75035

Ilmenite Basalt

1235 grams

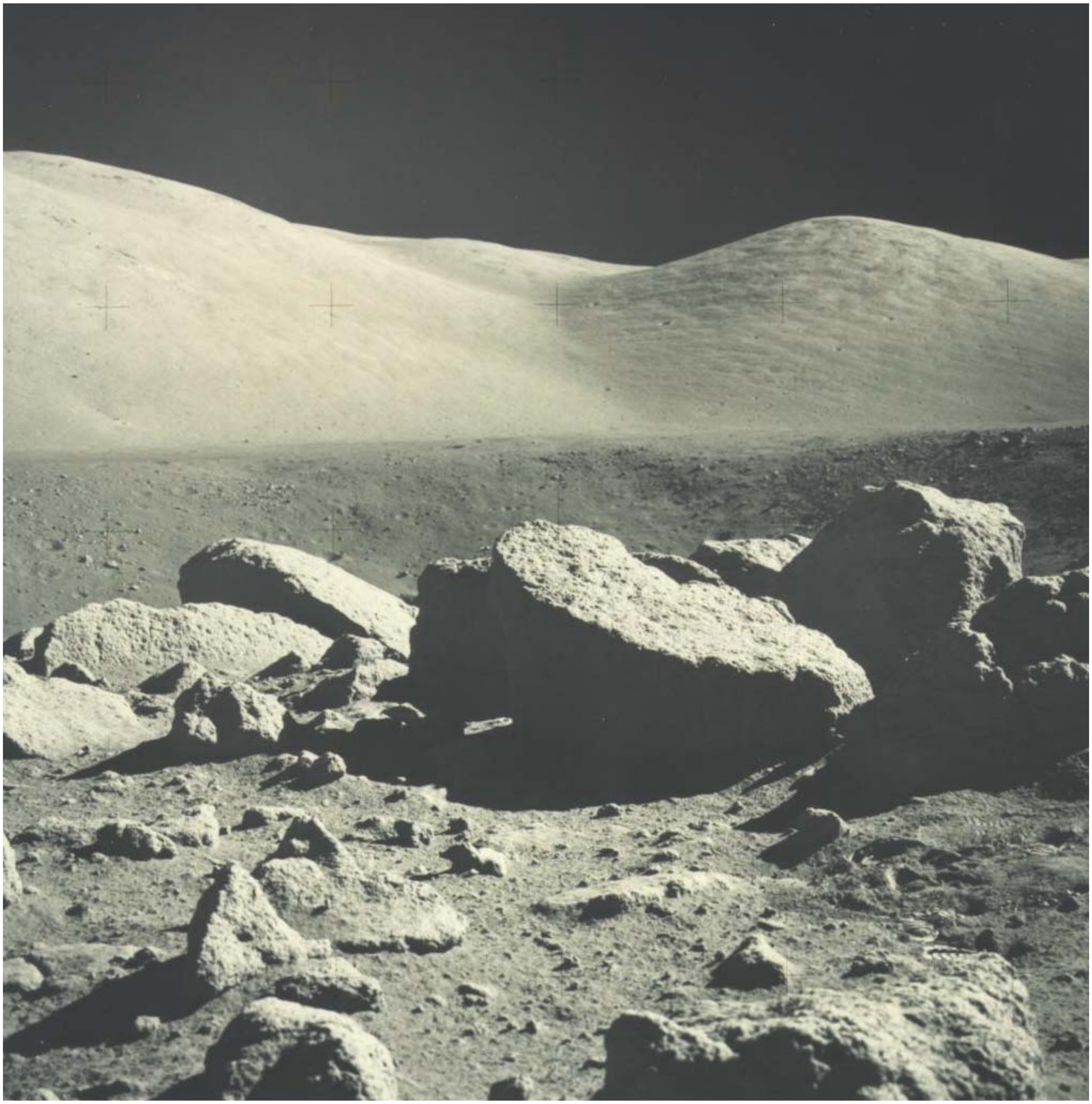


Figure 1: Basalt outcrop on rim of Camelot Crater, Taurus-Littrow. AS17-145-22159.

05 23 42+ Arrive station 5

CDR Talk about a block field!

LMP I think my guess of 30 percent was reasonably good before.

LMP This looks just like our old friend, the pyroxene gabbro with the shiney ilmenite platelets in the vugs and partially recrystallized vesicles. The texture variations are planer, and they're primarily – subplaner in the concentrations of vesicles.

LMP Boy this is certainly a subfloor, as we mapped it. It's cerainly a uniform rock type. I'll tell you. The only variation – is those grey zones which just seem to be either finer or the absence of vesicles.

Figure 2: Closeup of vesicular basalt outcrop at Camelot Crater - location of 75015, 75035, 75055 and 75075. NASA S17-133-20333.

LMP Here I am in the middle of a boulder field. The texture appears to be subophitic to – sort of like a diabase, although a little coarser. But it's unquestionably organized with that variation in vesicle concentration. I have the impression that these blocks are buried up here. That the mantle does exist, even on Camelot. There are a few blocks that look like they're lying more or less on the surface, you can attribute those to craters that have disrupted the block field. The big ones seem to be projecting out of the mantle.

CC Do you see any such mantle - - on top of them.

LMP No, I don't. What's there seems to be what could have been knocked up there. But I don't have the impression of draping, so much as I have just burial. And I have a feeling that the zap-pitting process just has cleaned these boulders off – of anything that may have been on top of them, in excess of what's around them, right now.

\- - -

LMP That looks like our old friend, the gabbro, all right. 75015 is Gene's fairly freshly fractured rock.

CDR Here's another right here. 75035 is another of the same variety. Wish we'd started on that structured rock because we're going to run out of time. Let's go over there and get a least one off of it.

CDR What did you have picked out?

LMP This in here with the layering in it.

LMP How about this chunk down there, Gene?

CDR I don't think that'll come off very easy.

CDR ***By golly, your geology training did come in handy. You learned where to hit rocks*** (75055).

CDR These rocks here have a much greater density of the white mineral in them, or crystals, that I've ever seen before, Jack. Where did we see these kind before?

