15076

Pigeonite Basalt

400.5 grams

Figure 1: Photo of 15076 showing large micrometeorite crater on S1 surface. Sample is 7 cm across. NASA S71-47679.

Introduction

15076 is a coarse-grained, porphyritic pigeonite basalt with subophitic matrix. It has been dated at 3.35 b.y. and has been exposed on the lunar surface for ~300 m.y. (Elbow Crater ?). The top surface is rounded with numerous micrometeorite craters.

Petrography

McGee et al. (1977) and Ryder (1985) provide detailed petrographic descriptions. 15076 and 15075 and have similar texture and pyroxene zoning (figures 3 and 4). Pyroxene is dominant, occurring both as large phenocrysts and subophitically intergrown with plagioclase laths in between. It zones outward to pyroxferroite. Plagioclase occurs as hollow straws. Other minerals are ilmenite, ulvospinel, tridymite, cristobalite, troilite and metallic iron. There is residual glass in the interstices (Brown et al. 1972).

Brett (1975), Lofgren et al. (1975), Onorato et al. (1979) and Walker and Grove (1977) studied the cooling rate of the basalt sequence 15065 – 15076 – 15085 to determine the thickness of the basalt flow sampled by Elbow Crater (~1 m?).

Mineralogical Mode for 15076

	Rhodes and Hubbard 1973	McGee et al. 1977	Brown et al. 1972	Sample catalog Butler 1971
Olivine			- -	
Pyroxene	66.3	53 – 66	53.3	55
Plagioclase	28.5	28 – 36	35.7	45
Opaques	2.4		3.9	3.2
Ilmenite		0.5		
Ti Spinel		1.4		
Troilite		0.5		
Christobalite	2.1	2 – 6	6.4	
Mesostasis	0.6	0.6	0.7	

Figure 2: Photomicrograph of thin section of 15076. NASA S71-52193. Section # and scale unknown.

Mineralogy

Olivine: none

Pyroxene: Brown et al. (1972) studied pyroxene zoning (figure 4).

Plagioclase: Plagioclase laths have hollow cores.

Metal: Taylor and Misra (1975) and Taylor et al. (1975) reported Ni, Co in metal grains (figure 5).

Chemistry

LSPET (1972), Rhodes and Hubbard (1973), Fruchter et al. (1973) and Cuttitta et al. (1973) determined the chemical composition of 15076 (table 1, figures 6 and 7). Gibson et al. (1975) determined the sulfur content (970 ppm).

Radiogenic age dating

Stettler et al. (1973) and Kirsten et al. (1973d) determined the age of 15076 as 3.35 ± 0.04 b.y. by Ar/Ar plateau technique (figures 9). Papanastassiou and Wasserburg (1973) determined 3.33 ± 0.08 b.y. by Rb/Sr internal isochron (figure 8). Note that Shaeffer and Schaeffer (1977) reported an older age for 15075 by Ar/Ar.

Cosmogenic isotopes and exposure ages

Eldridge et al. (1972) reported the cosmic ray exposure of ^{22}Na = 43 dpm/kg, ^{26}Al = 62 dpm/kg, ^{46}Sc = 6 dpm/kg, ^{54}Mn = 27 dpm/kg and ^{56}Co = 20 dpm/kg.

Stettler et al. (1973) and Kirsten et al. (1973d) determined the exposure age of 15076 by ^{38}Ar as 330 m.y. and 280 m.y. respectively (age of Elbow Crater?).

