10019 – 297 grams
10066 – 60 grams
Regolith Breccia

Figure 1: Photo of 10019,1. Cube is 1 inch and scale is in cm. NASA S76-23354.

Introduction

Kramer et al. (1077) reported that 10019 and 10066 appeared to be alike and their chemical compositions are found to be alike (figure 1 and 2). Fruland (1983) and Simon et al. (1984) included 10019 in the Regolith Breccia Initiative.

10019 has micrometeorite pits on the top surface (figure 1).

10066 has not been studied.

Simon's Mode for 10019

	S	L
Mare Basalt	4.4	10.8
Highland Component	0.6	
Regolith breccia	5.6	3
Agglutinate	11	1.8
Pyroxene	4.6	1.4
Olivine	0.5	
Plagioclase	2.2	0.2
Ilmenite	1.7	0.1
Orange glass	1.2	
Other glass	3	0.9
Matrix	47 %	

Figure 2: Photo of 10066,1. About 4 cm across. NASA S75-3112.

Petrography

10019 and 10066 are both glass-matrix regolith breccias (figure 3 and 4). Phinney et al. (1976) reported that 10019 was coherent with 10 % porosity. Phinney et al. termed 10019 a "vitric-matrix" breccia with 35 % glass in matrix and SEM evidence of apparent sintering - especially near glass spheres.

Simon et al. (1984) determined the mode for 10019 (see table). They calculated that it had about 25% highland component, but couldn't directly identify very many clasts of highland rock.

As is the case with other Apollo 11 breccias, Keil et al. (1970), Simon et al. (1984) and others have determined the composition of a wide range of glass particles in 10019. Some have the composition of the "orange glass" 74220, while one particle has the composition of HASP. A subset of the glass composition is different from the glass found in soil 10084, indicating that Apollo 11 breccias are derived from a different regolith (than 10084).

Significant Clasts

Keil et al. (1970) described an anorthosite clast in 10019 and determined the compositions of plagioclase, olivine and Mg-spinel.

Chemistry

Rhodes and Blanchard (1981) found that the composition of 10019 was similar to the other regolith breccias and 10084 (figure 5). The rare earth element patterns (figures 6 and 7) are exactly the same as for the soil. Rose et al. (1970) reported 157 ppm Ni.

Schonfeld and Meyer (1972) calculated that 10019 was a mix of mare basalt with ~19 % gabboic anorthosite and ~3.5 % KREEP, while Rhodes and Blanchard (1981) found it was a mix of soil and high-K basalt. However, Simon et al. (1984) could not identify such a high percentage of highland component.

Cosmogenic isotopes and exposure ages

The cosmic ray induced activity was reported by LSPET (1969) as ^{26}Al = 98 dpm/kg., ^{22}Na = 47 dpm/kg., ^{46}Sc = 10 dpm/kg., ^{54}Mn = 27 dpm/kg. and ^{56}Co = 35 dpm/kg.

Other Studies

Kirsten et al. (1970) used a microprobe technique to study the location of ^{4}He in a thin section of 10019.

Bloch et al. (1971) and Neukum et al. (1972) reported the size distribution of micrometeorite craters on 10019.

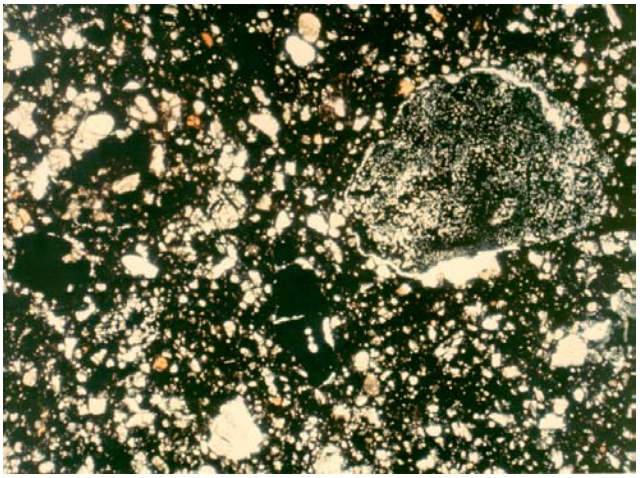


Figure 3: Transmitted light photomicrograph of thin section 10019,2 showing fine matrix with broken orange glass beads and rock clasts. Field of view is 2.5 mm. NASA# S70-19237.

