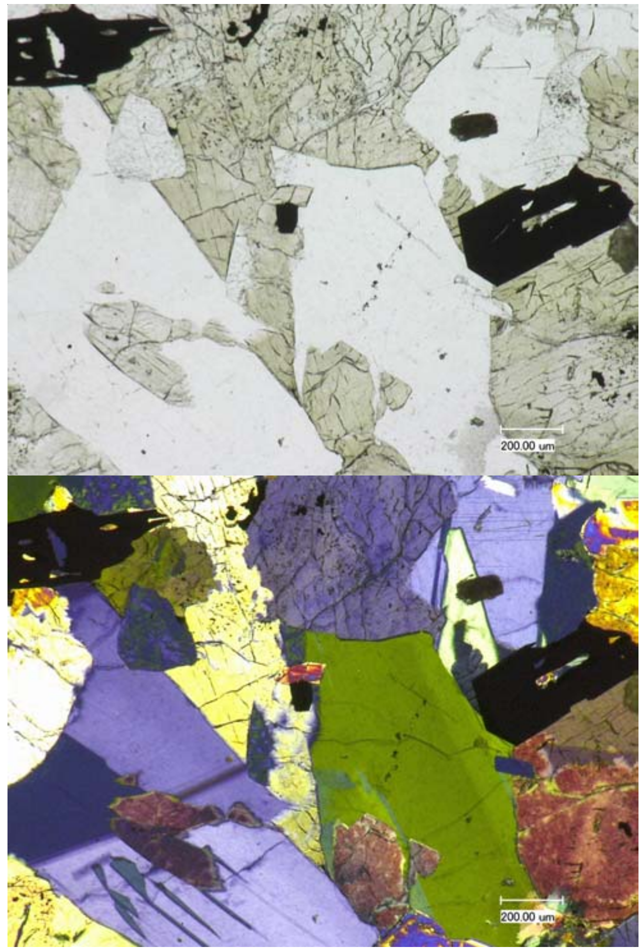


Figure 2d: Photomicrograph of thin section 12064,8 by C Meyer @ 100x (bottom is with crossed polarizers).

content is only 0.6 wt. %, which is considerably less than the coexisting brown clinopyroxene (1.1%)."

Hedenbergite: Kushiro et al. (1971) report that Fe-rich clinopyroxene ranges to heddenbergite composition in 12064 (figure 3).

Plagioclase: Anhedral plagioclase crystals are as large as 1.1 mm (Baldridge et al. 1979) and range from An_{93} to An_{86} (Kushiro et al. 1971).

Opaques: Ilmenite in 12064 occurs as rounded laths (1.0-2.4 mm). Ulvöspinel has ilmenite exsolution lamellae.

Mineralogical Mode of 12064

	McGee et al. 1977	Neal et al. 1994	Klein et al. 1971	Papike et al. 1976
olivine	1-2		1.6	
pyroxene	56-57	55.5	55.8	57.2
plagioclase	29-33	39.1	29.4	33.1
opaques	7		7.1	6.7
ilmenite		3.9		
chrom + usp		0.6		
"silica"	2-5	- -	5	2.3
mesostasis	1	0.9	0.9	0.7

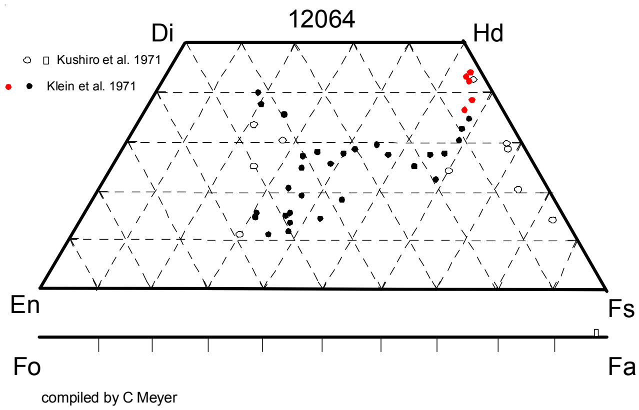


Figure 3: Pyroxene composition for 12064 (data mined from Kushiro et al. 1971 and Klein et al. 1971).