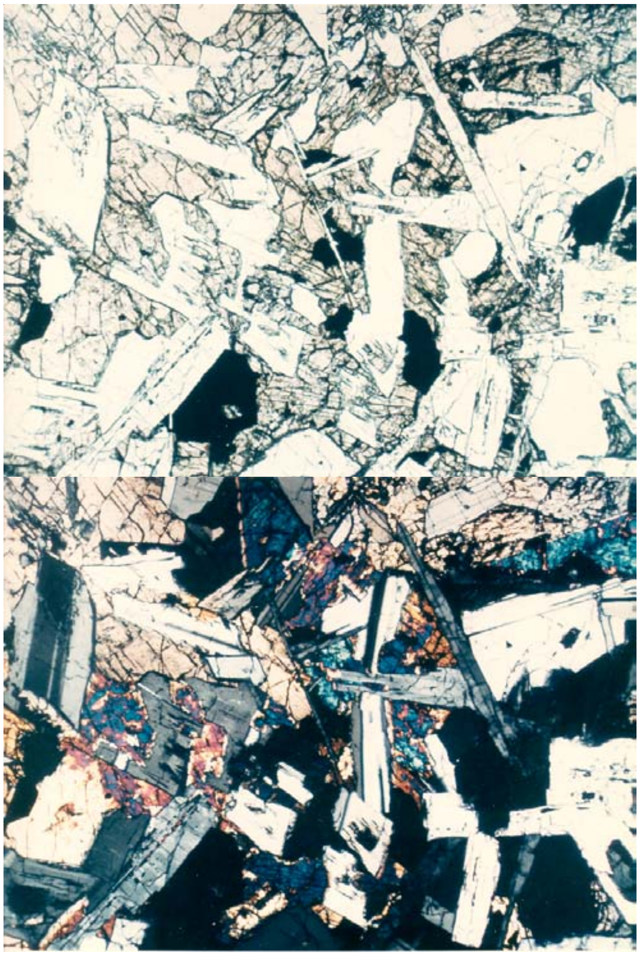


Figure 3: Photomicrographs of thin section of 15076. Top is plane polarized light; bottom is with crossed polarizers. NASA S71-51760 and 51783.

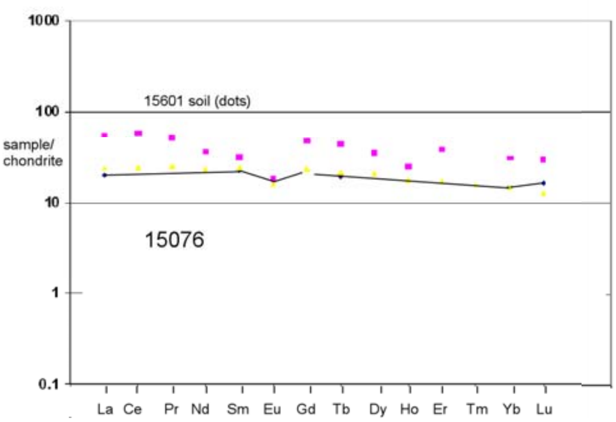


Figure 6: Normalized rare-earth-element pattern for 15076 compared with 15601 soil.

Other Studies

The concentrations of Sm, Nd, Lu and Hf and the isotopic ratios of $^{143}Nd/^{144}Nd$ and $^{176}Hf/^{177}Hf$ were determined by Unruh et al. (1984). U, Th and Pb isotopes were found to be similar to those of 15065 and 15085 by Tatsumoto et al. (1972) with an intercept at ~3.5 b.y.

Solar flare and cosmic ray tracks were studied by Storzer et al. (1973) and Kratschmer and Gentner (1975).

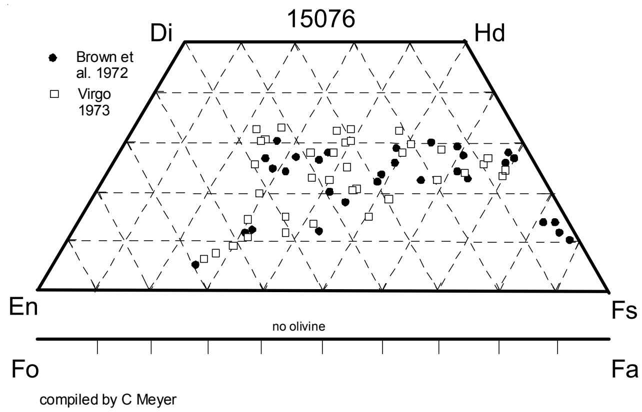


Figure 4 : Pyroxene composition of 15076.