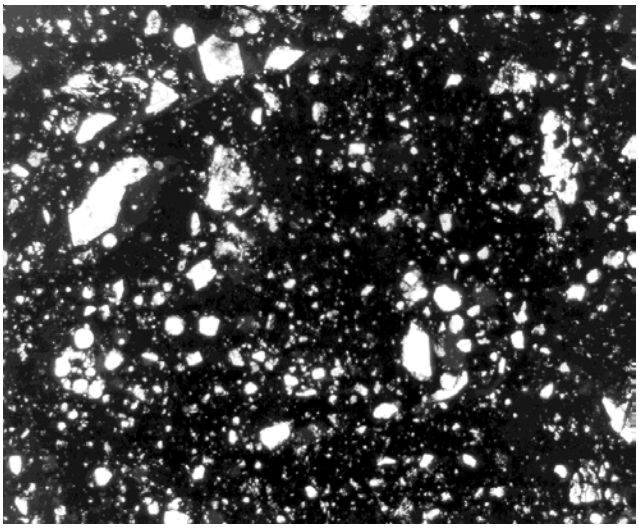
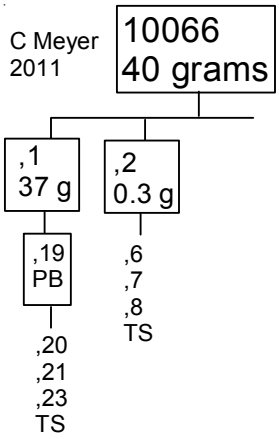


Figure 4: Photomicrograph of thin section 10066,20. NASA S76-26288.

Processing

10019 was one of the rocks in the F-201 at the time of the glove rupture (resulting in exposure to Houston air). Apollo 11 samples were originally described and cataloged in 1969 and "re-cataloged" by Kramer et al. (1977). There are 8 thin sections for 10019 and only 5 for 10066.



List of Photo #s for 10019

S69-46255 – 46333
S75-31360 – 31367
S76-26276 – 26278 TS

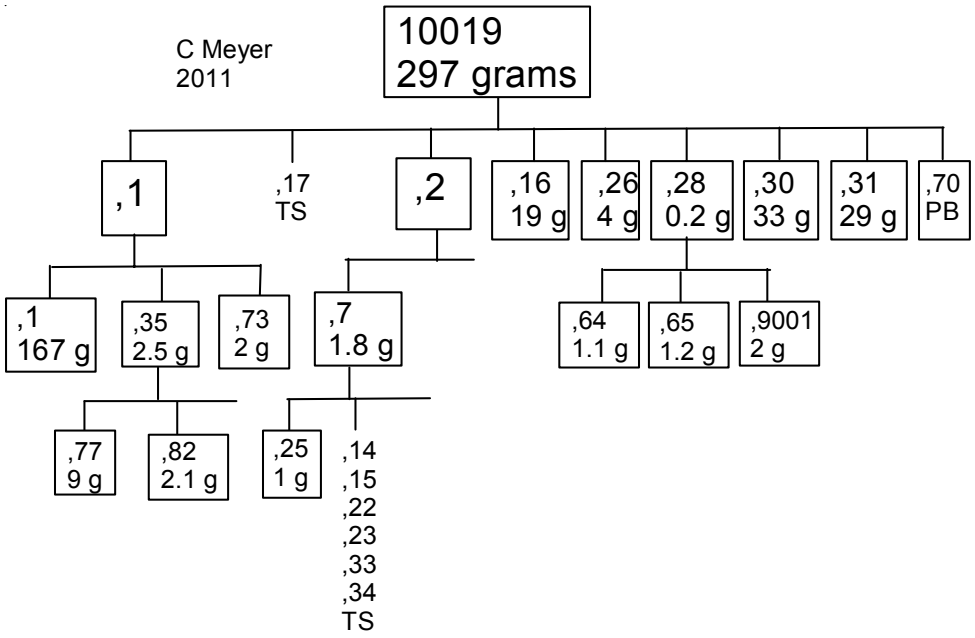


Table 1. Chemical composition of 10019.

