12054
Glass-coated Ilmenite Basalt
687 grams

Figure 1: Photograph of 12054,0 showing shiny glass coating and large (cm-sized) glass-lined micrometeorite pit with surrounding spall zone. The light-colored area was below the soil line and protected from the glass splash. Scale is in cm. NASA photo # S69-62793.

Introduction

Lunar sample 12054 is an ilmenite basalt with 4.7 wt. percent TiO_2 (Neal et al. 1994). It is one of only a few mare basalts with shock features (Schaal and Hörz 1977).

Much of 12054 has been coated by a large glass splash (figure 1). The glass is described as yellowish orange to reddish brown and is about 0.5 mm thick in most places. According to Schaal and Hörz, the glass coating did not form *in situ*, but was deposited as an "impact melt splash derived from a basalt similar to 12054" (not soil).

12054 has been used for numerous "consortium studies" related to exposure phenomena (micrometeorites, sputtering, solar-flare tracks, ion implantation etc). In fact, this rock was used as a sort of "standard" for micrometeorite "zap" pit, cosmic-ray track studies and irradiation history because it had a known orientation, glass coating and relatively simple history (Hartung et al. 1978, Zook 1978). The orientation of Apollo 12 samples is discussed in Sutton and Schaber (1971) and Hartung et al. (1978) who match a picture of 12054 from the lunar surface with artificial lighting in the laboratory.

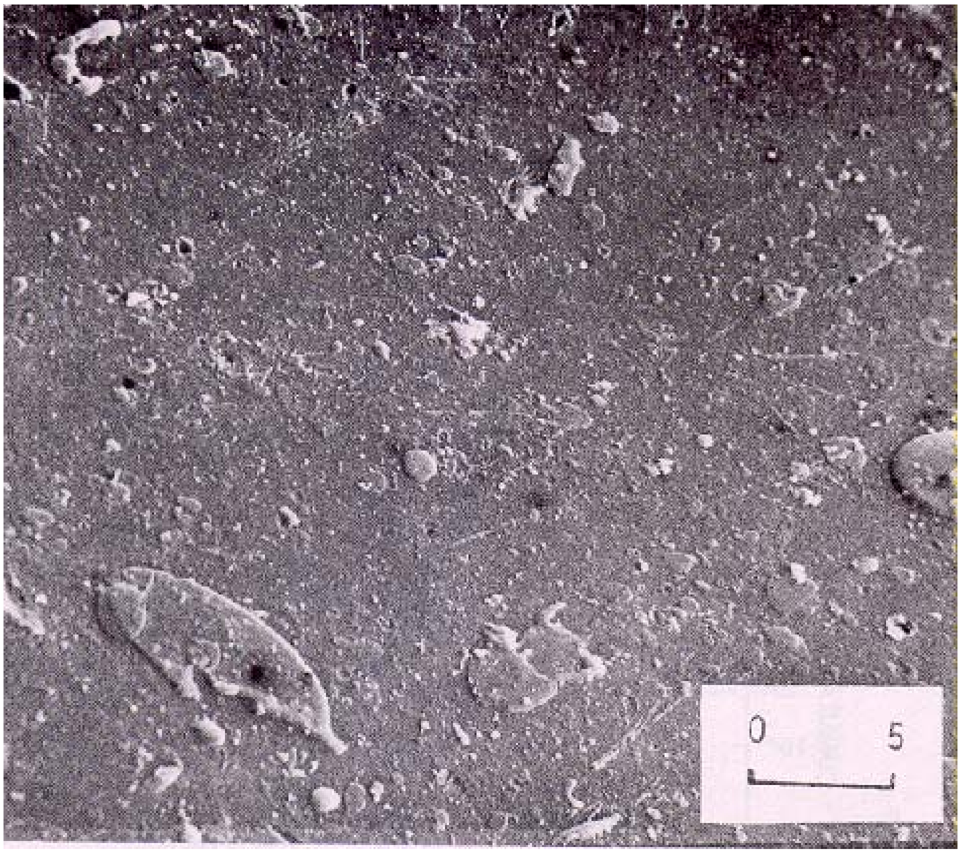


Figure 2: The very surface of the moon! This scanning electron microscope photo of the surface of 12054 shows that minute glass splashes and pancakes accrete on the exposed surfaces of moon rocks (from Morrison and Zinner 1977). Scale is 5 microns.