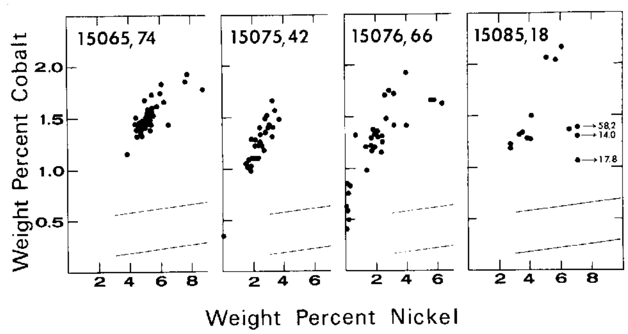


Figure 5: Composition of metal grains in basalt samples from Elbow Crater (from Taylor et al. 1975).

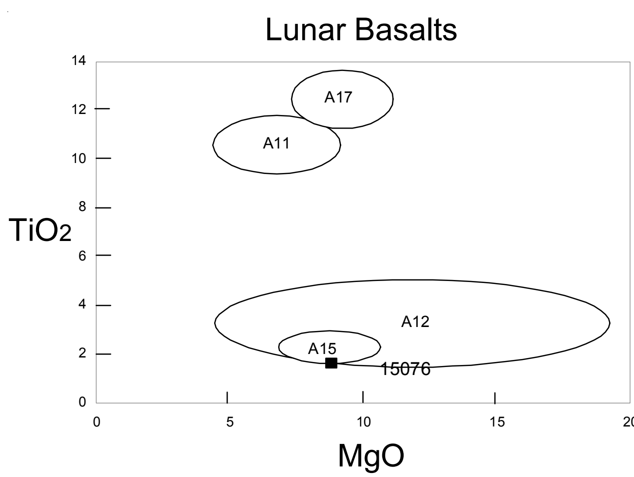


Figure 7: Chemical composition of 15076 compared with that of other lunar basalts.

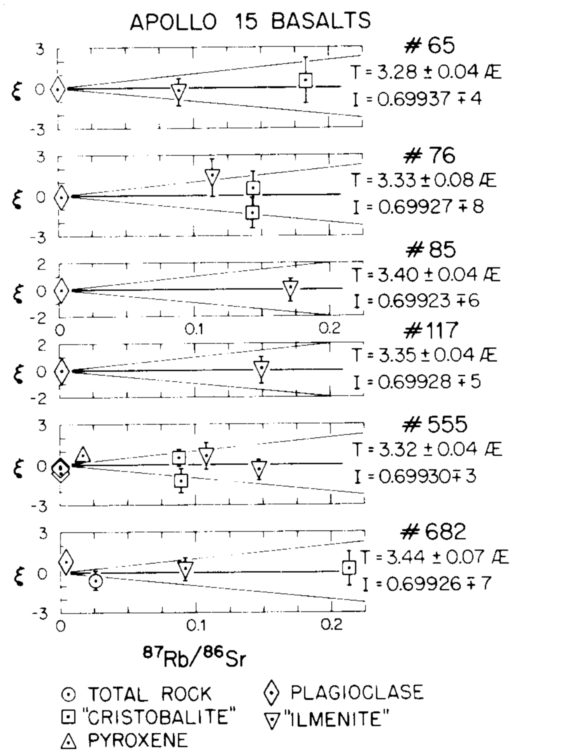


Figure 8: Rb/Sr isochron diagrams of various Apollo 15 basalts (from Papanastassiou and Wasserburg 1973).

