14072

Olivine Basalt

45 grams

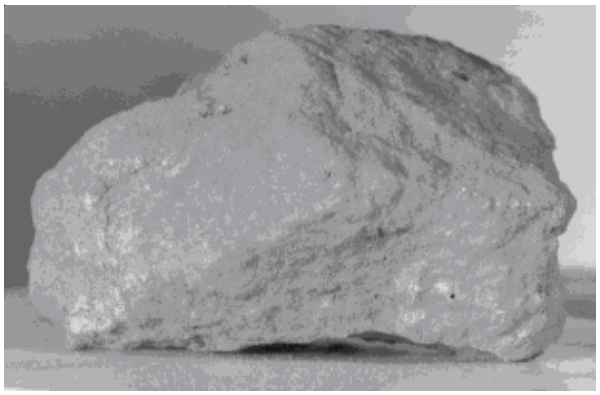


Figure 1: Photo of 14072. NASA S71-22317. Sample is 5 cm across.

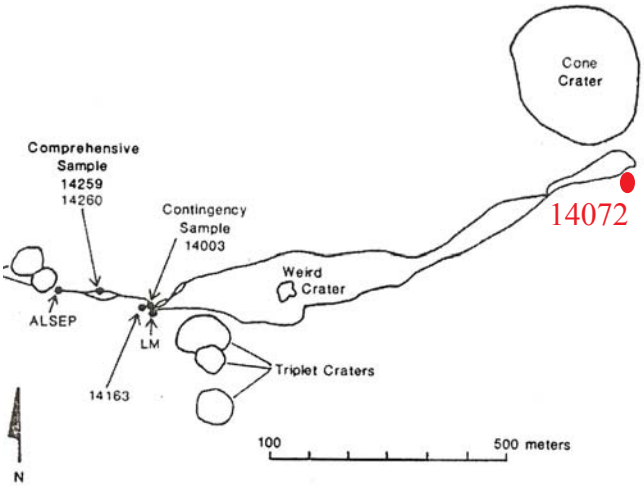


Figure 2: Traverse map for Apollo 14 showing location of 14072 on rim of Cone Crater.