Petrography

The basaltic texture of 12054 can be seen in the photos of the sawn surfaces (figure 8, 9). Dungan and Brown (1977) briefly describe 12054 as medium-grained, equigranular, with lath-shaped plagioclase and equant to slightly elongate pyroxene intergrown, suggestive of coetectic crystallization. Elongate ilmenite and small segregations of "symplectoid mesostasis" are common features. Schaal and Hörz (1977a) and Neal et al. (1994) classify 12054 as an ilmenite basalt. Schaal and Hörz find that 12054 has been shocked to ~250-450 kbars. Diaplectic feldspars are highly fractured. Pyroxene crystals exhibit pronounced undulatory extinction and decreased birefringence.

Mineralogical Mode for 12054

	Schaal and Horz 1977a	Neal et al. 1994
Olivine		10.8
Pyroxene	62	62.1
Plagioclase	29	27.9
Ilmenite	11	5.2
Chromite		~2
Mesostasis		~2

The glass coating is a flowed basaltic melt which thermally modified 12054 along its contact. The glass contains oblong vesicles (up to 1.2 mm) and schlieren up to 0.4 mm. Schaal and Hörz describe "dendrites" in some of the glass.

Hörz et al. (1971), Hartung et al. (1972, 1978), Morrison and Zinner (1977), and Mandeville (1977) carefully studied the size frequency distribution of micrometeorites and solar flare track density on the glass surface of 12054 (figure 9). McDonnell (1977) and Zook (1978) reported on the accreta and dust on the surfaces of 12054 (figures 2, 12).

Mineralogy

Pyroxene: Pyroxene shows "patchy extinction" and a "marked decrease in birefringence". Pyroxene compositions were determined by Schaal and Hörz (1977) (figure 3).

Plagioclase: Plagioclase in 12054 is shocked to maskelynite ($An_{93} – An_{89}$).

Ilmenite: Long ilmenite needles (~0.8 cm) can be seen in photos of the slabbed surfaces (figures 8, 10). Ilmenite is fractured and has "bent lamellae less than 15 micons wide".

Glass: The glass coating on 12054 (figure 9) was analyzed by Schaal and Hörz (1977).

Chemistry

O'Kelley et al. (1971a) determined U, Th and K by radiation counting (table 1). Neal et al. (1994) reanalyzed 12054 and found the earlier analysis by Rhodes et al. (1977) to be repeatable (figure 5).

Radiogenic age dating

The crystallization age of 12054 has not been determined. The age of the shock event is also unknown.

Cosmogenic isotopes and exposure ages

O'Kelley et al. (1971b) determined the activity ^{22}Na = 39 ± 7 dpm/kg, ^{26}Al = 50 ± 10 dpm/kg, ^{46}Sc = 52 ± dpm/kg, ^{54}Mn = 36 ± 5 dpm/kg, and ^{56}Co = 40 ± 10 dpm/kg.

Bogard et al. (1971) determined rare gasses in 12054 and Hartung et al. (1977) measured He, Ne and Ar on sunlit and shaded surfaces of 12054 by laser ablation mass spectroscopy. Kerridge (1991) used this data to calculate the sputter-erosion rate of the lunar surface (<0.24 microns/m.y.).

Morrison and Zinner (1977) calculate an exposure age of 1.75 x 10^5 yr. using the track production rate of Blanford et al. (1975) and 1.6 x 10^5 yr. based on ^{26}Al. This is comparable to the galactic cosmic ray exposure age of 1.5 x 10^5 yr. from the data of Bogard.

Other Studies

Samples were apparently allocated to Arnold and Nishiizumi for cosmic ray depth profile studies (unpublished?).

Processing

Figure 11 shows a schematic drawing of the slab that was cut through 12054 (figure 9, 10). Only two thin sections were prepared There are 4 thin sections.