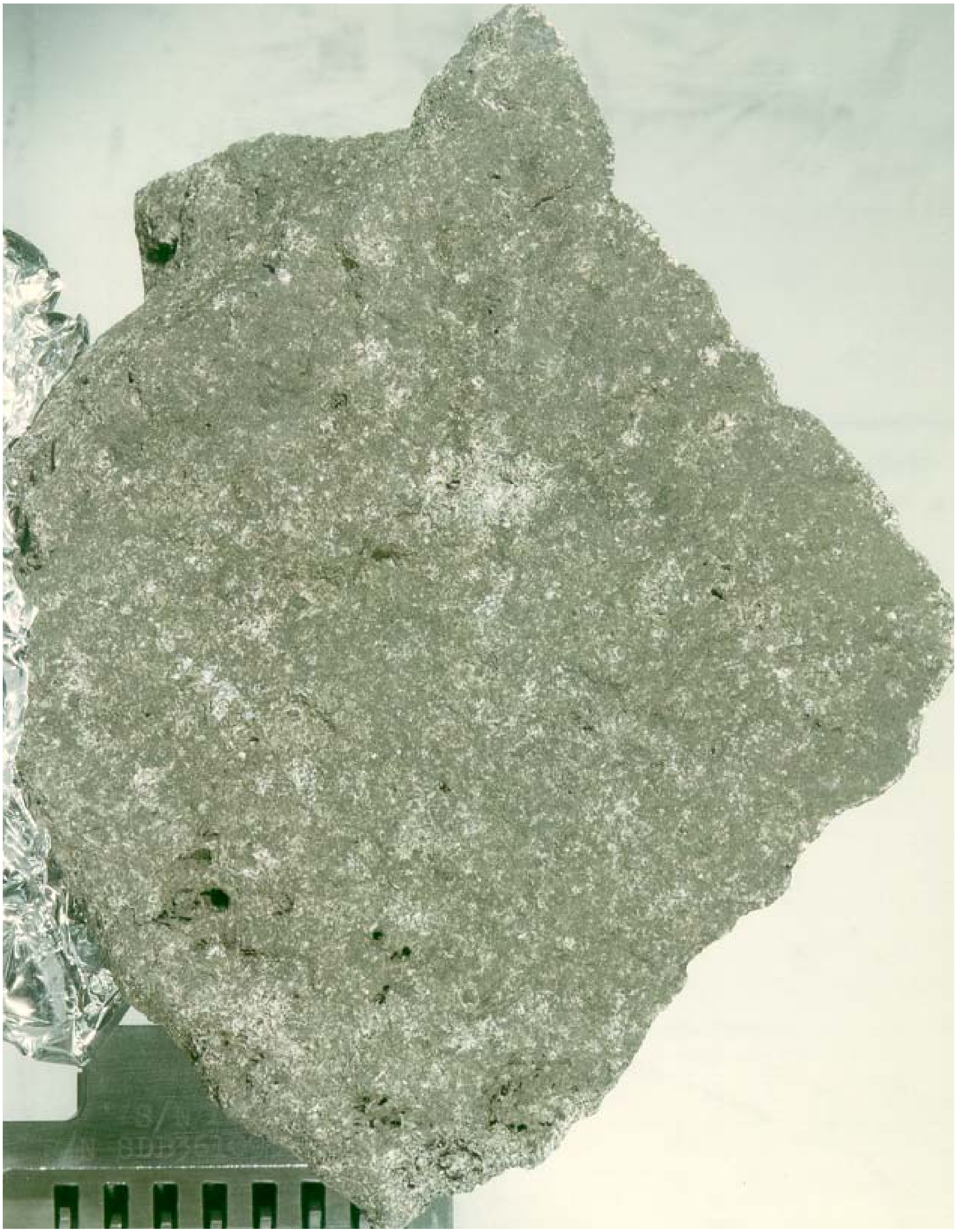


Figure 3: Photo of top, pitted side of 75035 showing micrometeorite pits. NASA S73-16257. Sample is 16 cm long.

LMP Well, when I looked at it first, that's what I thought – but I think that the zap pits are making the white stand out more. They're fooling you a little bit. Because with what I looked at it with the hand lense, it looked like a fairly normal gabbro – like some of these that have crystallized with the mare basalt.

CDR Wher are you?

LMP I'm back over here. What I want is sample of this soil off one of these rocks. But it looks to me like it's soil

Figure 4: Location and orientation of 75035 at rim of Camelot Crater, Apollo 17. NASA AS17-145-22138

that's been thrown up there rather than – this rock is about 3 meters in diameter but it only stands about – at the most – one-third of a meter high. But we can get up about a meter from the soil/rock interface and get some soil off the rock, I think (75060-5). It's about a centimeter deep and a half meter in.

CDR Let's take that chip there that's lying on top with the next scoop. That's the soil from the top of the rock. And we're taking piece of the rock itself, which looks pretty much like the other one. It might be a little bit more vesicular (75075).

LMP Let me get over here and try to get one bag of soil that's away from the boulder.

CC We'd just like to get the kilogram of soil somewhere in between the boulders – as open as you can.

LMP Let's do it right here.

CDR This will be a matched pair with our soil sample too.

CDR I'm sampling down to about 5 centimeters (75080-5).

Figure 5: *Texture of 75035 showing plagioclase laths enclosed in pyroxene with ilmenite needles (taken from Neal and Taylor 1993). Scale 2.5 mm.*

ntroduction

Lunar sample 75035 was collected from a small boulder on the rim of Camelot Crater (figure 4) and is presumed to represent a portion of a lava flow, deep beneath the regolith (Wolfe et al. 1981). This sample, along with 75015 and 75055 from the same location, is slightly more aluminous and less titanium rich, than other Apollo 17 basalts (Rhodes et al. 1976), and is surprisingly similar to some of the Apollo 11 basalts. It has the highest sulfur content (0.3 %) of any lunar sample.

The flat side of 75035 is pitted with micrometeorite craters and also shows about 2-3 % vugs or vesicles (figure). Zap pit are also found on the S, E and W sides. Surface photography allowed accurate orientation.

75035 has been dated at 3.76 b.y. with an ~80 m.y. exposure to cosmic rays.

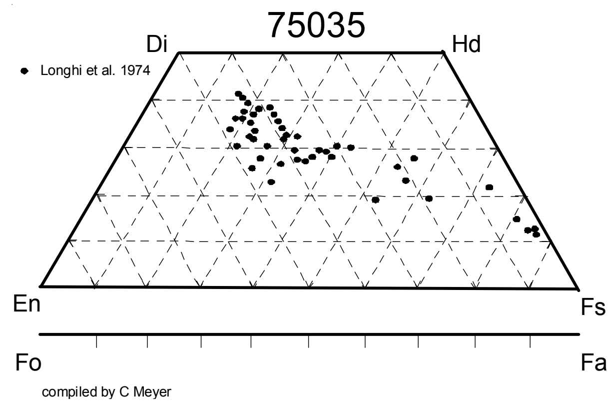


Figure 6: Pyroxene composition of 75035 (from Longhi et al. 1974).

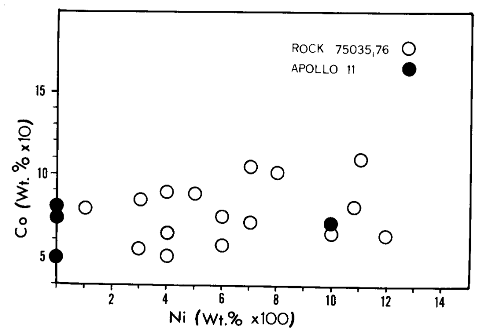


Figure 7: Ni and Co content of native iron in 75035 compared with Apollo 11 (this is figure 2 in Meyer and Boctor 1974).