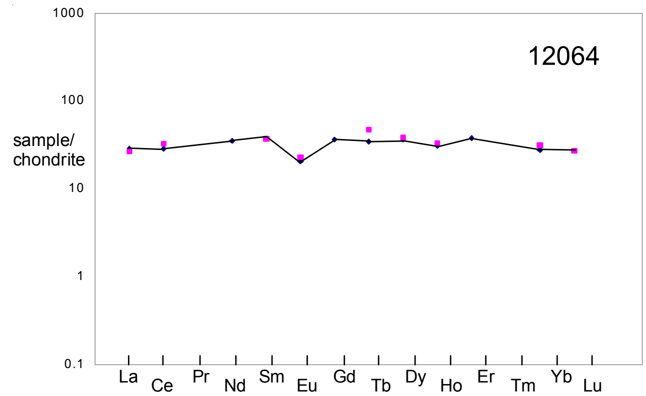


Figure 4: Normalized rare-earth-element diagram for lunar basalt 12064 (data from Haskin et al. 1971 connected by line).

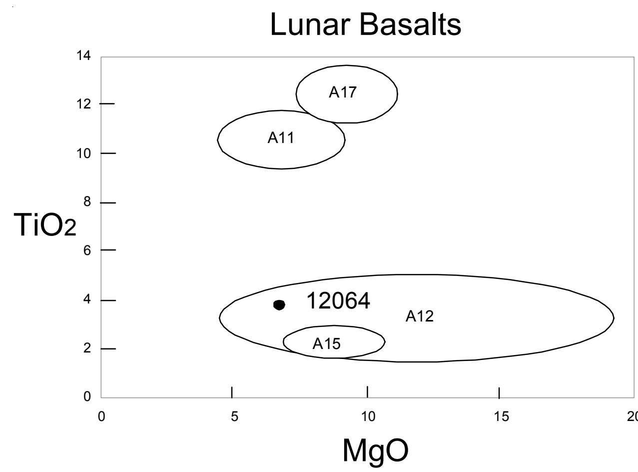


Figure 5: Composition of 12064 compared with other lunar basalts.

Silica: Long laths (1.5 mm) of tridymite are common in 12064 (Klein et al. 1971). Cristobalite occurs as anhedral to subhedral crystals.

K-spar: One K-feldspar in the coarse-grained mesostasis of 12064 was measured to have 11.6 % BaO (Kushiro et al. 1971).

Chemistry

Kushiro and Haramura (1971), Scoon et al. (1971) and others determined the chemical composition of 12064 (table 1). Wänke et al. (1971) and Haskin et al. (1971) reported the REE pattern (figure 4).

Radiogenic age dating

Papanastassiou and Wasserburg (1971a) determined the age of 12064 by Rb/Sr (3.18 ± 0.09)(figure 7). Horn et al. (1975) carefully compared the Ar release pattern for plagioclase with pyroxene from 12064 (figure 6) and obtained an age of 3.18 ± 0.01 b.y. Tatsumoto et al. (1971) reported U-Th-Pb isotopic data for density separations of 12064.

Cosmogenic isotopes and exposure ages

O'Kelly et al. (1971) determined the cosmic-ray-induced activity of ^{22}Na (40 dpm/kg), ^{26}Al (51 dpm/kg), ^{46}Sc (5 dpm/kg), ^{48}V (22 dpm/kg), ^{52}Mn (33 dpm/kg), ^{54}Mn (35 dpm/kg) and ^{56}Co (32 dpm/kg).

Horn et al. (1975) report an exposure age of 12064 of 255 m.y. Hintenberger et al. (1971) determined exposure ages for 12064 using ^{3}He (210 m.y.), ^{21}Ne (220 m.y.) and ^{38}Ar (190 m.y.).

Crozaz et al. (1971) determined the track density and estimated the "surface dwell time" of 1.5 ± 0.2 m.y.

Other Studies

Bogard et al. (1971) and Hintenberger et al. (1971) reported the content and isotopic composition of rare gases in 12064.

Epstein and Taylor (1971) and Clayton et al. (1971) reported oxygen isotopic analysis of mineral separates.

Processing

12064 was broken up with a rather large (17 cm) chisel (figure 8).