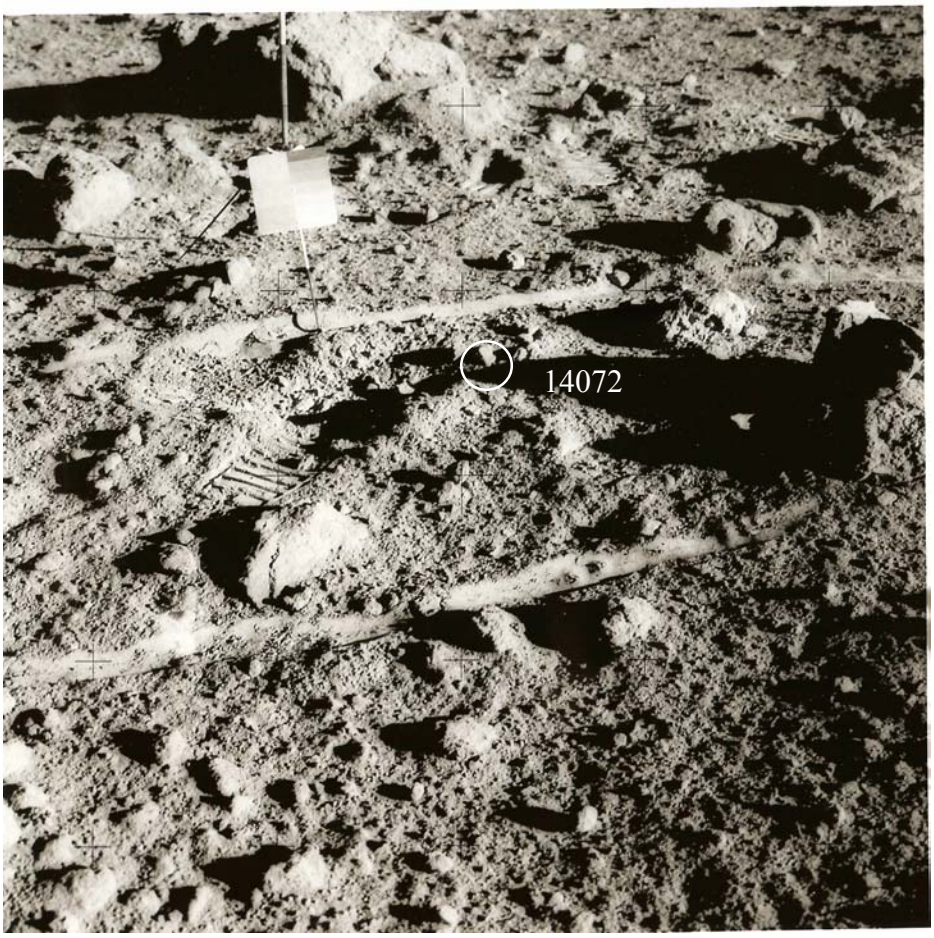


Figure 3: Location of 14072 between tracks left by MET. S71-64-9125.

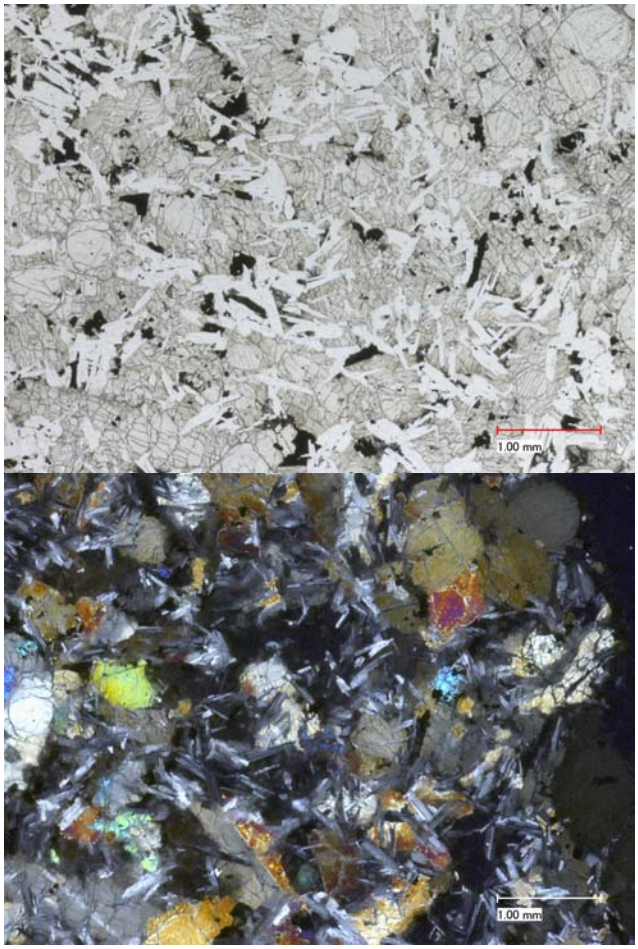


Figure 4: Photomicrographs of thin section 14072,11 by C Meyer @50x.

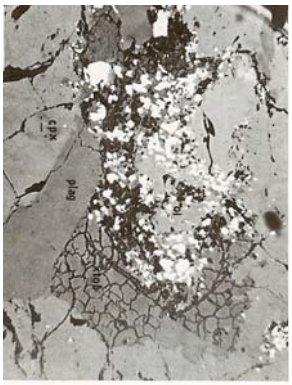


Figure 5: Photo of iron grains in mesostasis, with crystobilite etc (Longhi et al. 1972).