reference	Rhodes81		Rose70		Wiesmann75		Wakita70		Goles70		LSPET69		O'Kelley70		Gopalan70
weight					50 mg		532 mg	497 mg							Lovering71
SiO2 %	41.6	(a)	41.1	(b)			41.1	*33.6*	(d) 40.4						
TiO2	7.6	(a)	8.25	(b)				8.8	(d) 8.2						
Al2O3	12.6	(a)	13.7	(b)			12.7	13.2	(d) 13						
FeO	15.78	(a)	15.7	(b)			17.1	16.6	(d) 16.3						
MnO	0.21	(a)	0.22	(b)			0.22	0.25	(d) 0.19	(d)					
MgO	7.74	(a)	7.86	(b)			8.8	7.1	(d) 6.3						
CaO	11.74	(a)	11.9	(b)				12.5	(d) 12.6						
Na2O	0.47	(a)	*0.93*	(b)			0.47	0.46	(d) 0.47	(d)					
K2O	0.15	(a)	0.14	(b)	0.16	(c)	0.11	0.13	(e)		0.145	(f)	0.145	(f)	0.17
P2O5	0.11	(a)													
S %															
sum															
Sc ppm							64	64	(d) 60.9	(d)					
V							86	98	(d) 63	(d)					
Cr	2050	(a)	2190	(b)			2110	1990	(d) 1870	(d)					
Co							36	34	(d) 34.5	(d)					
Ni			tr.												
Cu															
Zn															
Ga															
Ge ppb															
As															
Se															
Rb					3.25	(c)	3.4		(e)						3.31
Sr					167	(c)									166.4
Y							91		(e)						
Zr			tr.		326	(c)	490	220	(d) 580	(d)					
Nb															
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb															
Cd ppb															
In ppb							5.2		(e)						
Sn ppb															
Sb ppb															
Te ppb															
Cs ppm							0.41		(e)						
Ba					174	(c)	340	130	(d)						
La					16.6	(c)	15.1	14.1	(e) 15.5	(d)					
Ce					47.2	(c)	56		(e) 54	(d)					
Pr									(e)						
Nd					37.7	(c)	42		(e)						
Sm					13.1	(c)	13.8	14.2	(e) 12.7	(d)					
Eu					1.77	(c)	1.9	2	(e) 1.78	(d)					
Gd					18.6	(c)	20.5		(e)						
Tb							3.8		(e)						
Dy					20.6	(c)	18		(e)						
Ho							5.9		(e) 5	(d)					
Er					12.1	(c)	14.1		(e)						
Tm							2		(e)						
Yb					11.1	(c)	12.4	12	(e) 11.7	(d)					
Lu							1.6	1.6	(e) 1.84	(d)					
Hf							13	14	(d) 10.8	(d)					
Ta									1.7	(d)					
W ppb															
Re ppb															0.73
Os ppb															7.8
Ir ppb															
Pt ppb															
Au ppb															
Th ppm					2.16	(c)	2.7	3.2	(d)		1.9	(f)	1.9	(f)	
U ppm					0.58	(c)			0.49	(d)	0.43	(f)	0.43	(f)	

technique: (a) XRF, (b) semimicro XRF, (c) IDMS, (d) INAA, (e) RNAA, (f) rad. Counting

Table 2. Chemical composition of 10066.

reference	Goles70	
weight		
SiO2 %	43.2	
TiO2	8.2	
Al2O3	12.2	
FeO	16.5	
MnO	0.2	(a)
MgO	7.6	
CaO	12	
Na2O	0.46	(a)
K2O		
P2O5		
S %		
sum		
Sc ppm	60.3	(a)
V	59	(a)
Cr	1910	(a)
Co	33.8	(a)
Ni		
Cu		
Zn		
Ga		
Ge ppb		
As		
Se		
Rb		
Sr		
Y		
Zr		
Nb		
Mo		
Ru		
Rh		
Pd ppb		
Ag ppb		
Cd ppb		
In ppb		
Sn ppb		
Sb ppb		
Te ppb		
Cs ppm		
Ba		
La	17.4	(a)
Ce	62	(a)
Pr		
Nd		
Sm	15.1	(a)
Eu	1.7	(a)
Gd		
Tb	2.8	(a)
Dy		
Ho	6.5	(a)
Er		
Tm		
Yb	11.8	(a)
Lu	1.9	(a)
Hf	10.6	(a)
Ta	2.1	(a)
W ppb		
Re ppb		
Os ppb		
Ir ppb		
Pt ppb		
Au ppb		
Th ppm		
U ppm	0.56	(a)