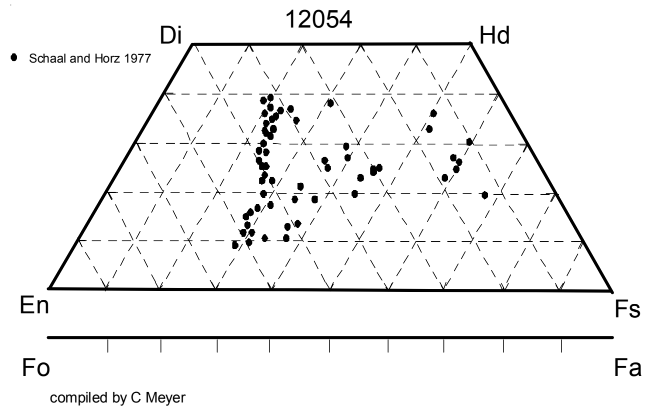


Figure 3: Pyroxene composition diagram for 12054 (from Schaal and Horz 1977).

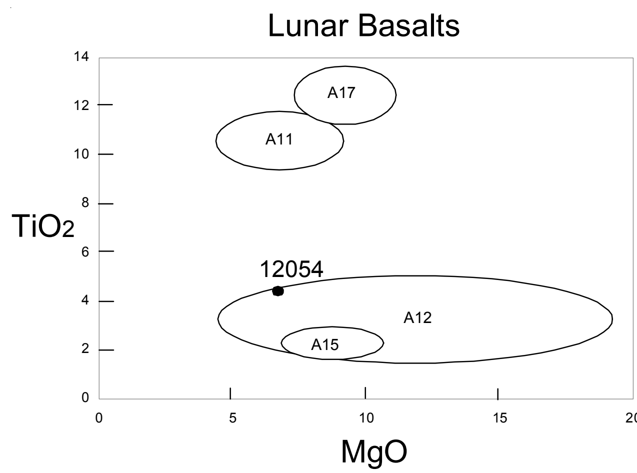


Figure 4: Composition of 12054 compared with that of other lunar basalts.

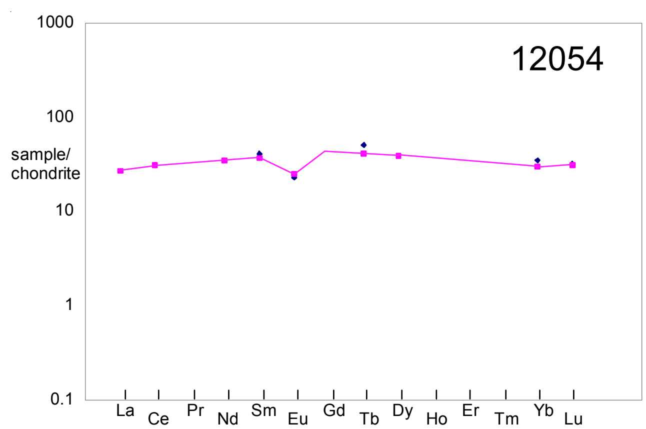


Figure 5: Normalized rare-earth-element diagram for 12054 (data from Neal et al. 1994 and Rhodes et al. 1977).

Table 1. Chemical composition of 12054.

