76215

Vesicular Micropoikilitic Impact Melt Breccia

644 grams

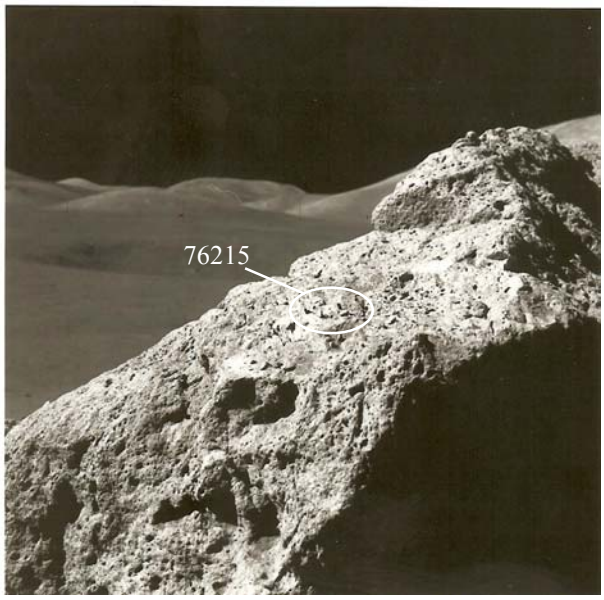


Figure 1: Photo of station 6 boulder with location of 76215 indicated. AS17-140-21421

Figure 2: Photo of 76215. Sample is about 10 cm. S72-56372. Location of slab indicated.

LMP There's a big spall lying on the ground here that has been knocked off up there, from right on top of the boulder. And, I tell you, the more I look at this – the south half of this boulder, the more heterogeneous in texture it looks. It look as if it may be either a recrystallized breccia of some kind, or you had a gabbroic anorthosite magma catch up an awful lot of inclusions. I guess I prefer the latter explanation because of the extreme vesicularity of the rock.

LMP A few of the inclusions are – well, they're all subrounded to rounded, and a few of them are very light colored.

—

LMP I think we ought to pick up a piece of that spall there by the gnomon.

CDR I can break it off.

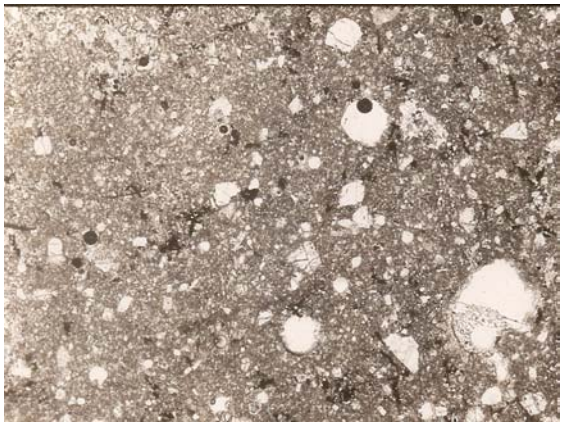


Figure 3: Thin scetion photomicrograph showing poikilitic texture of crystalline melt rock.

LMP There's one right by the gnomon we can just pick up. It's a finer grained vesicular rock than – I thought I was going to get this helf – Well, they like to have some of it black and white, you know.

CDR I'll get that rock. We want to get 500s of that boulder track.

LMP OK. A piece of that spalled rock that was sitting by the gnomon – watch out Gordon. How about that? – is in bag 535 (76215)

Introduction

76215 was collected from the lunar surface right next to the large Station 6 Boulder, but it was most certainly recently spalled from the top of block 4 of Boulder 6 (Wolfe et al. 1981), where there is a fresh mark that fits the sample directly above the location where the sample was found on top of the soil (figure 1). It is a sample of lithologic unit B of the big boulder and is similar in color, texture, composition and age to 76015 chipped from the top of adjacent boulder half.

76215 is a crystalline matrix breccia with a mostly poikilitic texture, but there are some areas that have an ophitic texture characteristic of crystallized (basaltic) melt. It has been dated at 3.94 b.y., with an exposure to cosmic rays for 19 m.y. and has an aluminous composition with high trace element content. It contains high concentrations of meteoritic siderophiles and is thought to be impact melt from the Serenitatis impact.