technique: (a) INAA

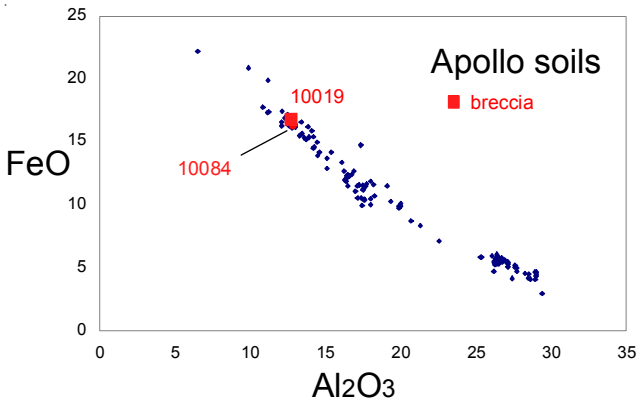


Figure 5: Composition of 10019 compared with Apollo soil samples.

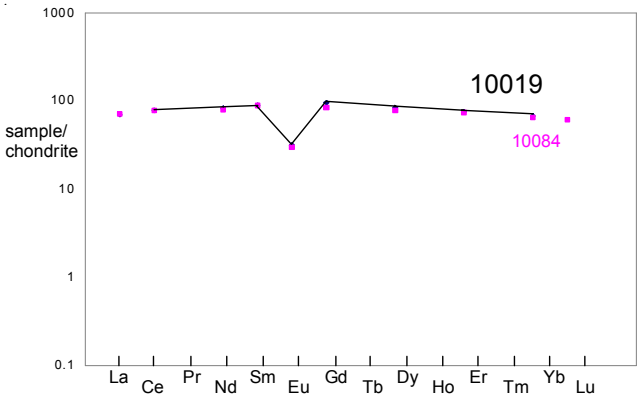


Figure 6: Normalized rare earth element diagram for breccia 10019 compared with soil 10084 (data from Wiesmann et al. 1970).

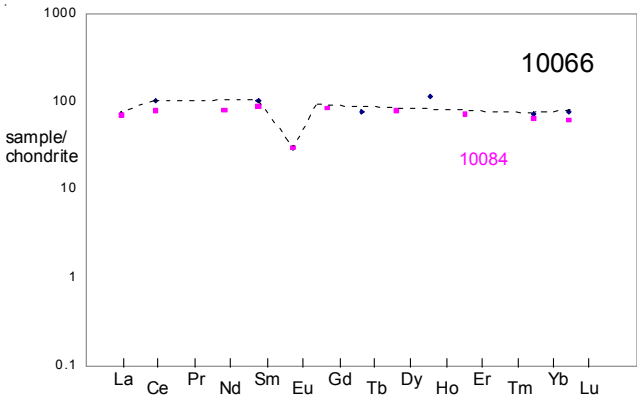


Figure 7: Normalized rare earth element diagram for breccia 10066 compared with soil 10084 (data from Goles et al. 1970).

References for 10019 and 10066

Bloch M.R., Fechtig H., Genter W., Neukum G. and Schneider E. (1971) Meteorite impact craters, crater simulations, and the meteoroid flux in the early solar system. *Proc. Second Lunar Sci. Conf.* 2639-2652

Cloud P., Margolis S.V., Moorman M., Barker J.M., Licari G. Kringsley D. and Barnes V.E. (1970) Micromorphology and Surface Characteristics of Lunar Dust and Breccia. *Proc. Apollo 11 Lunar Science Conf.* 1793- 1798.

Ehmann W.D. and Morgan J.W. (1970) Oxygen, silicon and aluminium in Apollo 11 rocks and fines by 14 MeV Neutron Activation. *Proc. Apollo 11 Lunar Science Conf.* 1071-1079.

Fruland Ruth M. (1983) Regolith Breccia Workbook. Curatorial Branch Publication # 66. JSC 19045.

Ganapathy R., Keays R.R., Laul J.C. and Anders E. (1970) Trace elements in Apollo 11 lunar rocks: Implications for meteorite influx and origin of moon. *Proc. Apollo 11 Lunar Sci. Conf.* 1117-1142.

Goles G., Randle K., Osawa M., Schmitt R.A., Wakita H., Ehmann W.D. and Morgan J.W. (1970) Elemental abundances by instrumental activation analyses in chips from 27 lunar rocks. *Proc. Apollo 11 Lunar Sci. Conf.* 1165-1176.

Gopalan K., Kaushal S., Lee-Hu C. and Wetherill G.W. (1970) Rb-Sr and U, Th-Pb ages of lunar materials. *Proc. Apollo 11 Lunar Sci. Conf.* 1195-1206.