Petrography

Longhi et al. (1974) found that 75035 was texturally and chemically like some of the Apollo 11 basalts (see also 75055). It is a medium-grained subophitic high-Ti basalt texturally similar to the Apollo 11 ophitic basalts (figure 2). Suhedral laths of plagioclase are surrounded by clumps of anhedral pyroxene. Large laths of ilmenite penetrate the plagioclase and pyroxene, providing evidence that ilmenite was the first phase to crystallize from the melt.

Mineralogical Mode of 75035

	Longhi et. al. 1974	Brown et al. 1975	Meyer and Boctor 1974
Olivine			
Pyroxene	44	45.4	45
Plagioclase	33	32.7	31
Ilmenite	15	13.8	17
Silica	5	6.2	5
Pyroxferroite	2		
Mesostasis	1	1.9	2

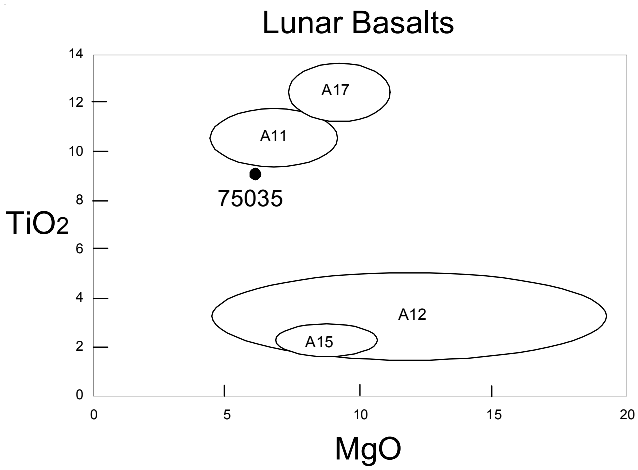


Figure 8: Composition of 75035 compared with other lunar basalts.

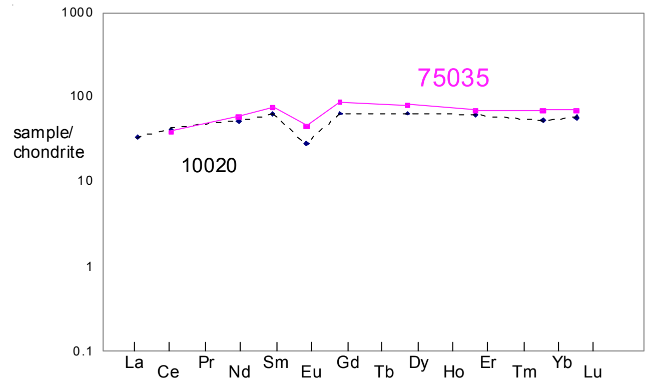


Figure 9: Normalized rare-earth-element diagram comparing 75035 with that of a typical Apollo 11 basalt (both determined by isotope dilution mass spectrometry Wiesmann et al 1975 and Philpotts et al. 1974).

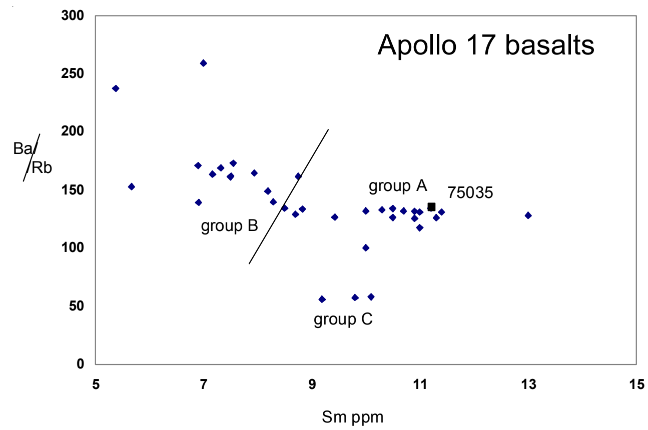


Figure 10: Composition of Apollo 17 basalts with 75035.

Meyer and Boctor (1974) studied the minor phase in 75035 and Roedder and Weiblen (1975) studied melt inclusions in ilmenite from 75035. Metallic iron appears to have crystallized from the melt as a minor phase throughout the crystallization sequence.

Shih et al. (1975) and Rhodes et al. (1976) discuss the origin and differentiation of Apollo 17 basalts. 75035 appears to be the result of low pressure mineral separation and elemental fractionation of a more mafic parental magma.

Mineralogy

Pyroxene: Pyroxene crystals in 75035 are highly zoned. The composition of early formed pyroxene ($Wo_{40}En_{43}Fs_{15}$) varies continuously to pyroxferroite (figure 6). Some pyroxene crystals are sector-zoned. Jagodzinski et al. (1975) reported pigeonite exsolution from the augite cores.

Plagioclase: Plagioclase (An_{88-72}) grains up to 1.5 mm show iron enrichment during crystallization (Longhi et al. 1974).

Ilmenite: Ilmenite laths as big as plagioclase are abundant in 75035 (Meyer and Boctor 1974).

Cristoballite: 75035 has about 5% silica as a residual phase in the interstitcies.

Metallic Iron: Meyer and Boctor (1974) found that metallic iron was associated with several accessory phases, and reported Ni and Co contents (figure 7). Iron grains were often associated with ulvospinel. Taylor and Williams (1974) reported ~1 % Co, but no Ni in iron grains.

Troilite: Meyer and Boctor (1974) determined the Ti content of troilite (but this is likely secondary flourescence)!

Tranquillityite: Careful analysis reported in Meyer and Boctor (1974) (Table 2).

Baddeleyite: Careful analysis reported in Meyer and Boctor (1974).

Zirconolite: Careful analysis reported in Meyer and Boctor (1974).

Chemistry

Papike et al. (1976) termed 75035 and 75055 as low-K Apollo 17 basalts. Note that these samples also have

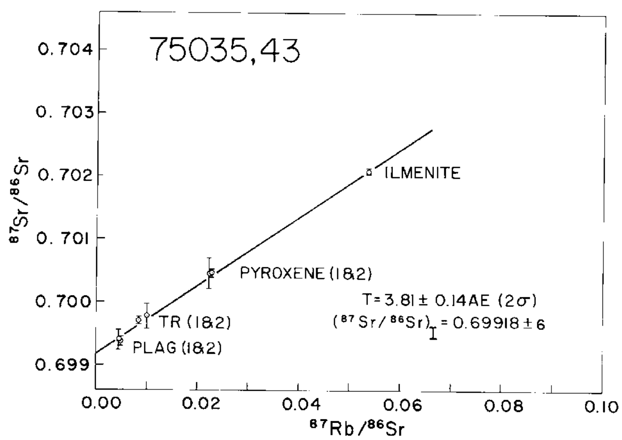


Figure 11: Rb/Sr mineral isochron for 75035 (from Murthy and Coscio 1976).