There is a large area on 76215 that has a surface coating, called patina, with variable thickness from top to bottom, which has not been eroded by bombardment by micrometeorites.

Figure 4: Plagioclase clast with necklace and overgrowth. Field of view 0.5 mm. (from McGee et al. 1977)

Petrography

Simonds (1975), McGee et al. (1977), Phinney (1981), and Meyer (1994) give descriptions of 76215. It is a vesicular, crystalline matrix breccia with a crude macroscopic foliation defined by the alignment of vesicles and cavities, including the roughly flat side of a large cavity that defines one side of the sample (figure 8). Over 90% of the matrix is poikilitic made up of a network of coalescing pigeonite and augite oikocrysts (0.5 to 2 mm) which enclose abundant tabular plagioclase chadocrysts (10-30 microns). Olivine occurs as irregular chadocrysts within pyroxene and as granular grains between oikocrysts. The remaining 10% of matrix has an ophitic texture with a fine intergrowth of euhedral plagioclase (0.2 to 0.35 mm) and subhedral pyroxene (0.2 to 0.8 mm). The contact between the two different matrix textures is said to be "distinct" (Simonds 1975). Some plagioclase clasts in the matrix have necklaces of mafic minerals and an overgrowth about 30 microns wide (figure 4).

Vugs in 76015 and 76215 contain euhedral crystals of troilite and metallic iron with crystal growth steps (Carter et al. 1975). Goldberg et al. (1975) reported thin coatings of F.

Significant Clast

Granulitic Anorthosite: ,70

McGee et al. (1977) describe a "large" anorthosite clast (2 mm) wuth polygonal grain boundaries and coarse texture in thin section 76215,70.

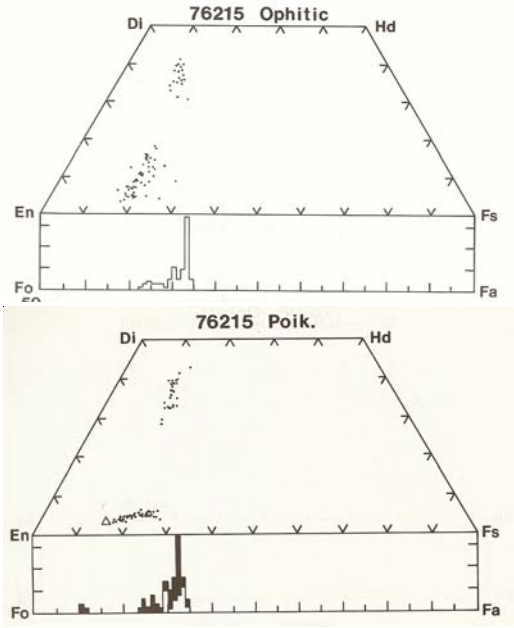


Figure 5: Pyroxene and olivine composition in 76215 (Phinney 1981).

Mineralogical Mode for 76215

	Simonds (1975)
Olivine	7-14 %
Low-Ca pyroxene	30
High-Ca Pyroxene	4-11
Plagioclase	50
Ilmenite	2

Mineralogy

Olivine: Olivine is Fo_{65-75}

Pyroxene: Simonds (1975) found that the pryoxene composition in the two different matrix textures was zoned slightly different (figure 5).

Plagioclase: Plagioclase is An_{95-80}

Metallic iron: Misra et al. (1976) determined the Ni and Co content of iron grains (figure 6).

Chemistry

Keith et al. (1974) determined the K, U and Th content of 76215 (complete sample). Simonds (1975) and Wiesmann and Hubbard (1975) found that the major and trace element composition of 76215 was identical to that of other samples of this boulder. Higuchi and Morgan (1975) determined trace volatile and siderophile elements. Puchtel et al. (2008) have