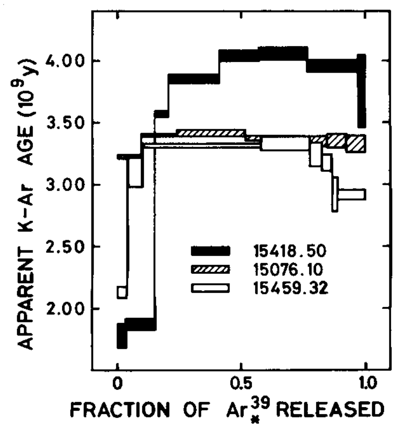


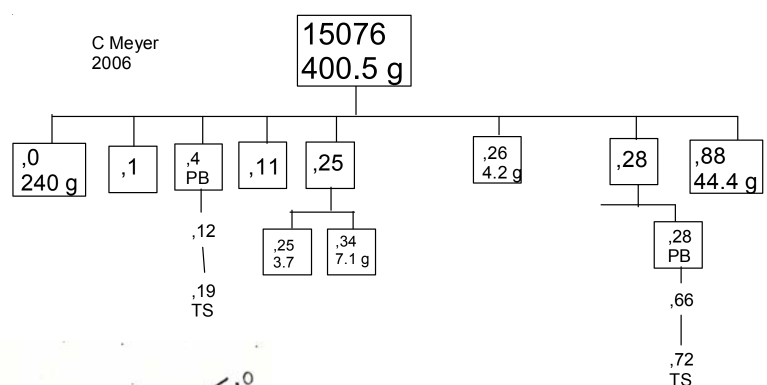
Figure 9: Ar/Ar plateau diagram for 15076 and other rocks (from Stettler et al. 1973).

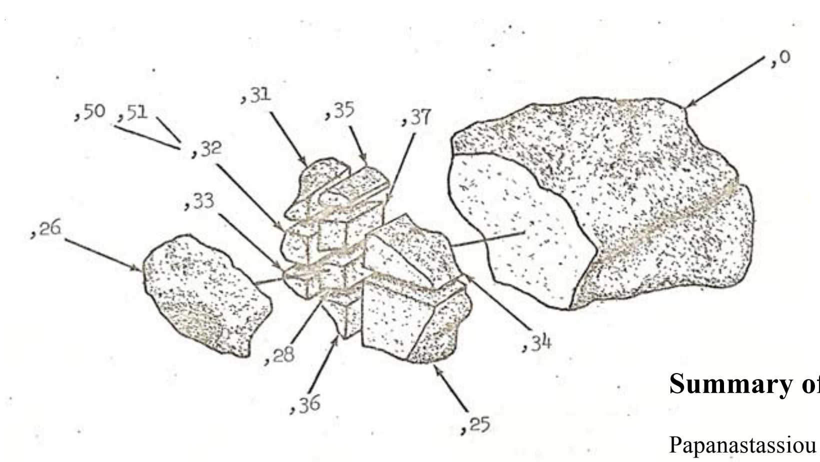
Morrison et al. (1973) and Schneider et al. (1973) reported the micrometeorite crater density.

Gose et al. (1972) and Pearce et al. (1973) reported magnetic data.

Processing

A small slab was cut from one end of 15076. There are 14 thin sections.





Summary of Age Data for 15076

	Ar/Ar	Rb/Sr
Papanastassiou and Wasserburg 1972		3.33 ± 0.08 b.y.
Stettler et al. 1973	3.35 ± 0.04	
Kirsten et al. 1973	3.35 ± 0.15	

Caution: Ages reported with original decay constants.

Table 1. Chemical composition of 15076.