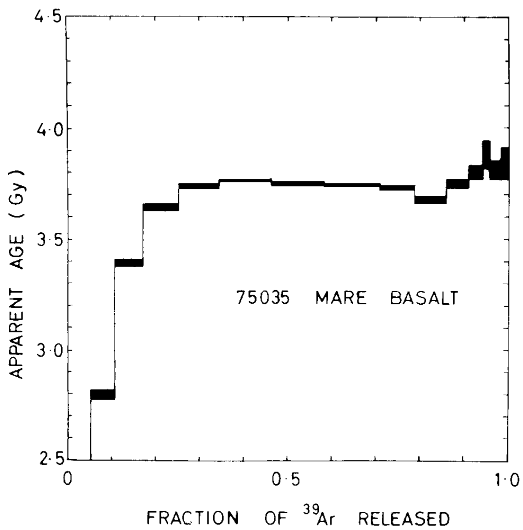


Figure 12: Argon release plateau for 75035 (from Turner and Cadogen 1974).

lower Ti content and are nearly identical in composition to Apollo 11 basalts (figures 8 and 9). Analyses include those by Laul et al. (1974), Wanke et al. (1975), Brunfeldt et al. (1974), Rose et al. (1975) and Duncan et al. (1976)(table 1). Paces et al. (1991) classify 75035 as a type A, Apollo 17 basalt (figure 10).

Summary of Age Data for 75035

	Pb/Pb	Rb/Sr	Ar/Ar
Nunes et al. 1974	3.56 ± 0.4 b.y.		
Murthy and Coscio 1976		3.81 ± 0.14	
Turner and Cadogen 1974			3.76 ± 0.05

Caution: Be cautious of old decay constants.

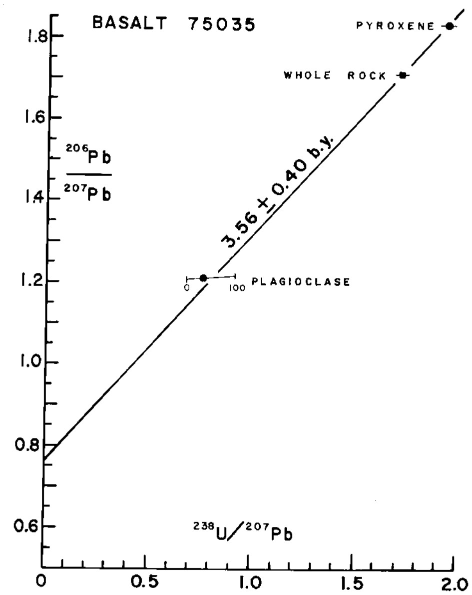


Figure 13: Pb/Pb age for 75035 (from Nunes et al. 1974).

Moore et al. (1974), Petrowski et al. (1974), Gibson and Moore (1974), Gibson et al. (1975), Moore (1975), Moore and Lewis (1976), Des Marias (1978) and Gibson et al. (1976) reported carbon, sulfur and nitrogen abundances. The sulfur content of 75035 (2770 ppm) is the highest recorded for any lunar sample (Gibson et al. 1976). Merlivat et al. (1974) determined the water content and isotopic ratio of hydrogen.

Radiogenic age dating

Murthy and Coscio (1976), Nunes et al. (1974), Turner et al. (1973) and Turner and Cadogen (1974) have each dated 75035 (figure 11-13). With an age of about 3.8 b.y., it is apparently one of the oldest mare basalts – nearly as old as the Serenitatis Basin.

Tera and Wasserburg (1974) discuss the U/Pb age of 75035 and 75055 – giving an intercept age age of 4.42 b.y. (age of source region ?).

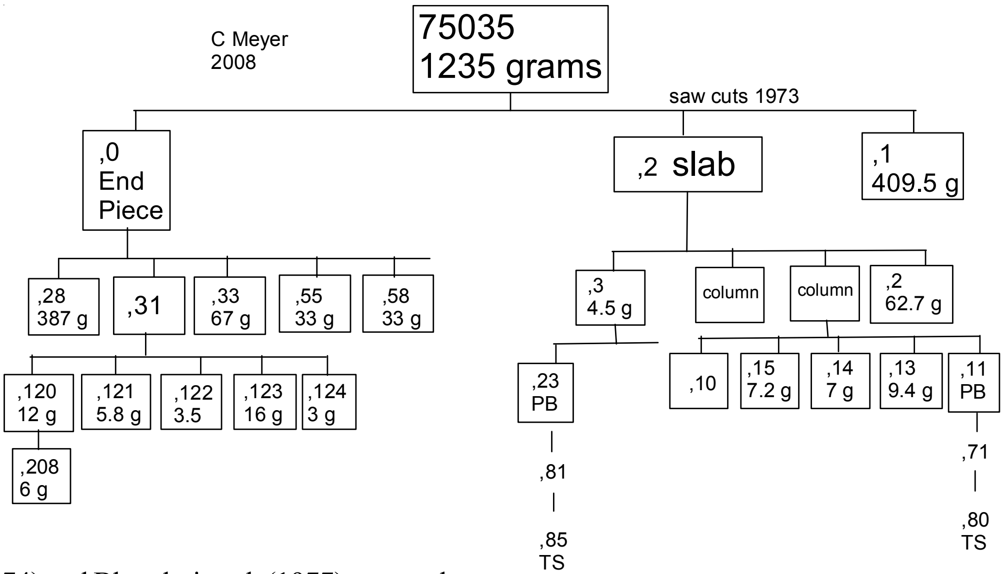
Cosmogenic isotopes and exposure ages

Turner and Cadogen (1974) reported a cosmic ray exposure age of 80 m.y. determined by ^{38}Ar. Crozaz et al. (1974) and Arvidson et al. (1976) reported a cosmic ray exposure age of 75035 of 72 ± 2 m.y. by the ^{81}Kr method. Marti et al. (quoted by Bhandari et al. 1977) determined 89 ± 3 m.y. by ^{81}Kr. This gives the apparent age of Camelot Crater.