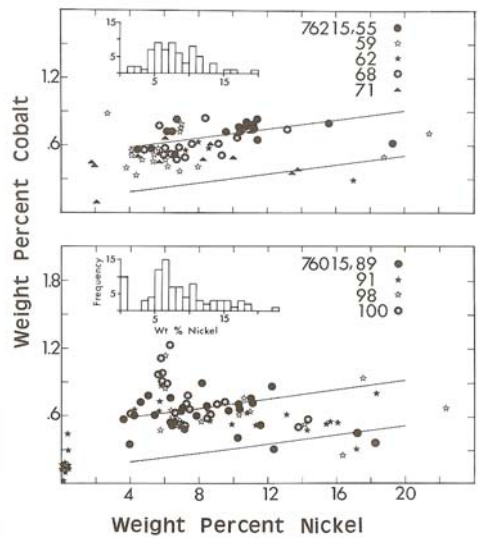


Figure 6: Ni and Co content of metal grains in 76015 and 76215 (Misra et al. 1976).

determined Re, Os, Ir, Ru, Pt, Pd and Os isotopes in 11 splits of 76215.

Radiogenic age dating

Cadogen and Turner (1976) dated 76215 along with other samples from the large boulder (figure 8). They obtained an age of 3.94 ± 0.04 b.y. by the Ar/Ar plateau technique.

Cosmogenic isotopes and exposure ages

Keith et al. (1974) determined the cosmic-ray-induced activity of ^{26}Al =56 dpm/kg., ^{22}Na = 60 dpm/kg., ^{54}Mn = 22 dpm/kg., ^{56}Co = 45 dpm/kg and ^{48}V = 5 dpm/kg.

Cadogen and Turner (1976) determined an exposure age of 19 m.y. by the ^{38}Ar method.

Other Studies

As in the case of 76015, 76215 has an apparently shielded interior surface of a large cavity (however, 76215 was recently broken from the boulder). The "lip" of this cavity has a thick, undisturbed patina which grades to thin (figure 9). Morrison and Zinner (1977) studied the crater size distribution and solar flare track density as function of depth in 76215.

Zinner et al. (1977) used 76215 to study Mg and Fe depth profiles in plagioclase due to solar flares, but this study is surely compromised by glass splashes on the exposed surface.

Table 1. Chemical composition of 76215.

	Higuchi75						
reference	Simonds75			Keith74		Putchel2008	
weight	Wiesmann75					ave.	
SiO2 %	46.13	46.02	(a)				
TiO2	1.24	1.52	(a)				
Al2O3	18.73	17.83	(a)				
FeO	8.08	8.7	(a)				
MnO							
MgO	12.43	12.21	(a)				
CaO	11.5	11.1	(a)				
Na2O							
K2O	0.24	0.28	(c)	0.26	(b)		
P2O5	0.24	0.28	(a)				
S %	0.07	0.1	(a)				
sum							
Sc ppm							
V							
Cr							
Co							
Ni	54		(d)				
Cu							
Zn	2.5		(d)				
Ga							
Ge ppb	31.5		(d)				
As							
Se	60		(d)				
Rb	6.1	6.89	(c)				
Sr							
Y							
Zr	459	495	(c)				
Nb							
Mo							
Ru						11.4	(c)
Rh							
Pd ppb						11.4	(c)
Ag ppb	0.87		(d)				
Cd ppb	1.08		(d)				
In ppb							
Sn ppb							
Sb ppb	0.44		(d)				
Te ppb							
Cs ppm	0.192						
Ba	294	352	(c)				
La	27.3	33.4	(c)				
Ce	68.9	83.6	(c)				
Pr							
Nd	43.7	52.2	(c)				
Sm	12.3	14.9	(c)				
Eu	1.7	1.99	(c)				
Gd	15.9	19.3	(c)				
Tb							
Dy	16.5	19.7	(c)				
Ho							
Er	9.9	11.8	(c)				
Tm							
Yb	9	10.9	(c)				
Lu							
Hf							
Ta							
W ppb							
Re ppb	0.07		(d)			0.6	(c)
Os ppb						6.064	(c)
Ir ppb	0.809		(d)			6.18	(c)
Pt ppb						15	(c)
Au ppb	0.526		(d)				
Th ppm	4.61	5.2	(c)	4.6	(b)		
U ppm	1.26	1.5	(c)	2.27	(b)		