Mineralogical Mode for 14072

	Longhi et al. 1972	McGee et al. 1977
Olivine	2.5 %	2 – 3 %
Pyroxene	50	50
Plagioclase	38.3	38
Ilmenite + Chromite-ulvo.	7.7	8
Cristobalite	1.7	2

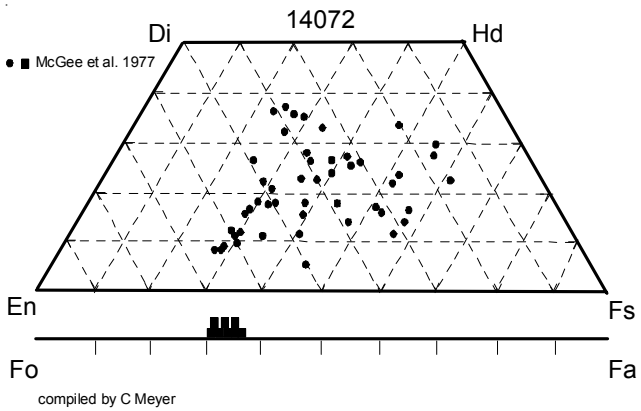


Figure 6: Pyroxene and olivine composition of 14072 (McGee et al. 1977).

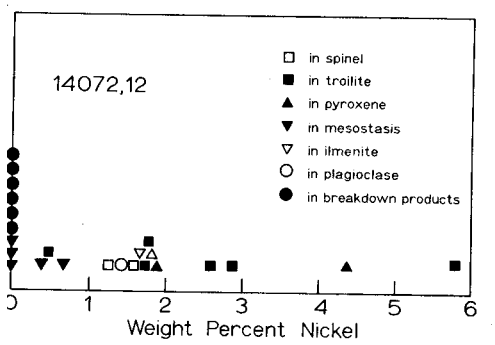


Figure 7: Composition of iron grains in 14072 (El Goresy et al. 1972).

Introduction

Sample 14072 was picked up on the rim of Cone Crater (Swann et al. 1971). It is a mare basalt with an old crystallization age of ~ 4.0 b.y. and an exposure age of 21 m.y. (Cone Crater age). 14072, and its companion 14053, are highly reduced with unique masses of spongy metallic iron in the mesostasis.

Petrography

17072 is a porphyritic basalt with medium-sized olivine phenocrysts, subophitc to ophitic texture and little glass in its residium (Longhi et al. 1972). Olivine appears in 14072 as large, subrounded pheopcrysts (Fo_{75}) up to 2 mm across, as inclusions (Fo_{65}) in large pyroxenes and as part of the late-stage assemblage (Fo_{35}) with cristobalite and spongy network of native iron (figure 5).

El Goresy et al. (1972) studied the opaque mineralogy.

Neal and Kramer (2006) claimed that "14072 is unique when compared with the other Apollo 14 basalts". However, it has some similarity with 14053.

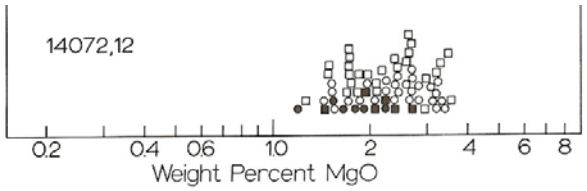


Figure 8: MgO content of ilmenite in 14072 (ELGoresy et al. 1972).

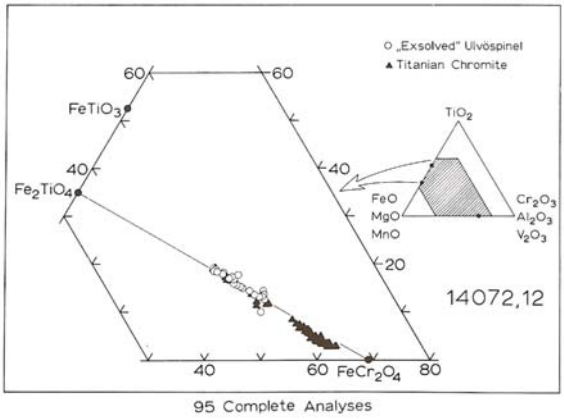


Figure 9: Chromite-ulvospinel composition for 14072 (ElGoresy et al. 1972).