Table 1. Chemical composition of 75035.

reference	Laul 74	Brunfelt74		Rose75		Wanke75		Duncan76		Murthy76		Philpotts74		Garg78			Morgan74	
weight	286 mg																	
SiO2 %				42.61	(c)			42.31	(d)									
TiO2	9	9.2	(a)	9.59	(c)	9.98	(a)	8.95	(d)									
Al2O3	9.9	9.7	(a)	10.05	(c)	9.24		10.3	(d)									
FeO	18.8	18.4	(a)	18.08	(c)	19.22		18.57	(d)					17.62		(a)		
MnO	0.236	0.25	(a)	0.27	(c)	0.269		0.262	(d)									
MgO	7	6.8	(a)	6.25	(c)	6.13		6.28	(d)									
CaO	11.3	10.6	(a)	12.53	(c)	11.69		12.15	(d)									
Na2O	0.42	0.404	(a)	0.39	(c)	0.46		0.53	(d)									
K2O	0.074	0.069	(a)	0.08	(c)	0.084		0.061	(d)	0.073	(b)	0.066	(b)					
P2O5				0.06	(c)	0.09		0.084	(d)									
S %						0.14		0.219	(d)									
sum																		
Sc ppm	76	82	(a)	74	(c)	83.6								79.3		(a)		
V	30	30	(a)	16	(c)													
Cr	1512	1070	(a)	1780	(c)	1608	(c)	1416	(d)					1380		(a)		
Co	16	13.7	(a)	18	(c)	14.5	(c)	19	(d)					16.6		(a)		
Ni		<10	(a)	11	(c)		(c)	13	(d)								1	(c)
Cu		3.8	(a)	32	(c)	3.34	(c)											
Zn		2	(a)	4.6	(c)	2.1	(c)										2.3	(c)
Ga		4.5	(a)	6.2	(c)	3.95	(c)											
Ge ppb						<20	(c)										1.27	(c)
As						1	(c)											
Se						<0.08	(c)										156	(c)
Rb		0.6	(a)			0.81	(c)	1.5	(d)	0.655	(b)	0.679	(b)				0.79	(c)
Sr		195	(a)	186	(c)	209	(c)	223	(d)	189.5	(b)	192	(b)					
Y				104	(c)	105	(c)	118	(d)									
Zr				255	(c)	300	(c)	319	(d)					437	336	(a)		
Nb						24	(c)	29	(d)									
Mo																		
Ru																		
Rh																		
Pd ppb																		
Ag ppb																	0.62	(c)
Cd ppb																	1.1	(c)
In ppb																		
Sn ppb																		
Sb ppb																	0.04	(c)
Te ppb																	1.5	(c)
Cs ppm		0.04	(a)			0.026											0.029	(c)
Ba	95	81	(a)	224	(c)	102		126	(d)	86.5	(b)	92.9	(b)					
La	7.3	7.6	(a)			9.07												
Ce	27	20.4	(a)			35						23.6	(b)					
Pr						6.5												
Nd	30		(a)			36.5						27.3	(b)					
Sm	10.8	12.9	(a)			13.6						11.2	(b)					
Eu	2.2	2.25	(a)			2.6						2.52	(b)	2.02		(a)		
Gd						19.8						17.1	(b)					
Tb	3.1	2.81	(a)			3.8								1.5		(a)		
Dy	20	22.9	(a)			24						19.7	(b)					
Ho						4.8												
Er						15						11.1	(b)					
Tm																		
Yb	10	10.7	(a)	10	(c)	13.2						11.4	(b)					
Lu	1.5	1.82	(a)			1.88						1.7	(b)					
Hf	8.7	10	(a)			11.2								13.6	11.4	(a)		
Ta	1.6	1.81	(a)			2.01												
W ppb		0.12	(a)			0.085												
Re ppb						<0.2	(c)										0.001	(c)
Os ppb																		
Ir ppb																	0.001	(c)
Pt ppb																		
Au ppb						0.033	(c)										0.008	(c)
Th ppm	0.3	0.35	(a)															
U ppm		0.113	(a)			0.149											0.153	(c)

technique: (a) INAA, (b) IDMS, (c) mixed, (d) XRF, (c) RNAA



Crozaz et al. (1974) and Bhandari et al. (1977) reported a track ages of 7.3 m.y. and 5.4 m.y. respectively. These are understood to be low because of the constant erosion of the rock surface by micrometeorite bombardment. Based on their study of the incidence angle of fossil cosmic ray tracks in plagioclase, Kratschmer and Genter (1976), determined that 75035 probably had a "complex burial history".

Yokoyama et al. (1974) determined that the surface of 75035 was "saturated" in ^{26}Al = 107 dpm/kg. (^{22}Na = 170 dpm/kg.)

Other Studies

The results obtained on 75035 are reviewed in the catalog by Neal and Taylor (1993).

Crozaz et al. (1974) determined the isotopic ratios of Xe and Kr.

Lugmair and Marti (1978) presented Sm and Nd isotope data in a diagram.

Turner and Cadogen (1974) used 75035 to evaluate the role of Ar recoil effects that might effect age dating plagioclase. Schaeffer et al. (1977) used 75035 to try to understand how a laser probe might be used to date an igneous rock of known age (they obtained a range of ages). Schaeffer et al. showed that Ar recoil effects are often confused with diffusion loss of Ar from high K phases. Note: Horn et al. (1975) used 75075 to investigate the effects of recoil on Ar/Ar ages.

Pearce et al. (1974), Brecher (1977) and Sigiura et al. (1979) determined the magnetic properties of 75035.

Longhi et al. (1974) and O'Hara and Humphries (1975) determined the low pressure phase diagram for Apollo 17 basalts, including 75035. Taylor and Williams (1974) and Usselman et al. (1975) determined the cooling rate of the sample. McCallum and Charette (1977, 1978) determined the crystal/liquid distriburtion coefficients of Zr and Nb for ilmenite, armalcolite and

Table 3: Analysis of tranquillityite.

SiO2	13.9	14.7	13.3
Al2O3	1.02	1.22	0.89
TiO2	21.2	20.5	20.7
FeO	42.4	40.9	41.1
MnO	0.09	0.35	0.04
MgO	0.35	0.02	0.17
CaO	1.06	0.94	0.82
ZrO2	16.2	18.5	17
Y2O3	3.01	2.69	3.56
HfO2	0.25	0.25	0.17
Nb2O5	0.68	0.82	0.59
total	100.16	100.89	98.34

(from Meyer and Boctor 1974)

Table 2	U ppm	Th ppm	K ppm	Rb ppm	Sr ppm	Nd ppm	Sm ppm	technique
Murthy and Coscio 1976			604	0.655	189.3			idms
Yokoyama et al. 1974 (top)	0.22	0.65						counting
Nunes et al. 1974	0.151	0.4879						idms
Brunfelt et al. 1974	0.113	0.35		0.6	195			inaa
Philpotts et al. 1974				0.679	192	27.3	11.2	idms
Wanke et al. 19754	0.149				36.5	13.6		inaa

Figure 14: Group photo of end pieces and sawn slab of 75035. NASA S73-31796. Small cube is 1 cm.