reference	Wiesmann75		Rhodes 73			Cuttitta73		Fruchter73		O'Kelley72		Unruh 84	
weight	Hubbard 73					Christian72							
SiO2 %			48.8	48.06	(b)	48.82	(c)						
TiO2	1.9	(a)	1.46	2.01	(b)	1.83	(c)	1.47	(d)				
Al2O3			9.3	9.63	(b)	8.31	(c)	9.26	(d)				
FeO	18.5		18.62	20.22	(b)	20.45	(c)	19.35	(d)				
MnO			0.27	0.29	(b)	0.29	(c)						
MgO	7.75		9.46	7.8	(b)	9.43	(c)						
CaO			10.82	10.74	(b)	10.3	(c)						
Na2O	0.3		0.26	0.29	(b)	0.4	(c)	0.3	(d)				
K2O	0.05	(a)	0.03	0.05	(b)	0.08	(c)			0.049	(e)		
P2O5			0.03	0.08	(b)	0.05	(c)						
S %			0.03	0.08	(b)								
sum													
Sc ppm						40	(c)	47	(d)				
V						135	(c)						
Cr						2121	(c)	3380	(d)				
Co						42	(c)	41	(d)				
Ni			11		(b)	32	(c)						
Cu						9.1	(c)						
Zn													
Ga						4.1	(c)						
Ge ppb													
As													
Se													
Rb	0.917	(a)	1.1		(b)	1.2	(c)						
Sr	112	(a)	120		(b)	98	(c)						
Y			29		(b)	26	(c)						
Zr			97		(b)	64	(c)						
Nb			6.2		(b)	<10							
Mo													
Ru													
Rh													
Pd ppb													
Ag ppb													
Cd ppb													
In ppb													
Sn ppb													
Sb ppb													
Te ppb													
Cs ppm													
Ba	62.7	(a)				58	(c)						
La	7.38	(a)				10	(c)	4.7	(d)				
Ce	15.1	(a)											
Pr													
Nd	10.6	(a)										11.85	(a)
Sm	3.52	(a)						3.4	(d)			3.796	(a)
Eu	0.978	(a)						0.98	(d)				
Gd	4.95	(a)											
Tb								0.7	(d)				
Dy	5.6	(a)											
Ho													
Er	3.4	(a)											
Tm													
Yb	2.77	(a)				3.7	(c)	2.4	(d)				
Lu	0.326	(a)						0.4	(d)			0.394	(a)
Hf								2.1	(d)			2.866	(a)
Ta								0.44	(d)				
W ppb													
Re ppb													
Os ppb													
Ir ppb													
Pt ppb													
Au ppb													
Th ppm										0.45	(e)		
U ppm	0.15	(a)								0.12	(e)		

technique: (a) IDMS, (b) XRF, (c) "microchemical", (d) INAA, (e) radiation counting

References for 15076

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.

Berking B., Jagodzinski H. and Schmid R. (1972) Crystallography of lunar feldspars and pyroxenes from 15076,55. *In* **The Apollo 15 Lunar Samples**, 29-33.

Brett R. (1975) Thickness of some lunar basalt flows and ejecta blankets based on chemical kinetic data. *Geochim. Cosmochem. Acta* **39**, 1135-1141.

Brown G.M., Emeleus C.H., Holland G.J., Peckett A. and Phillips R. (1972) Mineral-chemical variations in Apollo 14 and Apollo 15 basalts and granitic fractions. *Proc. 3rd Lunar Sci. Conf.* 141-157.

Butler P. (1971) Lunar Sample Catalog, Apollo 15. Curators' Office, MSC 03209

Carron M.K., Annell C.S., Christian R.P., Cuttitta F., Dwornik E.J., Ligon D.T. and Rose H.J. (1972) Elemental analysis of lunar soil samples from Apollo 15 mission. *In* **The Apollo 15 Lunar Samples,** 198-201.

Church S.E., Bansal B.M. and Wiesmann H. (1972) The distribution of K, Ti, Zr, U, and Hf in Apollo 14 and 15 materials. *In* **The Apollo 15 Lunar Samples**, 210-213.

Cuttita R., Rose H.J., Annell C.S., Carron M.K., Christian R.P., Ligon D.T., Dwornik E.J., Wright T.L. and Greenland L.P. (1973) Chemistry of twenty-one igneous rocks and soils returned by the Apollo 15 mission. *Proc. 4th Lunar Sci. Conf.* 1081-1096.

Eldridge J.S., O'Kelley G.D. and Northcutt K.J. (1972) Concentrations of cosmogenic radionuclides in Apollo 15 rocks and soils. *In* **The Apollo 15 Lunar Samples** 357-359. Lunar Sci. Institute, Houston.

Fruchter J.S., Stoeser J.W., Lindstrom M.M. and Goles G.G. (1973) Apollo 15 clastic materials and their relationship to local geologic features. *Proc. 4th Lunar Sci. Conf.* 1227-1237.

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.