reference	O'Kelley71		Rhodes77		Schaal77		Gibson77		Nyquist77		Neal 94		LSPET70		Neal2001	
weight	687 g				glass						0.694		687 g			
SiO2 %			45.86	(b)	43.27	(c)										
TiO2			4.63	(b)	4.72	(c)					4.7	(f)				
Al2O3			10.47	(b)	9.51	(c)					10.1	(f)				
FeO			19.51	(b)	19.57	(c)					20.2	(f)				
MnO			0.29	(b)	0.24	(c)					0.262	(f)				
MgO			6.67	(b)	9.22	(c)					7.7	(f)				
CaO			11.93	(b)	11.45	(c)					10	(f)				
Na2O			0.31	(f)	0.23	(c)					0.294	(f)				
K2O	0.064	(a)	0.07	(b)							0.062	(f)	0.063	(a)		
P2O5			0.06	(b)												
S %			0.09	(b)			0.141	(d)								
sum																
Sc ppm			64	(f)							64.3	(f)			78	(g)
V											144	(f)			193	(g)
Cr			2258	(f)	2463	(c)					2150	(f)			2841	(g)
Co			31	(f)							33.7	(f)			39	(g)
Ni											31	(f)			9.1	(g)
Cu															27	(g)
Zn															37	(g)
Ga															4.15	(g)
Ge ppb																
As																
Se																
Rb									0.408	(e)					1.14	(g)
Sr			162	(b)					388	(e)	111	(f)			171	(g)
Y			51	(b)											65	(g)
Zr			128	(b)											221	(g)
Nb			6.3	(b)											8.71	(g)
Mo																
Ru																
Rh																
Pd ppb																
Ag ppb																
Cd ppb																
In ppb																
Sn ppb																
Sb ppb																
Te ppb																
Cs ppm															0.03	(g)
Ba			64	(e)							76	(f)			73	(g)
La											6.3	(f)			7.13	(g)
Ce			18.8	(f)							18.7	(f)			19.7	(g)
Pr															3.3	(g)
Nd											16	(f)			16.7	(g)
Sm			6	(f)							5.5	(f)			6.11	(g)
Eu			1.27	(f)							1.4	(f)			1.37	(g)
Gd															8.65	(g)
Tb			1.85	(f)							1.48	(f)			1.54	(g)
Dy											9.4	(f)			10.2	(g)
Ho															2.12	(g)
Er															6.15	(g)
Tm															0.87	(g)
Yb			5.8	(f)							4.9	(f)			5.54	(g)
Lu			0.78	(f)							0.75	(f)			0.73	(g)
Hf			4.8	(f)							4.1	(f)			5.7	(g)
Ta											0.4	(f)			0.44	(g)
W ppb															80	(g)
Re ppb																
Os ppb																
Ir ppb																
Pt ppb																
Au ppb																
Th ppm	0.79	(a)									0.61	(f)	0.77	(a)	0.78	(g)
U ppm	0.22	(a)											0.21	(a)	0.23	(g)

technique: (a) radiation counting, (b) XRF, (c) e-probe, (d) sulfur, (e) IDMS, (f) INAA, (g) ICP-MS

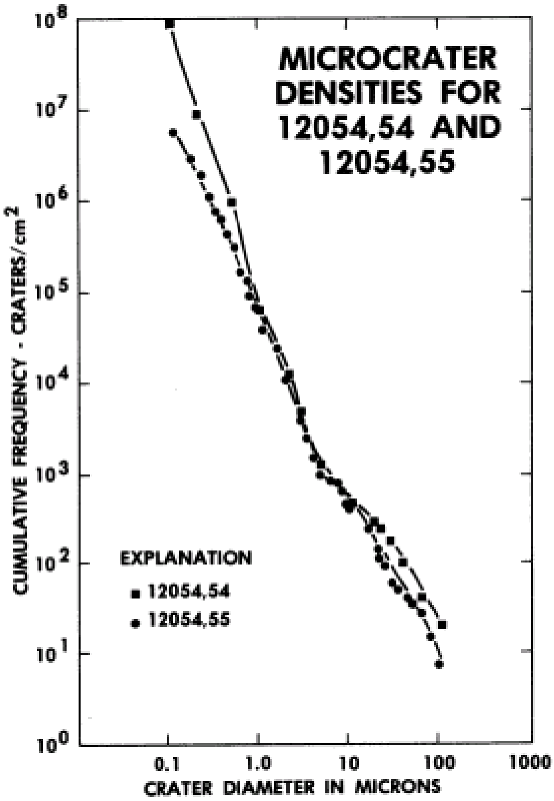


Figure 6: Size frequency distribution of micrometeorite craters on 12054 (from Morrison and Zinner 1977).