Summary of Age Data for 12064

	Ar/Ar	Rb/Sr
Horn et al. 1975	3.18 ± 0.01 b.y.	
	3.20 ± 0.04	
Papanastassiou and Wasserburg 1971a		3.18 ± 0.09

Caution: Beware the decay constant.

Table 1a. Chemical composition of 12064.

reference	Kushiro71		LSPET70	LSPET70		O'Kelly71		Wanke71		Scoon71		Haskin71		Dickenson89	
weight				1205 g		1205 g									
SiO2 %	46.19	(a)	40							46.41	(a)				
TiO2	3.83	(a)	4.9					4.34	(c)	4.14	(a)				
Al2O3	10.96	(a)	12							10.5	(a)				
FeO	19.83	(a)	22					19.43	(c)	19.95	(a)			18.9	(c)
MnO	0.26	(a)	0.32					0.294	(c)	0.27	(a)				
MgO	6.6	(a)	8							6.38	(a)				
CaO	11.84	(a)	12					14.3	(c)	11.71	(a)			12.2	(c)
Na2O	0.27	(a)	0.42					0.27	(c)	0.3	(a)			0.28	(c)
K2O	0.07	(a)	0.084	0.064	(b)	0.063	(b)	0.081	(c)	0.07	(a)				
P2O5	0.02	(a)								0.04	(a)				
S %										0.07	(a)				
sum															
Sc ppm			60					63.1	(c)					57	(c)
V			100												
Cr			3000					2160	(c)	2600	(a)			1700	(c)
Co			40					27.2	(c)					34	
Ni			15												
Cu								6.6	(c)						
Zn															
Ga															
Ge ppb														3	(c)
As															
Se															
Rb			0.76												
Sr			165											123	(c)
Y			55												
Zr			170											181	(c)
Nb															
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb															
Cd ppb															
In ppb															
Sn ppb															
Sb ppb															
Te ppb															
Cs ppm															
Ba			55											67	(c)
La								6.33	(c)			6.76	(c)	6	(c)
Ce								20	(c)			17.5	(c)	16	(c)
Pr															
Nd												16	(c)	14	(c)
Sm								5.5	(c)			5.51	(c)	4.8	(c)
Eu								1.3	(c)			1.161	(c)	1.2	(c)
Gd												7.2	(c)		
Tb								1.75	(c)			1.27	(c)	1.3	(c)
Dy								9.48	(c)			9.03	(c)		
Ho								1.87	(c)			1.72	(c)		
Er												6	(c)		
Tm														1.2	(c)
Yb								5.25	(c)			4.59	(c)	4	(c)
Lu								0.67	(c)			0.67	(c)	0.66	(c)
Hf								3.9	(c)					3.6	(c)
Ta								0.33	(c)					0.53	(c)
W ppb															
Re ppb															
Os ppb															
Ir ppb															
Pt ppb															
Au ppb															
Th ppm				0.88	(b)	0.87	(b)							0.78	(c)
U ppm				0.24	(b)	0.23	(b)								

technique: (a) conventional wet, (b) radiation counting, (c) INAA, (d) XRF, (e) IDMS

Table 1b. Chemical composition of 12064.

reference	Compston71		Brown71		Tats71		Neal2001	
weight								
SiO2 %								
TiO2								
Al2O3								
FeO								
MnO			0.27	(d)				
MgO								
CaO								
Na2O								
K2O			0.069	(d)				
P2O5								
S %								
sum								
Sc ppm							61.7	(f)
V	119	(d)					140	(f)
Cr	2020	(d)	3150	(d)			2097	(f)
Co	25	(d)					35.4	(f)
Ni	7	(d)	9	(d)			4.1	(f)
Cu	7	(d)	10	(d)			23	(f)
Zn							31	(f)
Ga	3.1	(d)					4.06	(f)
Ge ppb								
As								
Se								
Rb	1	(d)					1.19	(f)
Sr	134.8	(d)	138	(d)			144.6	(f)
Y	41	(d)	46	(d)			50	(f)
Zr	114	(d)	127	(d)			142	(f)
Nb	7	(d)	7	(d)			8.7	(f)
Mo								
Ru								
Rh								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb								
Sn ppb								
Sb ppb							0.21	(f)
Te ppb								
Cs ppm							0.01	(f)
Ba	70	(d)	38	(d)			74	(f)
La	5	(d)					6.77	(f)
Ce	13	(d)					18.4	(f)
Pr							2.84	(f)
Nd							14.1	(f)
Sm							5.06	(f)
Eu							1.156	(f)
Gd							7.17	(f)
Tb							1.23	(f)
Dy							8.4	(f)
Ho							1.71	(f)
Er							4.92	(f)
Tm							0.69	(f)
Yb							4.61	(f)
Lu							0.57	(f)
Hf							4.1	(f)
Ta							0.45	(f)
W ppb								
Re ppb								
Os ppb								
Ir ppb								
Pt ppb								
Au ppb								
Th ppm					0.977	(e)	0.83	(f)
U ppm					0.278	(e)	0.23	(f)