Gose W.A., Pearce G.W., Strangway D.W. and Carnes J. (1972) Magnetism of Apollo 15 samples. *In* **The Apollo 15 Lunar Samples** 415-417.

Grove T.L. and Walker D. (1977) Cooling histories of Apollo 15 quartz-normative basalts. *Proc. 8th Lunar Sci. Conf.* 1501-1520.

Grove T.L. and Lindsley D.H. (1979) The partitioning of Fe, Mg, and Ca between pigeonite and liquid in lunar basalts (abs). *Lunar Planet. Sci.* **X**, 473-475. Lunar Planetary Institute, Houston.

Hubbard N.J., Rhodes J.M., Gast P.W., Bansal B.M., Shih C.-Y., Wiesmann H. and Nyquist L.E. (1973b) Lunar rock types: The role of plagioclase in non-mare and highland rock types. *Proc. 4th Lunar Sci. Conf.* 1297-1312.

Hughes S.S. and Schmitt R.A. (1985) Zr-Hf-Ta fractionation during lunar evolution. *Proc. 16th Lunar Planet. Sci. Conf.* D31-D45. *in* J. Geophys. Res. **90**.

Kirsten T., Horn P. and Kiko J. (1973d) Ar40-Ar39 dating of Apollo 16 and Apollo 15 rocks and rare gas analysis of Apollo 16 soils (abs). *Lunar Sci.* **IV**, 438-440. The Lunar Sci. Institute, Houston.

Kratschmer W. and Gentner W. (1975) The feasibility of ion identification on cosmic-ray tracks in lunar feldspars. *Proc. 6th Lunar Sci. Conf.* 3577-3585.

Jagodzinski H. and Korekawa M. (1973) Diffuse x-ray scattering by lunar materials. *Proc. 4th Lunar Sci. Conf.* 933-951.

Lofgren G.E., Donaldson C.H. and Usselman T.M. (1975) Geology, petrology and crystallization of Apollo 15 quartz-normative basalts. *Proc. 6th Lunar Sci. Conf.* 79-99.

LSPET (1972a) The Apollo 15 lunar samples: A preliminary description. Science 175, 363-375.

LSPET (1972b) Preliminary examination of lunar samples. Apollo 15 Preliminary Science Report. NASA SP-289, 6-1—6-28.

McGee P.E., Warner J.L. and Simonds C.H. (1977) Introduction to the Apollo Collections. Part I: Lunar Igneous Rocks. Curators Office, JSC.

Morrison D.A., McKay D.S., Fruland R.M. and Moore H.J. (1973) Microcraters on Apollo 15 and 16 rocks. *Proc. 4th Lunar Sci. Conf.* 3235-3253.

Nyquist L.E., Hubbard N.J., Gast P.W., Bansal B.M., Wiesmann H. and Jahn B-M. (1973) Rb-Sr systematics for chemically defined Apollo 15 and 16 materials. *Proc. 4th Lunar Sci. Conf.* 1823-1846.

O'Kelley G.D., Eldridge J.S. and Northcutt K.J. (1972a) Abundances of primordial radioelements K, Th, and U in

Apollo 15 samples, as determined by non-destructive gamma-ray spectrometry. *In* **The Apollo 15 Lunar Samples**, 244-246.

O'Kelley G.D., Eldridge J.S., Schonfeld E. and Northcutt K.J. (1972b) Primordial radionuclides and cosmogenic radionuclides in lunar samples from Apollo 15. *Science* **175**, 440-443.

O'Kelley G.D., Eldridge J.S., Northcutt K.J. and Schonfeld E. (1972c) Primordial radionuclides and cosmogenic radionuclides in lunar samples from Apollo 15. *Proc. 3rd Lunar Sci. Conf.* 1659-1670.

Onorato P.I.K., Yinnon H., Uhlmann D.R. and Taylor L.A. (1979) Partioning as a cooling rate indicator. *Proc. 10th Lunar Planet. Sci. Conf.* 479-491.