Walker et al. (1972) determined the phase diagram for a melt with the composition of 14072 (figure 13).

Mineralogy

Olivine: Haggerty (1977) carefully studied the various types of olivine in 14072. Olivine phenocrysts are found to have symplectite.

Pyroxene: McGee et al. (1977) determined the pyroxene composition (figure 6).

Metallic iron: Haggerty (1977) found that the metallic iron that is an apparent reduction phenonemen is low in Co, while the initial iron grains included in olivine had high Co content (figure 7).

Ilmenite: von Engelhardt (1979) noticed that ilmenite in 14072 was similar to that in 14053 – a mare basalt. ElGoresy et al. (1972) determined that it had 2 % MgO (figure 8). Haggerty (1977) also reported on ilmenite.

Chromite-Ulvospinel: Haggerty (1977) and ElGoresy et al. (1972) studied the "breakdown" and exsolution in ulvospinel (figure 9).

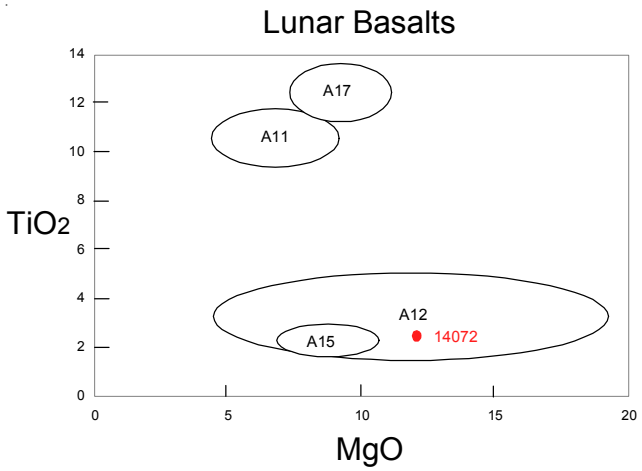


Figure 10: Composition of 14072 compared with other Apollo basalts.

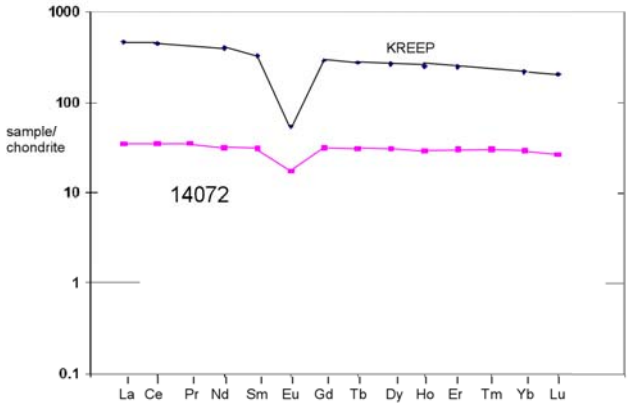


Figure 11: Normalized rare-earth-element diagram for 14072.

Chemistry

Helmke et al. (1972), Taylor et al. (1972), Dickenson et al. (1985, 1989) and Neal (2001) determined the chemical composition of 14072 (figures 10 and 11). Hughes et al. (1973) also reported data for siderophile and volatile element concentrations. Note that their data indicate that 14072 is uncontaminated by meteoritic material (unlike 14310). Warner et al. (1980) noted that the composition of 14072 was somewhat like that of 14053.