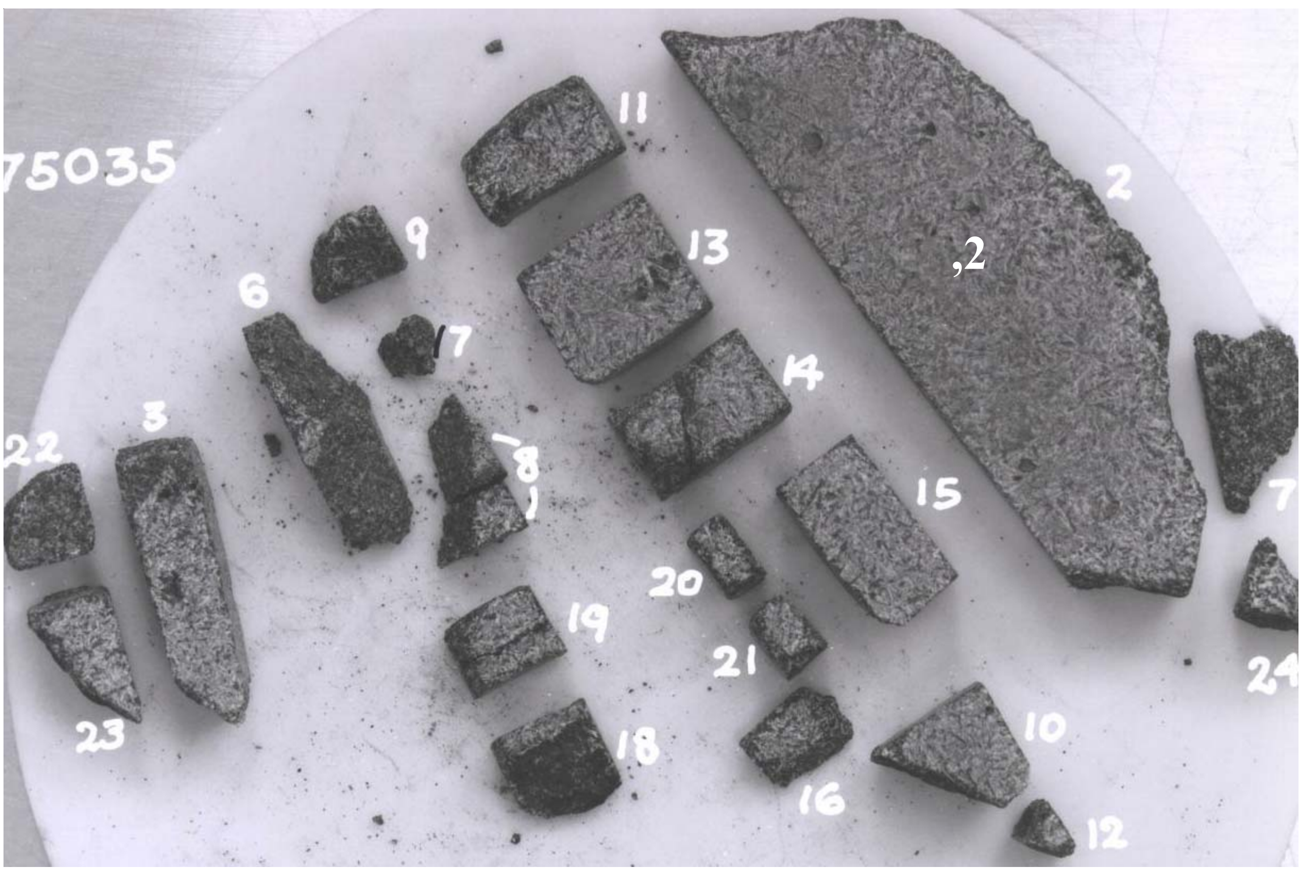


Figure 15: Geneology of slab cut from 75035. ,19 is 1 cm x 0.9 cm. NASA S71-73-31797.

clinopyroxene. Longhi et al. (1978) experimentally studied the Fe/Mg partitioning between olivine and melt using 75035 (*although the rock itself has no olivine*).

Schaal and Horz (1977), Schaal et al. (1979) and Harrison and Horz (1981) reported studies of shock metamorphism of a basalt using samples of 75035 as starting material.

Figure 16: Closeup photo of some surface pieces derived from 75035,31. S76-20728. Scale is cm.

Petrowski et al. (1974) and Gibson et al. (1975) determined the isotopic composition of carbon and sulfur in 75035.

Processing

In 1973, 75035 was sawn to create a slab (figures 14 and 15). However, the orientation of the columns cut from this slab do not appear to be normal to the lunar surface orientation (beware!).

75035 is used for public display, including a small piece for the Astronaut Ambassador Program.

References for 75035

Arvidson R., Drozd R., Guiness E., Hohenberg C., Morgan C., Morrison R. and Oberbeck V. (1976) Cosmic ray exposure ages of Apollo 17 samples and the age of Tycho. Proc. 7th Lunar Sci. Conf. 2817-2832.

Bhandari N. (1977a) Solar flare exposure ages of lunar rocks and boulders based on ^{26}A1. Proc. 8th Lunar Sci. Conf. 3607-3615.

Bhandari N. (1977b) Solar flare induced A1-26 in short exposure age rocks (abs). Lunar Sci. VIII, 100-102. Lunar Planetary Institute, Houston. ‘

Brecher A. (1977a) Interrelationships between magnetization directions, magnetic fabric and oriented petrographic features in lunar rocks. Proc. 8th Lunar Sci. Conf. 703-723.

Brown G.M., Peckett A., Emeleus C.H., Phillips R. and Pinsent R.H. (1975a) Petrology and mineralogy of Apollo 17 mare basalts. Proc. 6th Lunar Sci. Conf. 1-13.

Brown G.M., Peckett A., Phillips R. and Emeleus C.H. (1975b) Mineralogy and petrology of Apollo 17 basalts (abs). Lunar Sci. VI, 95-97. Lunar Planetary Institute, Houston.

Brunfelt A.O., Heier K.S., Nilssen B., Steinnes E. and Sundvoll B. (1974) Elemental composition of Apollo 17 fines and rocks. Proc. 5th Lunar Sci. Conf. 981-990.

Butler P. (1973) **Lunar Sample Information Catalog Apollo 17.** Lunar Receiving Laboratory. MSC 03211 Curator’s Catalog. pp. 447.

Crozaz G., Drozd R., Hohenberg C., Morgan C., Ralston C., Walker R. and Yuhas D. (1974a) Lunar surface dynamics: Some general conclusions and new results from Apollo 16 and 17. Proc. 5th Lunar Sci. Conf. 2475-2499.

Des Marais D.J. (1978a) Carbon, nitrogen and sulfur in Apollo 15, 16 and 17 rocks. Proc. 9th Lunar Planet. Sci. Conf. 2451-2467.

Des Marais D.J. (1978b) Carbon isotopes, nitrogen and sulfur in lunar rocks (abs). Lunar Planet. Sci. IX, 247-249.

Duncan A.R., Erlank A.J., Sher M.K., Abraham Y.C., Willis J.P. and Ahrens L.H. (1976a) Some trace element constraints on lunar basalt genesis. Proc. 7th Lunar Sci. Conf. 1659-1671.

Garg A.N. and Ehmann W.N. (1976a) Zr-Hf fractionation in chemically defined lunar rock groups. Proc. 7th Lunar Sci. Conf. 3397-3410.