technique: (a) XRF, (b) radiation counting, (c) IDMS, (d) ICP-MS

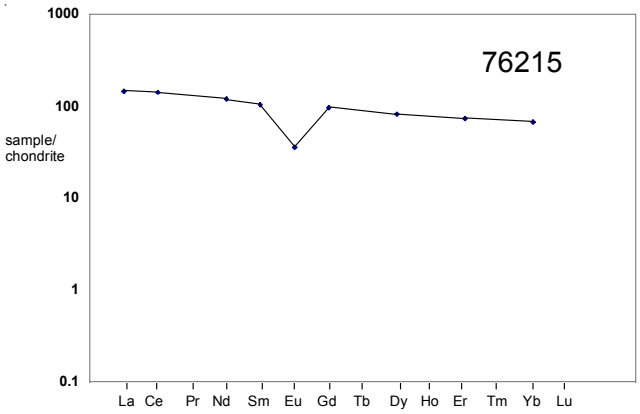


Figure 7: Normalized rare-earth-element diagram for 76215.

Gose et al. (1978) and Brecher (1976) have carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder, finding that the direction of magnetization was generally aligned with direction of foliation.

Bogard (1974) determined the content and isotopic ratio of rare gases in 76215.

Summary of Age Data for 76215

	Ar/Ar
Cadogen and Turner (1976)	3.94 ± 0.04 b.y.

Caution: Decay constant - -

Processing

A slab was cut through the middle of 76215 and columns were cut from the slab (figure 11). However, their orientation with respect to the surface of the Moon, and direction of cosmic rays, is unknown. In addition, it is not known how long the sample was exposed where it was found, on top of the regolith.

There are 22 thin sections of 76215.

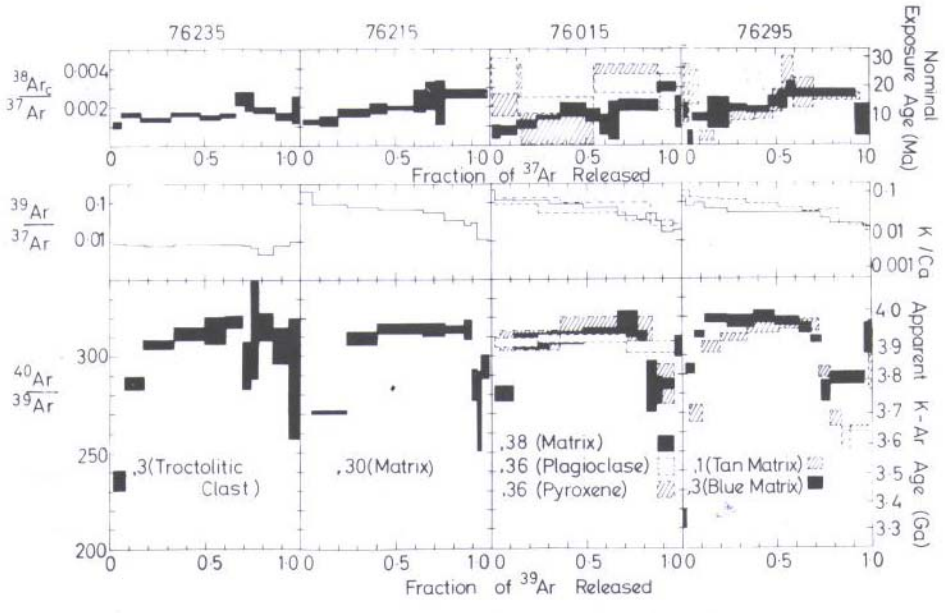


Figure 8: Argon release diagrams for samples of station 6 boulder including 76215 etc. (Cadogen and Turner 1976).