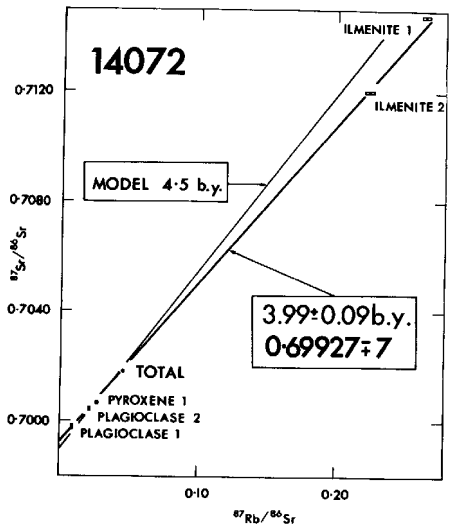
Radiogenic age dating

Compston et al. (1971) determined a Rb/Sr mineral isochron with age of 3.99 ± 0.09 b.y. (figure 12). York et al. (1972) reported an Ar-Ar age of 4.04 ± 0.05 b.y. for 14072.

Table 1. Chemical composition of 14072.

reference	Neal2001	Neal 2006	Hubbard72	Taylor72	Dickinson85	Helmke72	Dickinson89	Longhi72	Hughes73
weight									
SiO2 %			45.2 (c)	45.15 (c)				44.94 (e)	
TiO2			2.57 (c)	2.57 (c)	2.6 (b)			2.56 (e)	
Al2O3			11.1 (c)	11.07 (c)	11.1 (b)			11.31 (e)	
FeO			17.8 (c)	17.82 (c)	17.8 (b)		16.5 17.7 (b)	17.07 (e)	
MnO			12.2 (c)	0.27 (c)	0.27 (b)				
MgO				12.16 (c)	12.2 (b)			12.21 (e)	
CaO			9.84 (c)	9.84 (c)	9.3 (b)		8 8.82 (b)	9.63 (e)	
Na2O			0.32 (c)	0.32 (c)	0.32 (b)		0.32 0.34 (b)	0.38 (e)	
K2O			0.08 (c)	0.08 (c)	0.08 (b)			0.11 (e)	
P2O5			0.08 (c)	0.08 (c)					
S %				0.51 (c)					0.135 (f)
sum									
Sc ppm	57.3	51.6 (d)				47.1 (b)	51 54 (b)		
V	117	104 (d)			(c)				
Cr	3558	2994 (d)	3490 (c)	2500 (c)	2463 (b)	3880 (b)	4200 3800 (b)		
Co	40.8	39.7 (d)				32 (b)	32 37 (b)		
Ni	47.2	52.4 (d)				31 (b)			
Cu	17.2								
Zn	20.1					8 (b)			
Ga	3.13	5.2 (d)				3.8 (b)	37 23 (b)		
Ge ppb							1200 1008 (b)		
As									
Se									120 (f)
Rb	1.53	1.55 (d)		1.5 1.3 (a)					
Sr	83.3	93.4 (d)		110 106 (a)			101 125 (b)		
Y	46.8	41.4 (d)		40 36 (a)					
Zr	141	141 (d)		160 172 (a)	170 (b)				
Nb	13.6	12.9 (d)		9.9 13 (a)					
Mo	0.44	0.16 (d)							
Ru									
Rh									
Pd ppb									
Ag ppb									2.5 (f)
Cd ppb									
In ppb									
Sn ppb				300 (a)					
Sb ppb									
Te ppb									
Cs ppm	0.05	0.12 (d)							
Ba	105	107 (d)		135 120 (a)	127 (b)		211 129 (b)		
La	7.96	7.8 (d)		8.7 8.7 (a)	8.7 (b)	6.76 (b)	8.2 9.1 (b)		
Ce	20.8	20.2 (d)		26 27 (a)	26 (b)	17.9 (b)	22 23 (b)		
Pr	3.1	2.87 (d)		3.4 3.2 (a)					
Nd	14.1	12.9 (d)		13 13 (a)	13 (b)	13 (b)	16 19 (b)		
Sm	4.45	4.21 (d)		4.3 4.4 (a)	4.4 (b)	3.93 (b)	5.1 (b)		
Eu	0.97	0.98 (d)		1.02 0.97 (a)	1 (b)	0.88 (b)	1 1.1 (b)		
Gd	6.12	5.23 (d)		5.3 6.4 (a)		4.2 (b)			
Tb	1.08	1.02 (d)		0.88 0.93 (a)	0.9 (b)	0.98 (b)	1.2 1.3 (b)		
Dy	7.35	6.95 (d)		6.3 5.9 (a)	6.1 (b)	6 (b)			
Ho	1.59	1.46 (d)		1.9 1.6 (a)		1.5 (b)			
Er	4.71	4.28 (d)		4.4 4.7 (a)		3.5 (b)			
Tm	0.72	0.64 (d)		0.79 0.76 (a)			0.48 0.61 (b)		
Yb	4.69	4.01 (d)		4 4 (a)	4 (b)	4.05 (b)	4.9 5.2 (b)		
Lu	0.63	0.59 (d)				0.61 (b)	0.92 0.83 (b)		
Hf	3.87	3.68 (d)		3 3.2 (a)	3.1 (b)	6.9 (b)	3.8 4.4 (b)		
Ta	0.75	0.73 (d)					0.89 0.9 (b)		
W ppb	0.14			200 100 (a)					
Re ppb									0.11 (f)
Os ppb									2.4 (f)
Ir ppb									0.15 (f)
Pt ppb									
Au ppb									0.089 (f)
Th ppm	1.13	1.02 (d)		0.78 1.04 (a)	0.9 (b)		1.3 1.3 (b)		
U ppm	0.31	0.29 (d)		0.22 0.29 (a)					