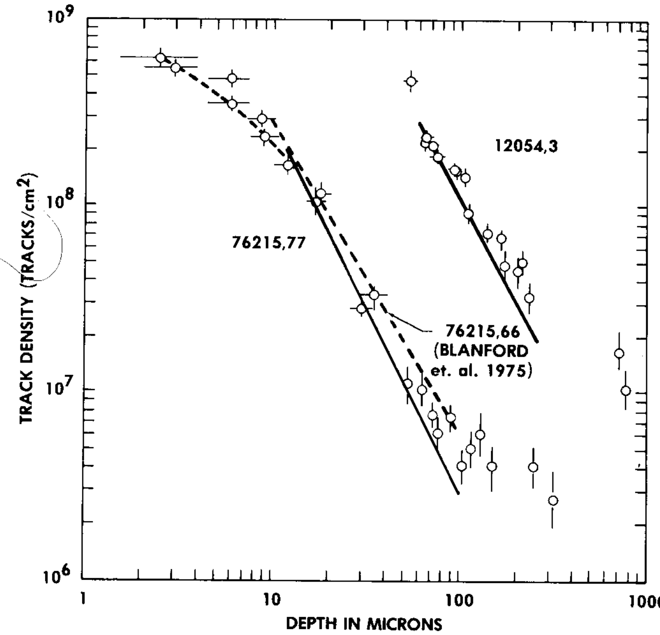


Figure 7: Solar flare track density as function of depth in glass on 12054 (from Morrison and Zinner 1977).

List of Photo #s 12054

S69-60972	Science
S69-62772-795	color mug shots
S70-22984-998	close up, surface
S75-34420	,11 butt end
S76-21409	surface of slab
S76-21417	slab pieces
S78-23277	glass splash
S70-22988	surface, close up

Figure 8: Photo of end-piece 12054,11, after sawing, illustrating basaltic texture. NASA # S75-34420. Sample is 7 cm across.

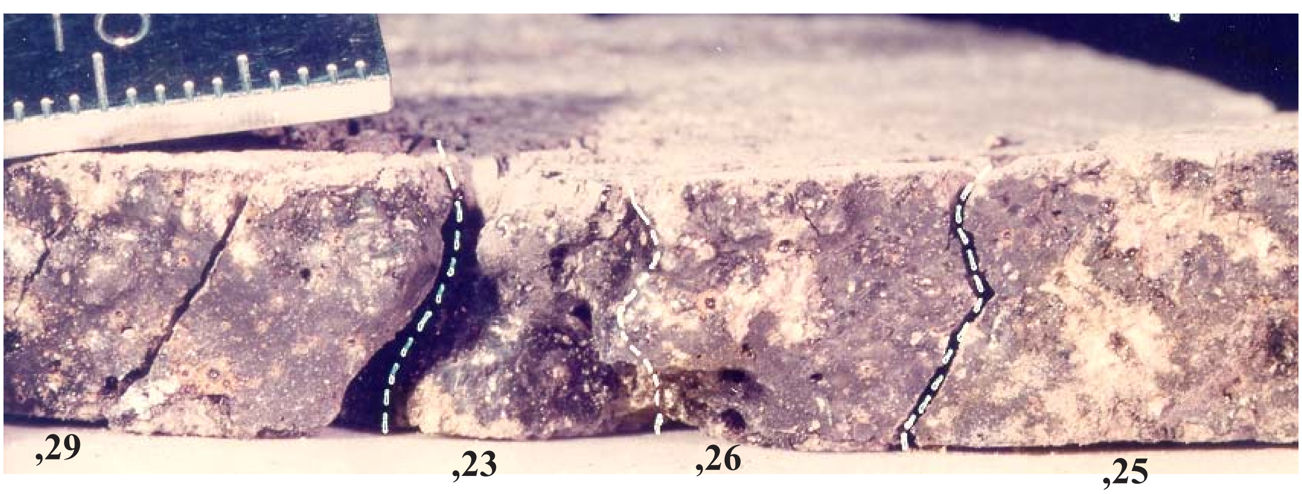


Figure 9: Surface of slab cut from 12054. NASA # S76-21409. Scale in mm.

Figure 10: Photo of cm-thick slab (,29) cut through the middle of 12054. Cube is 1 cm. NASA # S76-21417.