Papanastassiou D.A. and Wasserburg G.J. (1973) Rb-Sr ages and initial strontium in basalts from Apollo 15. *Earth Planet. Sci. Lett.* **17**, 324-337.

Pearce G.W., Gose W.A. and Strangway D.W. (1973) Magnetic studies on Apollo 15 and 16 lunar samples. *Proc. 4th Lunar Sci. Conf.* 3045-3076.

Rhodes J.M. and Hubbard N.J. (1973) Chemistry. classification, and petrogenesis of Apollo 15 mare basalts. *Proc. 4th Lunar Sci. Conf.* 1127-1148.

Ryder G. (1985) Catalog of Apollo 15 Rocks (three volumes). Curatoial Branch Pub. # 72, JSC#20787

Schneider E., Storzer D. and Fechtig H. (1972) Exposure ages of Apollo 15 samples by means of microcrater statistics and solar flare partile tracks. *In* **The Apollo 15 Lunar Samples** 415-417.

Schneider E., Storzer D., Hartung J.B., Fechtig H. and Genter W. (1973) Microcraters on Apollo 15 and 16 samples and corresponding cosmic dust fluxes. *Proc. 4th Lunar Sci. Conf.* 3277-3290.

Stettler A., Eberhardt Peter, Geiss J., Grogler N. and Maurer P. (1973) Ar^{39}-Ar^{40} ages and Ar^{37}-Ar^{38} exposure ages of lunar rocks. *Proc. 4th Lunar Sci. Conf.* 1865-1888.

Storzer D., Poupeau G. and Kratschmer W. (1973) Track-exposure and formation ages of some lunar samples. *Proc. 4th Lunar Sci. Conf.* 2363-2377.

Swann G.A., Hait M.H., Schaber G.C., Freeman V.L., Ulrich G.E., Wolfe E.W., Reed V.S. and Sutton R.L. (1971b) Preliminary description of Apollo 15 sample environments. U.S.G.S. Interagency report: 36. pp219 with maps

Swann G.A., Bailey N.G., Batson R.M., Freeman V.L., Hait M.H., Head J.W., Holt H.E., Howard K.A., Irwin J.B., Larson K.B., Muehlberger W.R., Reed V.S., Rennilson J.J., Schaber G.G., Scott D.R., Silver L.T., Sutton R.L., Ulrich G.E., Wilshire H.G. and Wolfe E.W. (1972) 5. Preliminary Geologic Investigation of the Apollo 15 landing site. In Apollo 15 Preliminary Science Rpt. NASA SP-289. pages 5-1-112.

Tatsumoto M., Hedge C.E., Knight R.J., Unruh D.M. and Doe Bruce R. (1972b) U-Th-Pb, Rb-Sr and K measurements on some Apollo 15 and Apollo 16 samples. *In* **The Apollo 15 Lunar Samples,** 391-395.

Taylor L.A. and Misra K.C. (1975a) Pyroxene-phyric basalt 15075: Petrography and petrogenesis. *Proc. 6th Lunar Sci. Conf.* 165-179.

Taylor L.A., Uhlmann D.R., Hopper R.W. and Misra K.C. (1975b) Absolute cooling rates of lunar rocks: Theory and application. *Proc. 6th Lunar Sci. Conf.* 181-191.

Thode H.G. and Rees C.E. (1972) Sulphur concentrations and isotope ratios in Apollo 14 and 15 samples. *In* **The Apollo 15 Lunar Samples**, 402-403.

Unruh D.M., Stille P., Patchett P.J. and Tatsumoto M. (1984) Lu-Hf and Sm-Nd evolution in lunar mare basalts. *Proc. 14th Lunar Planet. Sci. Conf.* in J. Geophys. Res. **88**, B459-B477.

Virgo D. (1973) Clinopyroxene from Apollo 15: Fe2+, Mg intercrystalline distributions (abs). *Lunar Sci.* **IV**, 749-751.

Wiesmann H. and Hubbard N.J. (1975) A compilation of the Lunar Sample Data Generated by the Gast, Nyquist and Hubbard Lunar Sample PI-Ships. Unpublished. JSC