technique: (a) spark source ms, (b) INAA, (c) XRF, (d) ICP-MS, (e) the easy way, (f) the hard way



Firuge 12: Rb/Sr isochron for 14072 (Compston et al. 1972).

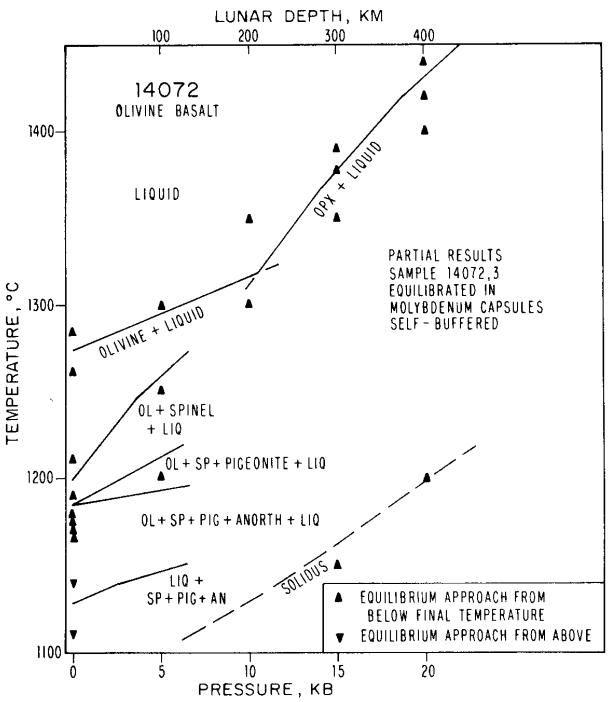


Figure 13: Phase diagram for 14072 (Walker et al. 1972).