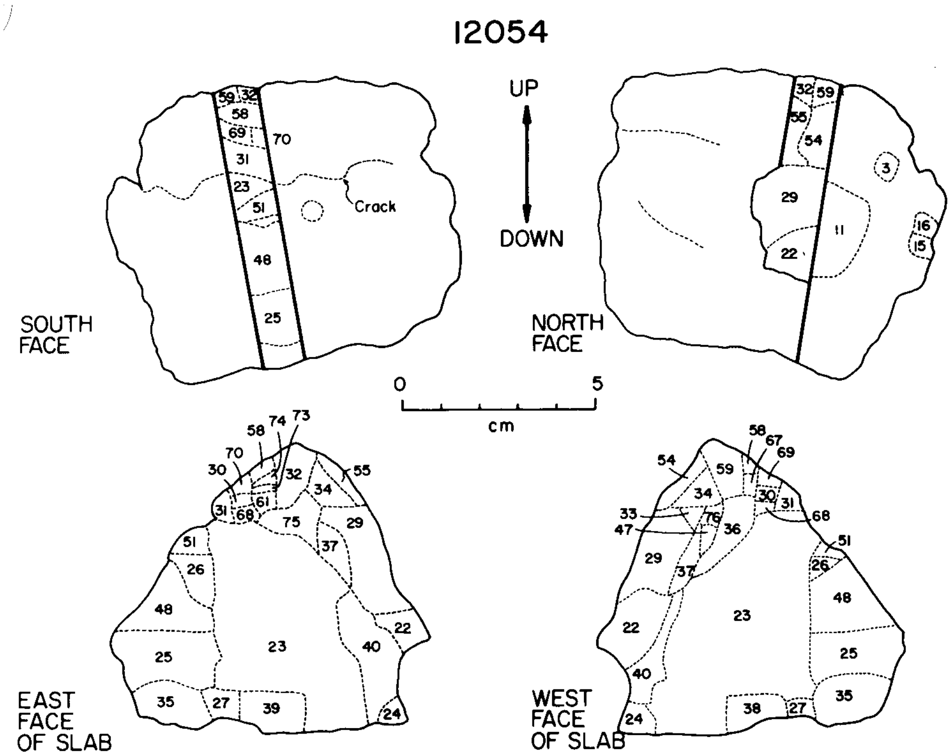
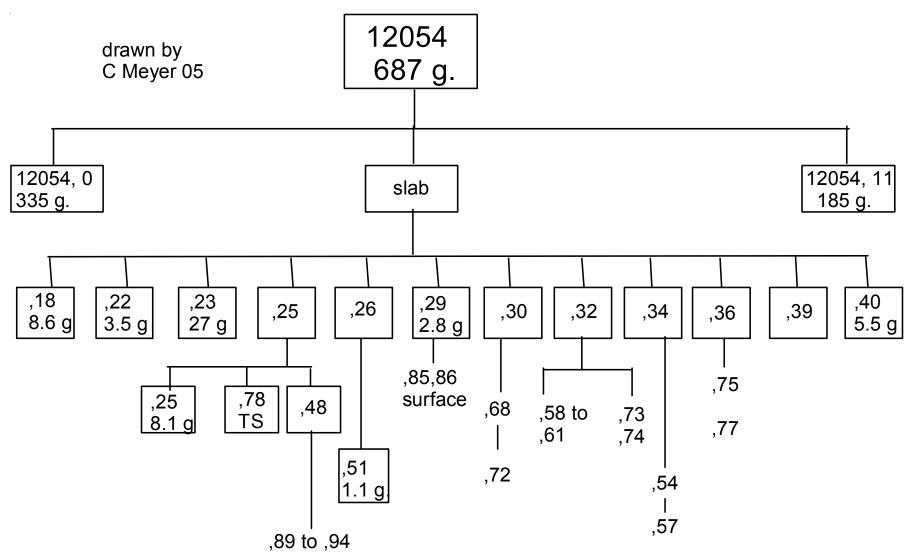


Figure 11: Cutting diagram for 12054 showing position and orietation of of slab (from Hartung et al. 1978).