Gibson E.K. and Moore G.W. (1974a) Sulfur abundances and distributions in the valley of Taurus-Littrow. Proc. 5th Lunar Sci. Conf. 1823-1837.

Gibson E.K. and Moore G.W. (1974b) Total sulfur abundances and distributions in the valley of Taurus-Littrow: Evidence of mixing (abs). Lunar Sci. V, 267-269. Lunar Planetary Institute, Houston

Gibson E.K., Chang S., Lennon K., Moore G.W. and Pearce G.W. (1975a) Sulfur abundances and distributions in mare basalts and their source magmas. Proc. 6th Lunar Sci. Conf. 1287-1301.

Gibson E.K., Chang S., Lennon K., Moore G.W. and Pearce G.W. (1975b) Carbon, sulfur, hydrogen and metallic iron abundances in Apollo 15 and Apollo 17 basalts (abs). Lunar Sci. VI, 290-292. Lunar Planetary Institute, Houston

Gibson E.K., Usselman T.M. and Morris R.V. (1976a) Sulfur in the Apollo 17 basalts and their source regions. Proc. 7th Lunar Sci. Conf. 1491-1505.

Green D.H., Ringwood A.E., Ware N.G. and Hibberson W.O. (1974) Petrology and petrogenesis of Apollo 17 basalts and Apollo 17 orange glass (abs). Lunar Sci. V, 287-289. Lunar Planetary Institute, Houston

Green D.H., Ringwood A.E., Hibberson W.O. and Ware N.G. (1975a) Experimental petrology of Apollo 17 mare basalts. Proc. 6th Lunar Sci. Conf. 871-893.

Green D.H., Ringwood A.E., Ware N.G. and Hibberson W.O. (1975b) Experimental petrology and petrogenesis of Apollo 17 mare basalts (abs). Lunar Sci. VI, 311-313. Lunar Planetary Institute, Houston

Harrison W.J. and Horz F. (1981) Experimental shock metamorphism of calcic plagioclase (abs). Lunar Planet. Sci. XII, 395-397.

Jagodzinski H., Korekawa M., Muller W.F. and Schropfer L. (1975a) X-ray diffraction and electron microscope studies of clinopyroxenes from lunar basalts 75035 and 75075. Proc. 6th Lunar Sci. Conf. 773-778.

Jagodzinski H., Korekawa M., Muller W.F. and Schropfer L. (1975b) X-ray study of clinopyroxenes of lunar basalts 75035 and 75075 (abs). Lunar Sci. VI, 432-434. Lunar Planetary Institute, Houston

Kirsten T., Horn P. and Heymann D. (1973b) Chronology of the Taurus-Littrow region. 1 Ages of two major rock types from the Apollo 17 site. Earth Planet. Sci. Lett. 20, 125-130.

Kirsten T., Horn P., Heymann D., Hubner W. and Storzer D. (1973c) Apollo 17 crystalline rocks and soils: Rare gases, ion tracks, and ages (abs). EOS 54, 595-597. AGU

Kirsten T. and Horn P. (1974a) Chronology of the Taurus-Littrow region III: ages of mare basalts and highland breccias and some remarks about the interpretation of lunar highland rock ages. Proc. 5th Lunar Sci. Conf. 1451-1475.

Kratschmer W. and Gentner W. (1976) The long-term average of the galactic cosmic-ray iron group composition studied by the track method. Proc. 7th Lunar Sci. Conf. 501-511.

Laul J.C., Hill D.W. and Schmitt R.A. (1974d) Chemical studies of Apollo 16 and 17 samples. Proc. 5th Lunar Sci. Conf. 1047-1066.

Longhi J., Walker D., Grove T.L., Stolper E.M. and Hays J.F. (1974) The petrology of the Apollo 17 mare basalts. Proc. 5th Lunar Sci. Conf. 447-469.

LSPET (1973) Apollo 17 lunar samples: Chemical and petrographic description. Science 182, 659-672.

LSPET (1973) Preliminary Examination of lunar samples. Apollo 17 Preliminary Science Rpt. NASA SP-330. 7-1 – 7-46.

McCallum I.S. and Charette M.P. (1977) Partitioning of Zr between crystals and coexisting high-TI mare basalt melt (abs). Lunar Sci. VIII, 637-639. Lunar Planetary Institute, Houston

McCallum I.S. and Charette M.P. (1978) Zr and Nb distribution coefficients: Further constraints on the genesis of high-Ti mare basalts and KREEP (abs). Lunar Planet. Sci. IX, 711-713. Lunar Planetary Institute, Houston.

Meyer H.O.A. and Boctor N.Z. (1974a) Opaque mineralogy: Apollo 17, rock 75035. Proc. 5th Lunar Sci. Conf. 707-716.

Meyer H.O.A. and Boctor N.Z. (1974b) Opaque minerals in basaltic rock 75035 (abs). Lunar Sci. V, 512-514. Lunar Planetary Institute, Houston.

Merlivat L., Lelu M., Nief G. and Roth E. (1974a) Deuterium, hydrogen, and water content of lunar material. Proc. 5th Lunar Sci. Conf. 1885-1895.

Moore C.B., Lewis C.F. and Cripe J.D. (1974a) Total carbon and sulfur contents of Apollo 17 lunar samples. Proc. 5th Lunar Sci. Conf. 1897-1906.

Moore C.B., Lewis C.F., Cripe J.D. and Volk M. (1974b) Total carbon and sulfur contents of Apollo 17 lunar samples (abs). Lunar Sci. V, 520-522. Lunar Planetary Institute, Houston.

Moore C.B. and Lewis C.F. (1976) Total nitrogen contents of Apollo 15, 16 and 17 lunar rocks and breccias (abs). Lunar Sci. VII, 571-573. Lunar Planetary Institute, Houston.

Morgan J.W., Ganapathy R., Higuchi H., Krahenbuhl U. and Anders E. (1974a) Lunar basins: Tentative characterization of projectiles, from meteoritic dements in Apollo 17 boulders. Proc. 5th Lunar Sci. Conf. 1703-1736.

Muehlberger et al. (1973) Documentation and environment of the Apollo 17 samples: A preliminary report. Astrogeology 71 322 pp superceeded by Astrogeolgy 73 (1975) and by Wolfe et al. (1981)

Muehlberger W.R. and many others (1973) Preliminary Geological Investigation of the Apollo 17 Landing Site. *In* **Apollo 17 Preliminary Science Report.** NASA SP-330.

Murthy V.R. and Coscio C. (1976) Rb-Sr ages and isotopic systematics of some Serenitatis mare basalts. Proc. 7th Lunar Sci. Conf. 1529-1544.

Murthy V.R. and Coscio C. (1977) Rb-Sr isotopic systematics and initial Sr considerations for some lunar samples (abs). Lunar Sci. VIII, 706-708. Lunar Planetary Institute, Houston.