Keil K., Bunch T.E. and Prinz M. (1970) Mineralogy and composition of Apollo 11 lunar samples. *Proc. Apollo 11 Lunar Sci. Conf.* 561-598.

King E.A. *and a cast of thousands* (1969) Lunar Sample Information Catalog, Apollo 11. Lunar Receiving Laboratory, MSC 412 pp

Kirsten T., Muller O., Steinbrunn F. and Zahringer J. (1970) Study of the distribution and variations of rare gases in Lunar Material by a microprobe technique. *Proc. Apollo 11 lunar science Conf.* 1331-1344.

Kramer F.E., Twedell D.B. and Walton W.J.A. (1977) **Apollo 11 Lunar Sample Information Catalogue** (revised). Curator's Office, JSC 12522

Lofgren G.E. (1971b) Devitrified glass fragments from Apollo 11 and Apollo 12 lunar samples. *Proc. 2nd Lunar Sci. Conf.* 949-955

Lovering J.F. and Ware N.G. (1970a) Electron probe microanalyses of minerals and glasses in Apollo 11 lunar samples. *Proc. Apollo 11 Lunar Sci. Conf.* 633-654.

Lovering J.F. and Hughes T.C. (1971) Re and Os determinations and meteoritic contamination levels in Apollo 11 and Apollo 12 lunar samples. *Proc. Second Lunar Sci. Conf.* 1331-1335.

LSPET (1969) Preliminary examination of lunar samples from Apollo 11. *Science* **165**, 1211-1227.

McKay D.S., Greenwood W.R. and Morrison D.A. (1970) Origin of small lunar particles and breccias from the Apollo 11 site. *Proc. Apollo 11 Lunar Sci. Conf.* 673-693.

Neukum G., Schneider E., Mehl A., Storzer D., Wagner G.A., Fectig H. and Bloch M.R. (1972) Lunar craters and exposure ages derived from crater statistics and solar flar tracks. *Proc. 3rd Lunar Sci. Conf.* 2793-2810.

O'Kelley G.D., Eldridge J.S., Schonfeld E. and Bell P.R (1970) Primordial radionuclide abundances, solar proton and cosmic ray effects and ages of Apollo 11 lunar samples by non-destructive gamma-ray spectrometry. *Proc. Apollo 11 Lunar Sci. Conf.* 1407-1424.

Phinney W.C., McKay D.S., Simonds C.H. and Warner J.L. (1976a) Lithification of vitric- and clastic-matrix breccias: SEM photography. *Proc. 7th Lunar Sci. Conf.* 2469-2492.

Rhodes J.M. and Blanchard D.P. (1981) Apollo 11 breccias and soils: Aluminous mare basalts or multi-component mixtures? *Proc. 12th Lunar Planet. Sci. Conf.* 607-620.

Rose H.J., Cuttitta F., Dwornik E.J., Carron M.K., Christian R.P., Lindsay J.R., Ligon D.T. and Larson R.R. (1970a) Semimicro chemical and X-ray fluorescence analysis of lunar samples. *Science* **167**, 520-521.

Rose H.J., Cuttitta F., Dwornik E.J., Carron M.K., Christian R.P., Lindsay J.R., Ligon D.T. and Larson R.R. (1970b) Semimicro X-ray fluorescence analysis of lunar samples. *Proc. Apollo 11 Luanr Sci. Conf.* 1493-1497.

Schmitt H.H., Lofgren G., Swann G.A. and Simmons G. (1970) The Apollo 11 samples: Introduction. *Proc. Apollo 11 Lunar Science Conf.* 1-54.

Simon S.B., Papike J.J., Shearer C.K. and Laul J.C. (1983) Petrology of the Apollo 11 highland component. *Proc. 14th Lunar Planet. Sci. Conf. in J. Geophys. Res.* **88**, B103-138.

Simon S.B., Papike J.J. and Shearer C.K. (1984) Petrology of Apollo 11 regolith breccias. *Proc. 15th Lunar Planet. Sci. Conf.* in *J. Geophys. Res.* **89**, C109-132.

Wakita H., Schmitt R.A. and Rey P. (1970) Elemental abundances of major, minor, and trace elements in Apollo 11 lunar rocks, soil, and core samples. *Proc. Apollo 11 Lunar Sci. Conf.* 1685-1717.