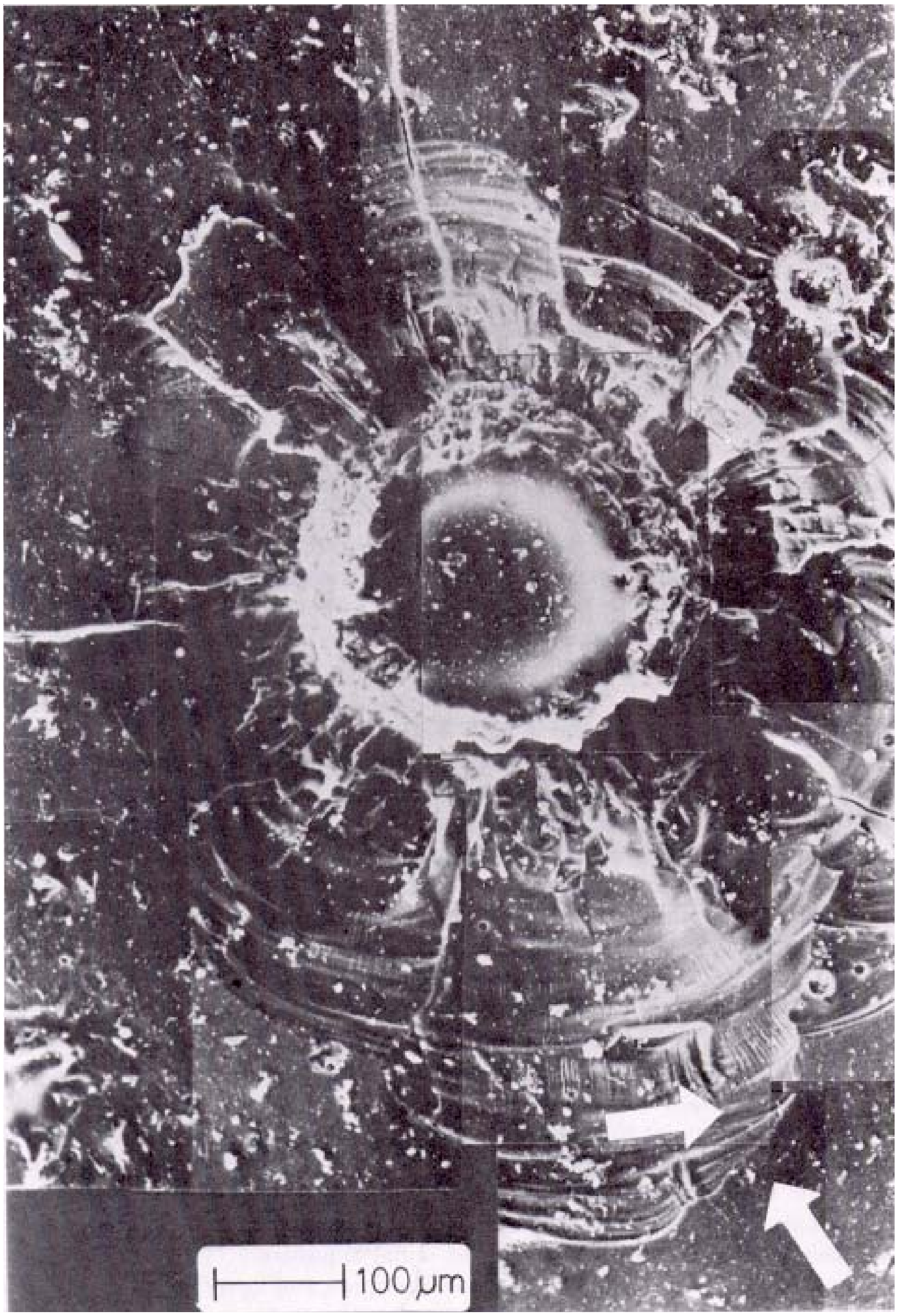


Figure 12: Large micrometeorite crater (zap pit) with surrounding spall zone on surface of 12054 (from McDonnell 1977). Note the materials that have acreted since the crater formed.

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