Neal C.R., Taylor L.A., Patchen A.D., Hughes S.S. and Schmitt R.A. (1990a) The significance of fractional crystallization in the petrogenesis of Apollo 17 Type A and B high-Ti basalts. Geochim. Cosmochim. Acta 54, 1817-1833.

Neal C.R. and Taylor L.A. (1993) Catalog of Apollo 17 rocks. Vol. 3 Central Valley

Nunes P.D., Tatsumoto M. and Unruh D.M. (1974b) U-Th-Pb systematics of some Apollo 17 lunar samples and implications for a lunar basin excavation chronology. Proc. 5th Lunar Sci. Conf. 1487-1514.

Nunes P.D., Tasumoto M. and Unruh D.M. (1974c) U-Th-Pb systematics of some Apollo 17 samples (abs). Lunar Sci. V, 562-564. Lunar Planetary Institute, Houston

Nyquist L.E. (1977) Lunar Rb-Sr chronology. Phys. Chem. Earth 10, 103-142.

Paces J.B., Nakai S., Neal C.R., Taylor L.A., Halliday A.N. and Lee D.-C. (1991) A strontium and neodymium isotopic study of Apollo 17 high-Ti mare basalts: Resolution of ages, evolution of magmas, and origin of source heterogeneities. Geochim. Cosmochim. Acta 55, 2025-2043.

Papike J.J., Hodges F.N., Bence A.E., Cameron M. and Rhodes J.M. (1976) Mare basalts: Crystal chemistry, mineralogy and petrology. Rev. Geophys. Space Phys. 14, 475-540.

Philpotts J.A., Schuhmann S., Kouns C.W., Lum R.K.L. and Winzer S. (1974a) Origin of Apollo 17 rocks and soils. Proc. 5th Lunar Sci. Conf. 1255-1267.

Petrowski C., Kerridge J.F. and Kaplan I.R. (1974) Light element geochemistry of the Apollo 17 site. Proc. 5th Lunar Sci. Conf. 1939-1948.

Pearce G.W., Strangway D.W. and Gose W.A. (1974a) Magnetic properties of Apollo samples and implications for regolith formation. Proc. 5th Lunar Sci. Conf. 2815-2826.

Rhodes J.M., Hubbard N.J., Wiesmann H., Rodgers K.V., Brannon J.C. and Bansal B.M. (1976a) Chemistry, classification, and petrogenesis of Apollo 17 mare basalts. Proc. 7th Lunar Sci. Conf. 1467-1489.

Roedder E. and Weiblen P.W. (1975a) Anomalous low-K silicate melt inclusions in ilmenite from Apollo 17 basalts. Proc. 6th Lunar Sci. Conf. 147-164.

Rose H.J., Baedecker P.A., Berman S., Christian R.P., Dwornik E.J., Finkelman R.B. and Schnepfe M.M. (1975a) Chemical composition of rocks and soils returned by the Apollo 15, 16, and 17 missions. Proc. 6th Lunar Sci. Conf. 1363-1373.

Rose H.J., Christian R.P., Dwomik E.J. and Schnepfe M.M. (1975b) Major elemental analysis of some Apollo 15, 16, and 17 samples (abs). Lunar Sci. VI, 686-688. Lunar Planetary Institute, Houston

Schaeffer O.A., Muller H.W. and Grove T.L. (1977a) Laser 39Ar-40Ar study of Apollo 17 basalts. Proc. 8th Lunar Sci. Conf. 1489-1499.

Schaeffer O.A., Muller H.W. and Grove T.L. (1977b) Laser $^{39}Ar^{40}Ar$ study of Apollo 17 basalts (abs). Lunar Planet. Sci.

VIII, 837-839. Lunar Planetary Institute, Houston

Schaal R.B. and Hörz F. (1977a) Shock metamorphism of lunar and terrestrial basalts. Proc. 8th Lunar Sci. Conf. 1697-1729.

Schaal R.B. and Hörz F. (1977b) Shock effects in some lunar basalts (abs). Lunar Planet. Sci. VIII, 832-834. Lunar Planetary Institute, Houston

Schaal R.B., Hörz F., Thompson T.D. and Bauer J.F. (1979a) Shock metamorphism of granulated lunar basalt. Proc. 10th Lunar Planet. Sci. Conf. 2547-2571.

Schaal R.B., Thompson T.D., Hörz F. and Bauer J.F. (1979b) Experimentally shocked lunar basalt: Massive and particulate (abs). Lunar Planet. Sci. X, 1055-1057. Lunar Planetary Institute, Houston

Sugiura N., Strangway D.W. and Pearce G.W. (1978) Heating experiments and paleointensity determinations. Proc. 9th Lunar Planet. Sci. Conf. 3151-3163.

Sugiura N. and Strangway D.W. (1980b) Thellier paleointensity: Studies of lunar samples (abs). Lunar Planet. Sci. XI, 1111-1113. Lunar Planetary Institute, Houston

Tatsumoto M., Nunes P.D., Knight R.J., Hedge C.E. and Unruh D.M. (1973) U-Th-Pb, Rb-Sr, and K measurements of two Apollo 17 samples (abs). EOS 54, 614-615.

Taylor L.A. and Williams K.L. (1974a) Formational history of lunar rocks: applications of experimental geochemistry of the opaque minerals. Proc. 5th Lunar Sci. Conf. 585-596.

Tera F., Papanastassiou D.A. and Wasserburg G.J. (1974a) Isotopic evidence for a terminal lunar cataclysm. Earth Planet. Sci. Lett. 22, 1-21.

Tera F., Papanastassiou D.A. and Wasserburg G.J. (1974b) The lunar time scale and a summary of isotopic evidence for a terminal lunar cataclysm (abs). Lunar Sci. V, 792-794. Lunar Planetary Institute, Houston.

Turner G and Cadogen P.H. (1974) The history of lunar bombardment inferred from 40Ar-39Ar dating of highland rocks. Proc. 6th Lunar Sci. Conf. 1509-1538.

Usselman T.M., Lofgren G.E., Donaldson C.H. and Williams R.J. (1975) Experimentally reproduced textures and mineral chemistries of high-titanium mare basalts. Proc. 6th Lunar Sci. Conf. 997-1020.

Wänke H., Palme H., Baddenhausen H., Dreibus G., Jagoutz E., Kruse H., Palme C., Spettel B., Teschke F. and Thacker R. (1975a) New data on the chemistry of lunar samples: Primary matter in the lunar highlands and the bulk composition of the moon. Proc. 6th Lunar Sci. Conf. 1313-1340.

Wolfe E.W., Bailey N.G., Lucchitta B.K., Muehlberger W.R., Scott D.H., Sutton R.L. and Wilshire H.G. (1981) The geologic investigation of the Taurus-Littrow Valley: Apollo 17 Landing Site. US Geol. Survey Prof. Paper, 1080, pp. 280.