Summary of Age Data for 14072

	Ar/Ar	Rb/Sr
York et al. 1972	4.04 ± 0.05 b.y.	
Compston et al. 1971		3.99 ± 0.09

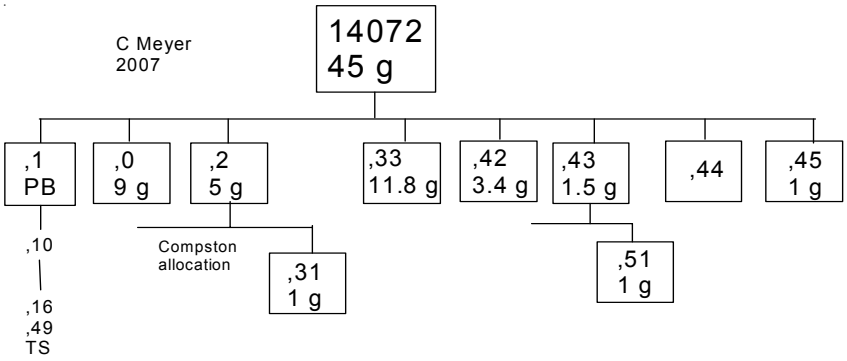
Caution: be careful of decay constant and Ar standard.

Cosmogenic isotopes and exposure ages

York et al. (1972) determined an ^{38}Ar exposure age of 21 m.y.

Processing

14072 was returned in bag 10N in ALSRC 1006. There are 7 thin sections for 14072.



References for 14072

Arvidson R., Crozaz G., Drozd R.J., Hohenberg C.M. and Morgan C.J. (1975) Cosmic ray exposure ages of features and events at the Apollo landing sites. *The Moon* **13**, 259-276.

Carlson I.C. and Walton W.J.A. (1978) **Apollo 14 Rock Samples**. Curators Office. JSC 14240

Clayton R.N., Hurd J.M. and Mayeda T.K. (1972) Oxygen isotopic compositions and oxygen concentrations of Apollo 14 and Apollo 15 rocks and soils. *Proc. 3rd Lunar Sci. Conf.* 1455-1463.

Compston W. Vernon M.J., Berry H. and Rudoski R. (1971) The age of the Fra Mauro formation: A radiometric older limit. *Earth Planet. Sci. Lett.* 12, 55-58.

Compston W., Vernon M.J., Berry H., Rudowski R., Gray C.M., Ware N., Chappell B.W. and Kaye M. (1972) *Proc. 3rd Lunar Sci. Conf.* 1487-1501.

Dickinson T., Taylor G.J., Keil K., Schmitt R.A., Hughes S.S. and Smith M.R. (1985) Apollo 14 aluminous mare basalts and their possible relationship to KREEP. *Proc. 15th Lunar Planet. Sci. Conf.* C365-C374.

Dickinson T., Taylor G.J., Keil K. and Bild R.W. (1989) Germanium abundances in lunar basalts: Evidence of mantle metasomatism. Proc. *19th Lunar Planet. Sci.* 189-198. LPI

El Goresy A., Taylor L.A. and Ramdohr P. (1972) Fra Mauro crystalline rocks: Mineralogy, geochemistry and subsolidus reduction of the opaque minerals. *Proc. 3rd Lunar Sci. Conf.* 333-349.

von Engelhardt W. (1979) Ilmenite in the crystallization sequence of lunar rocks. *Proc. 10th Lunar Sci. Conf.* 677-694.

Haggerty S.E. (1977) Apollo 14: Oxide, metal and olivine mineral chemistries in 14072 with a bearing on the temporal relationships of subsolidus reduction. *Proc. 8th Lunar Sci. Conf.* 1809-1829.

Helmke P.A., Haskin L.A., Korotev R.L. and Ziege K.E. (1972) Rare earths and other trace elements in Apollo 14 samples. *Proc. 3rd Lunar Sci. Conf.* 1275-1292.

Hubbard N.J., Gast P.W., Rhodes J.M., Bansal B.M., Wiesmann H. and Church S.E. (1972) Nonmare basalts: Part II. *Proc. 3rd Lunar Sci. Conf.* 1161-1179.

Hughes T.C., Keays R.R. and Lovering J.F. (1973) Siderophile and volatile trace elements in Apollo 14, 15 and 16 rocks and fines: Evidence for extralunar component and Tl-, Au- and Ag-enriched rocks in the ancient lunar crust (abs). *LS* **IV**, 400-402.