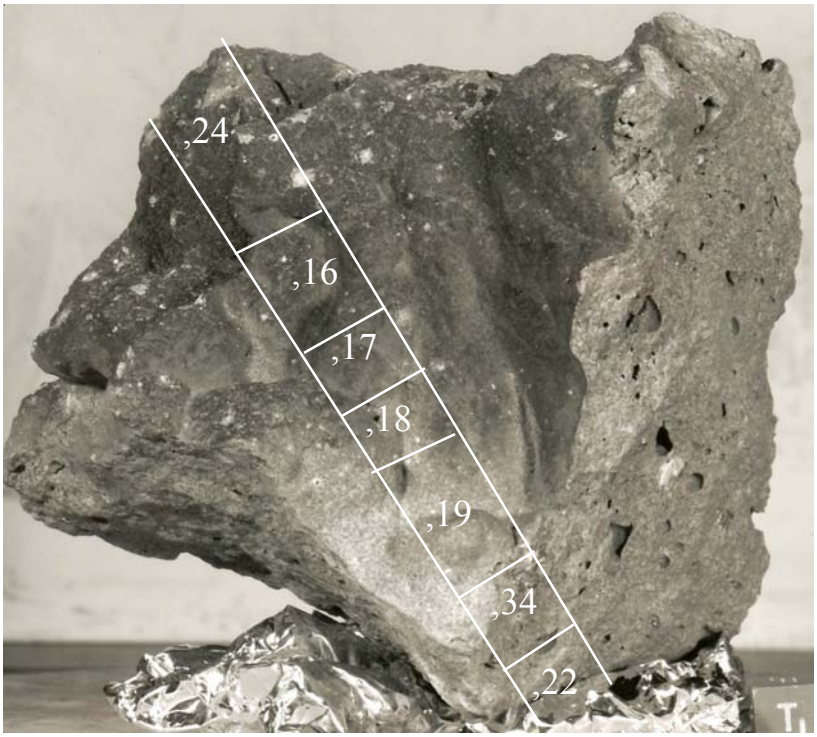


Figure 9: Patina-covered surface of 76215 showing thick patina at top with minor zap pits gradational to thin patina and no zap pits at bottom. Cube is 1 cm. S73-28422.

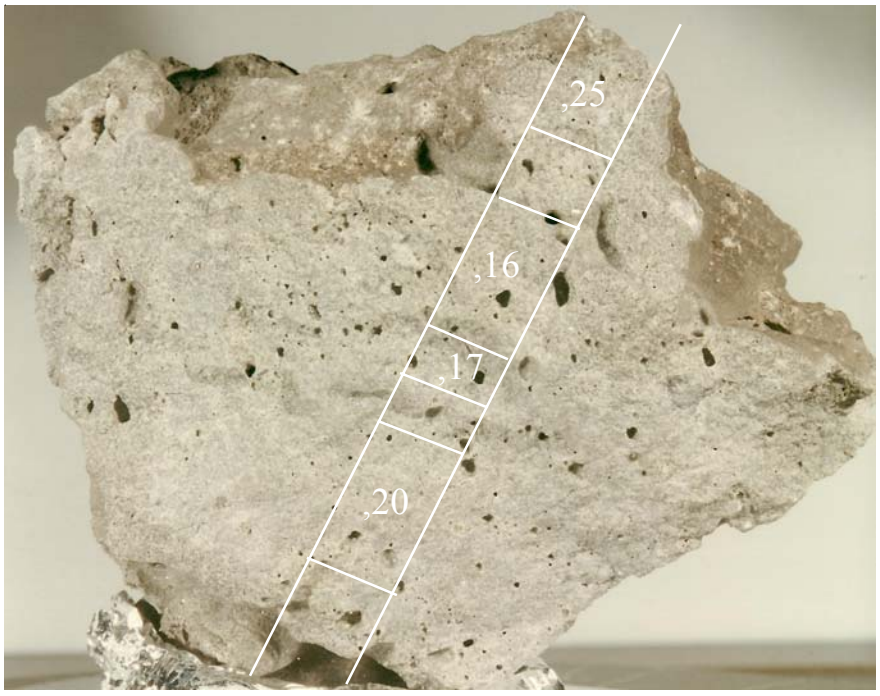


Figure 10: Broken surface of 76215 (B1) showing position of slab. S72-56374.