technique: (c) INAA, (d) XRF, (e) IDMS, (f) ICP-MS

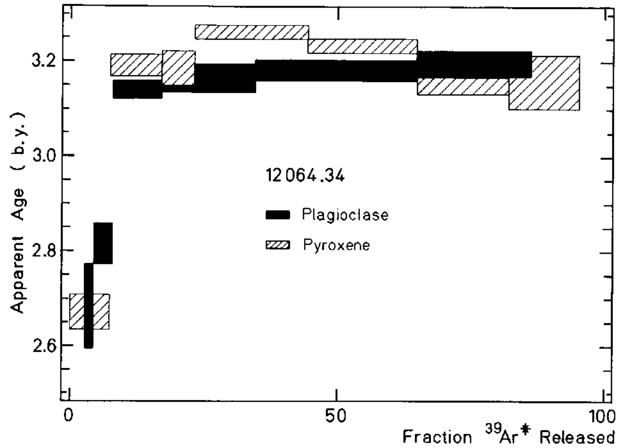


Figure 6: Argon release pattern for 12064 (from Horn et al. 1975).

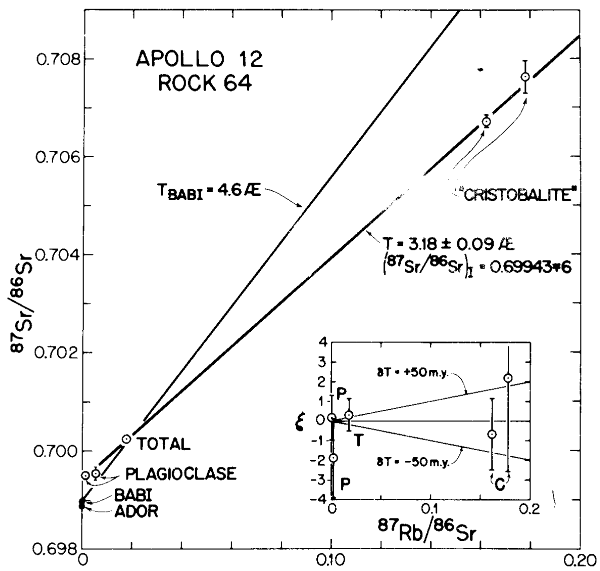
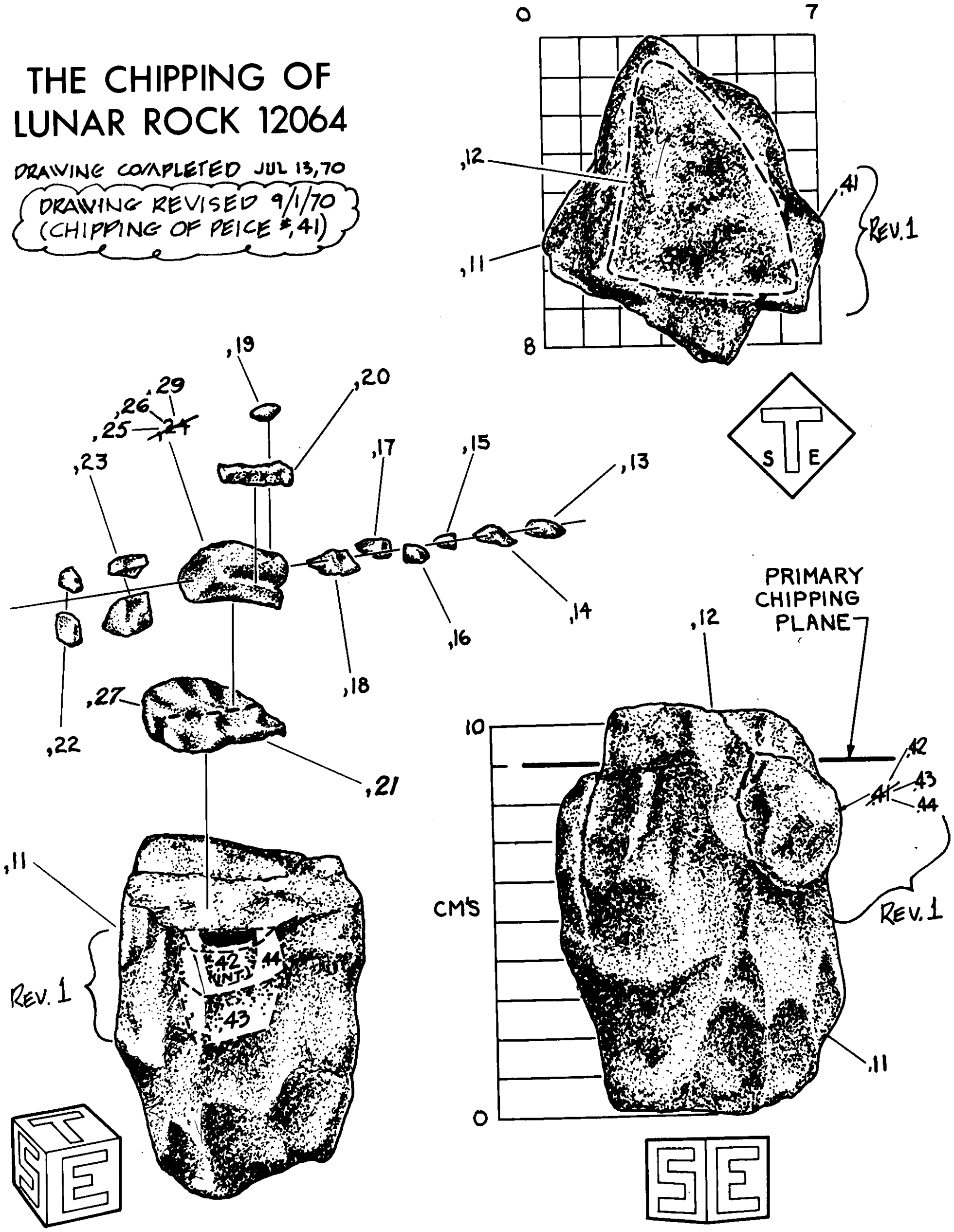


Figure 7: Rb-Sr isochron for lunar basalt 12064 (from Papanastassiou and Wasserburg 1971a).