Longhi J., Walker D. and Hays J.F. (1972) Petrology and crystallization history of basalts 14310 and 14072. *Proc. 3rd Lunar Sci. Conf.* 131-139.

Lovering J.F., Wark D.A., Geadow A.J.W. and Sewell D.K.B. (1972) Uranium and potasium fractionation in pre-Imbrian lunar crstral rocks. *Proc. 3rd Lunar Sci. Conf.* 281-294.

LSPET (1971) Preliminary examination of lunar samples from Apollo 14. *Science* **173**, 681-693.

Neal C.R. (2001) Interior of the moon: The presence of garnet in the primitive deep lunar mantle. *J. Geophys. Res.* **106**, 27865-27885.

Neal C.R. (2007) Mining the literature for new data: Expanding the Apollo 14 high-alumina basalt isotope database (abs). *Lunar Planet. Sci.* **XXXVIII** #2398

Neal C.R., Shih C-Y., Reese Y., Nyquist L.E. and Kramer G.Y. (2006) Derivation of Apollo 14 high-Al basalts from distinct source regions at discrete times: New constraints (abs). *Lunar Planet. Sci.* **XXXVII** #2003

Neal C.R. and Kramer G.Y. (2006) The petrogenesis of the Apollo 14 high-Al mare basalts. *Am. Mineralogist* **91**, 1521-1535.

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.

Ryder G. and Spudis P. (1980) Volcanic rocks in the lunar highlands. *Proc. Conf. Lunar Highlands Crust* 353-375. eds. Papike and Merrill LPI

Simonds C.H., Phinney W.C., Warner J.L., McGee P.E., Geeslin J., Brown R.W. and Rhodes J.M. (1977) Apollo 14 revisited, or breccias aren't so bad after all. *Proc. 8th Lunar Sci. Conf.* 1869-1893.

Sutton R.L., Hait M.H. and Swann G.A. (1972) Geology of the Apollo 14 landing site. *Proc. 3rd Lunar Sci. Conf.* 27-38.

Swann G.A., Trask N.J., Hait M.H. and Sutton R.L. (1971a) Geologic setting of the Apollo 14 samples. *Science* **173**, 716-719.

Swann G.A., Bailey N.G., Batson R.M., Eggleton R.E., Hait M.H., Holt H.E., Larson K.B., Reed V.S., Schaber G.G., Sutton R.L., Trask N.J., Ulrich G.E. and Wilshire H.G. (1977)

Geology of the Apollo 14 landing site in the Fra Mauro Highlands. U.S.G.S. Prof. Paper 880.

Swann G.A., Bailey N.G., Batson R.M., Eggleton R.E., Hait M.H., Holt H.E., Larson K.B., McEwen M.C., Mitchell E.D., Schaber G.G., Schafer J.P., Shepard A.B., Sutton R.L., Trask N.J., Ulrich G.E., Wilshire H.G. and Wolfe E.W. (1972) 3. Preliminary Geologic Investigation of the Apollo 14 landing site. *In* Apollo 14 Preliminary Science Rpt. NASA SP-272. pages 39-85.

Taylor S.R., Kaye M., Muir P., Nance W., Rudowski R. and Ware N. (1972) Composition of the lunar uplands: Chemistry of Apollo 14 samples from Fra Mauro. *Proc. 3rd Lunar Sci. Conf.* 1231-1249.

Walker D., Longhi J. and Hays J. F. (1972) Experimental petrology and origin of Fra Mauro rocks and soils. *Proc. 3rd Lunar Sci. Conf.* 797-817.

Wilshire H.G. and Jackson E.D. (1972) Petrology and stratigraphy of the Fra Mauro Formation at the Apollo 14 site. U.S. Geol. Survey Prof. Paper 785.

York D., Kenyon W.J. and Doyle R.J. (1972) 40Ar-39Ar ages of Apollo 14 and 15 samples. *Proc. 3rd Lunar Sci. Conf.* 1613-1622.