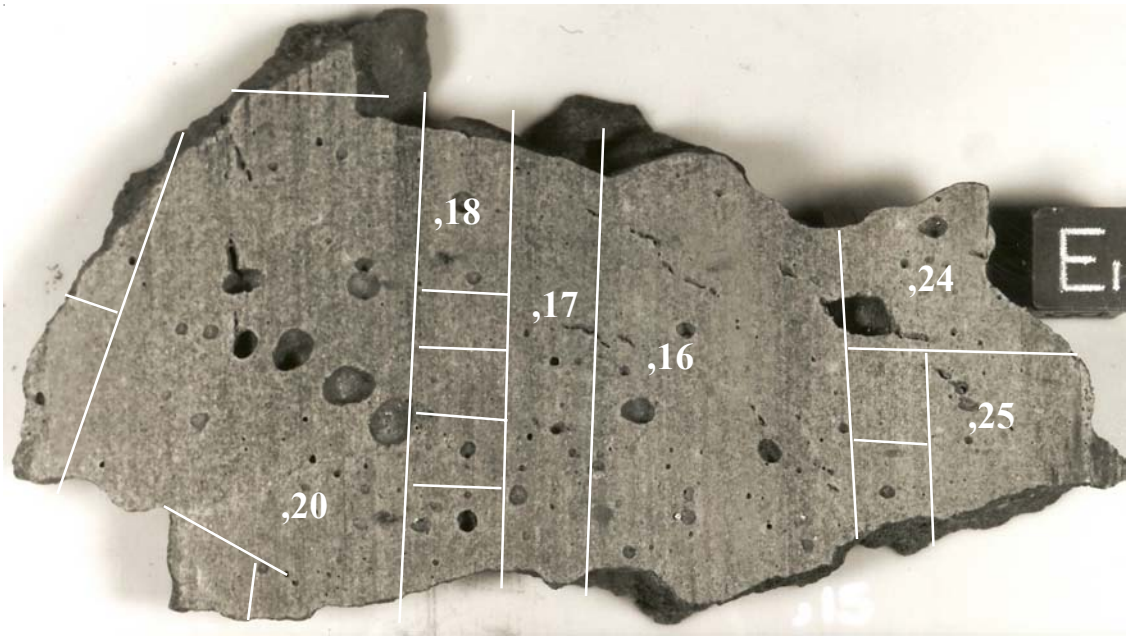
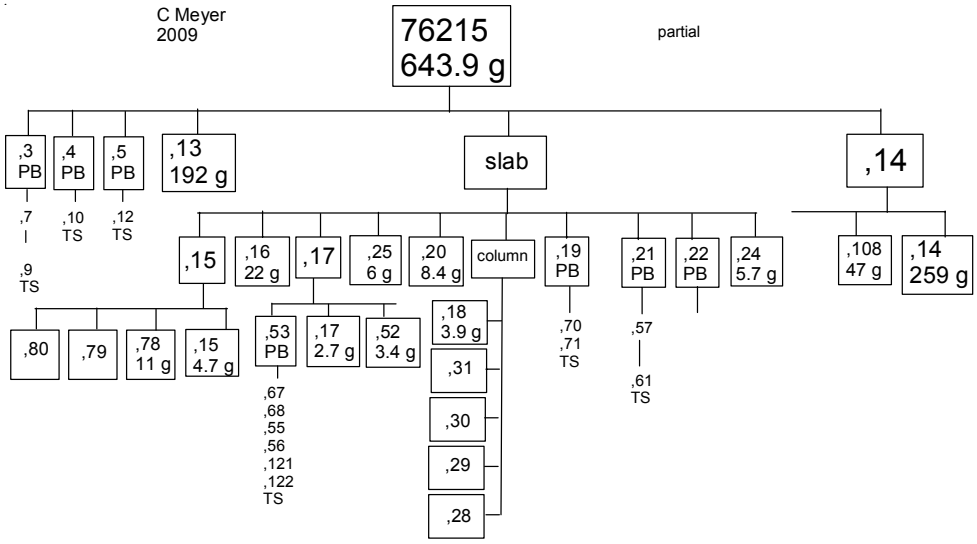


Figure 11: Photo of slab ,15 cut from 76215. Cube is 1 cm. S74-20758. Location of columns indicated.



References for 76215

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

Cadogan P.H. and Turner G. (1976) The chronology of the Apollo 17 Station 6 boulder. Proc. 7th Lunar Sci. Conf. 2267-2285.