List of Photo #s for 12064

S69-19071 – 19080	B & W mug
S69-60884 – 60907	B & W mug
S70-16774 – 16775	
S70-44450 – 44459	
S70-31562	TS
S70-31580	TS
S75-33930 – 33933	texture, color
S79-27110 – 27112	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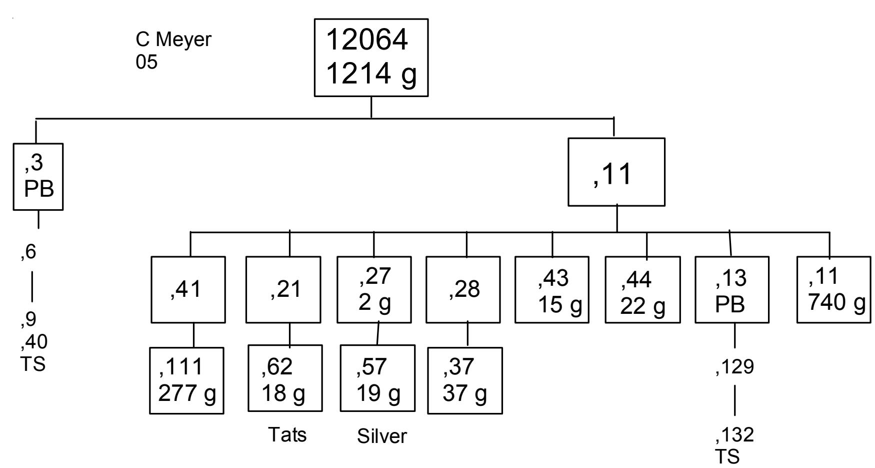
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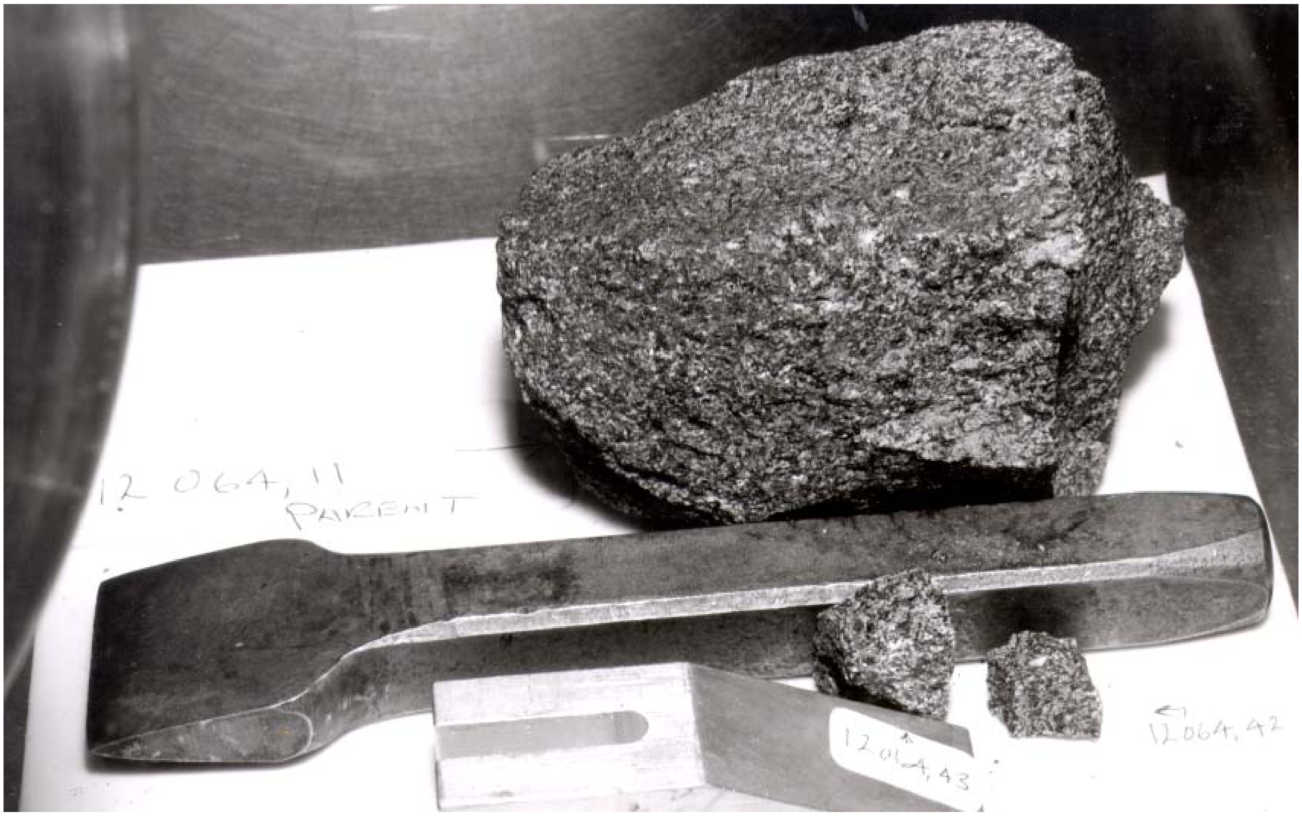

Figure 8: 12064,11 with chisel 17 cm long. NASA # S70-19624.

Figure 9: 12064,21 with dice. Scale is cm. (unnumbered photo)

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