Carter J.L., Clanton U.S., Fuhrman R., Laughton R.B., McKay D.S. and Usselman T.M. (1975) Morphology and composition of chalcopyrite, chromite, Cu, Ni-Fe, pentandite, and troilite in vugs of 76015 and 76215. Proc. 6th Lunar Sci. Conf. 719-728.

Heiken G.H., Butler P., Simonds C.H., Phinney W.C., Warner J., Schmitt H.H., Bogard D.D. and Pearce W.G. (1973a) Preliminary data on boulders at Station 6, Apollo 17 landing site. NASA TMX-58116, pp. 56.

Higuchi H. and Morgan J.W. (1975a) Ancient meteoritic component in Apollo 17 boulders. Proc. 6th Lunar Sci. Conf. 1625-1651.

Keith J.E., Clark R.S. and Bennett L.J. (1974a) Determination of natural and cosmic ray induced radionuclides in Apollo 17 lunar samples. Proc. 5th Lunar Sci. Conf. 2121-2138.

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.

McGee P.E., Simonds C.H., Warner J.L. and Phinney W.C. (1979) Introduction to the Apollo Collections: Part II Lunar Breccias. Curators Office.

Meyer C. (1994) Catalog of Apollo 17 rocks. Vol. 4 North Massif

Misra K.C., Walker B.M. and Taylor L.A. (1976b) Native FeNi metal particles in Apollo 17 Station 6 boulder (abs). Lunar Sci. VII, 565-567. Lunar Planetary Institute, Houston.

Misra K.C., Walker B.M. and Taylor L.A. (1976a) Textures and compositions of metal particles in Apollo 17, Station 6 boulder samples. Proc. 7th Lunar Sci. Conf. 2251-2266.

Morrison D.A. and Zinner E. (1975) Studies of solar flares and impact craters in partially protected crystals. Proc. 6th Lunar Sci. Conf. 3373-3390.

Morrison D.A. and Zinner E. (1977a) 12054 and 76215: New measurements of interplanetary dust and solar flare fluxes. Proc. 8th Lunar Sci. Conf. 841-863.

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.

Palme H. (1980) The meteoritic contamination of terrestrial and lunar impact melts and the problem of indigenous siderophiles in the lunar highlands. Proc. 11th Lunar Sci. Conf. 481-506.

Phinney W.C. (1981) Guidebook for the Boulders at Station 6, Apollo 17. Curatorial Branch Publication 55, JSC- 17243 pp. 125.

Puchtel I.S., Walker R.J., James O.B. and Kring D.A. (2008) Osmium isotope and highly siderophile element systematics of lunar impact melt breccias: Implications for the late accretion history of the Moon and Earth. Geochim. Cosmochim. Acta 72, 3022-3042.

Simonds C.H., Phinney W.C. and Warner J.L. (1974) Petrography and classification of Apollo 17 non-mare rocks with emphasis on samples from the Station 6 boulder. Proc. 5th Lunar Sci. Conf. 337-353.

Simonds C.H. (1975) Thermal regimes in impact melts and the petrology of the Apollo 17 Station 6 boulder. Proc. 6th Lunar Sci. Conf. 641-672.

Simonds C.H., Phinney W.C., Warner J.L. and Heiken G.H. (1975) Thermal regimes in crater debris as deduced from the petrology of the Apollo 17 Station 6 boulder and rake samples (abs). Lunar Sci. VI, 747-749. Lunar Planetary Institute, Houston.

Spudis P.D. and Ryder G. (1981) Apollo 17 impact melts and their relation to the Serenitatis basin. In Multi-Ring Basins. 133-148. (Schultz and Merrill eds.) Lunar Planetary Institute, Houston.

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

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.

Zinner E., Walker R.M., Chaumont J. and Dran J.C. (1976a) Ion probe analysis of artificially implanted ions in terrestrial samples and surface enhanced ions in lunar sample 76215,77. Proc. 7th Lunar Sci. Conf. 953-984.

Zinner E., Walker R.M., Chaumont J. and Dran J.C. (1977a) Ion microprobe surface concentration measurements of Mg and Fe and microcraters in crystals from lunar rock and soil samples. Proc. 8th Lunar Sci. Conf. 3859-3883.