14311

Impact melt Breccia

3204 grams

Figure 1: Photo of dust covered 14311. Note the large mottled white clast in the lower left corner (,213). NASA S71-32958. Sample is about 15 cm across.

Introduction

14311 was one of the largest samples returned from Apollo 14, and is sort of an "end-member" in the metamorphic sequence proposed by (Warner, Williams, Simonds and others). However, it has not been well analyzed and there is only one radiometric age (3.8 b.y).

14311 is a very coherent impact melt breccia, with a texture that is somewhat like that of the large station 6 boulder at Apollo 17 (Simonds et al. 1976). The melted and recrystallized matrix has reacted with, and perhaps dissolved, some of the clasts. Void space in the matrix has annealed to form larger vugs. It was collected from a small crater at station Dg, but was not photographed in place. Orientation was determined by location of micrometeorite pits (Horz et al. 1972; Morrison et al. 1972).

Three large pieces of rock from the same bag were initially labeled 14308, but were found to fit 14311 (figures 1 and 2) and relabeled.

The exposure age of 14311 is old - 661 m.y.

Petrography

Dence and Plant (1972) found the 14311 was "more thoroughly annealed and contains many vug linings and inclusions of potassic granitic glass, some partly devitrified." Wilshire and Jackson (1972) noted that

Mineralogical Mode for 14311

	Simonds et al 1977
Matrix	75 %
Clasts	
Plagioclase	6.5
Mafic	3
Breccia	2.5
Granulite	4.5
Pore space	8.5

Figure 2: Photo of 14308, which was found to be part of 14311 (see figure 1). NASA S71-21491.

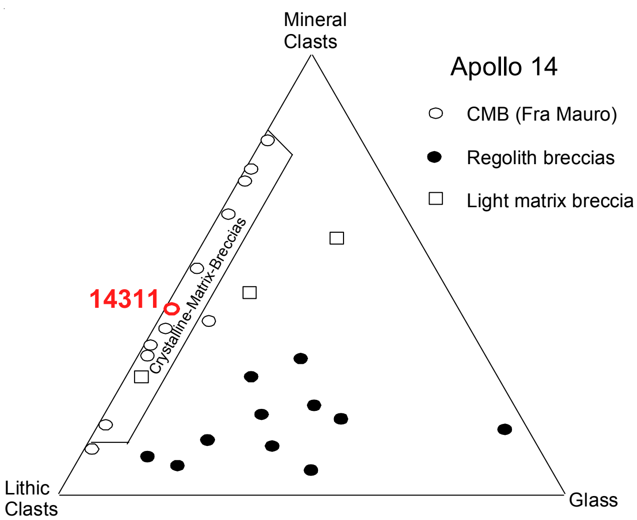


Figure 3: Ratio of clast abundances in Apollo 14 breccias (a la Simonds et al. 1977).

14311 was a fragmental breccia with dark clasts and a coherent matrix. Warner (1972), Chao et al. (1972), Quaide and Wrigley (1972), von Engelhart et al. (1972) and Simonds et al. (1977) all recognized that 14311 had a crystalline matrix. McGee et al. (1977) and Carlson and Kramer (1978) have summarized the petrography of 14311.

14311 contains relatively large vugs with some obvious alignment (Swann et al. 1977). It is as though the void space in this breccia gathered itself together to form large vugs and vesicles.

Whitlockites (phosphates) in rock 14311 have fewer fission tracks than expected indicating a postformation annealing event (Crozaz et al. 1972). This observation appaers to be at odds with the old “crystallization” age of 3.8 b.y. (see below).

Significant Clasts

Ilmenite “ore” ,90

Meyer et al. (1989, 1996) studied a large euhedral zircon (200 x 800 micron) in an ilmenite-filled vug found in thin section 14311,90 (figure 9). They determined the U/Pb age for the zircon as 4.250 ± 0.002 b.y. Since the zircon had high U (300 ppm) and contained patches of K-spar, this broken fragment, or vug filling, was grouped along with lunar granites. A large exsolved pyroxene grain in the same patch was found to be iron-rich (En_{43})(figure 10).

W2 “c” Gabbronorite ,213 ,220

Twedell et al. (1978) and Warren et al. (1983) reported a large white clast of gabbro with cataclastic texture (figures 1 and 7). It is apparently monomict and has ~75% plagioclase (An_{85}), 11% orthopyroxene (En_{62}), 10% pigeonite, 2.2% augite and 2 % ilmenite. Warren gives an analysis with high Ir (table 1), but considers it “marginally pristine” (Warren 1993).

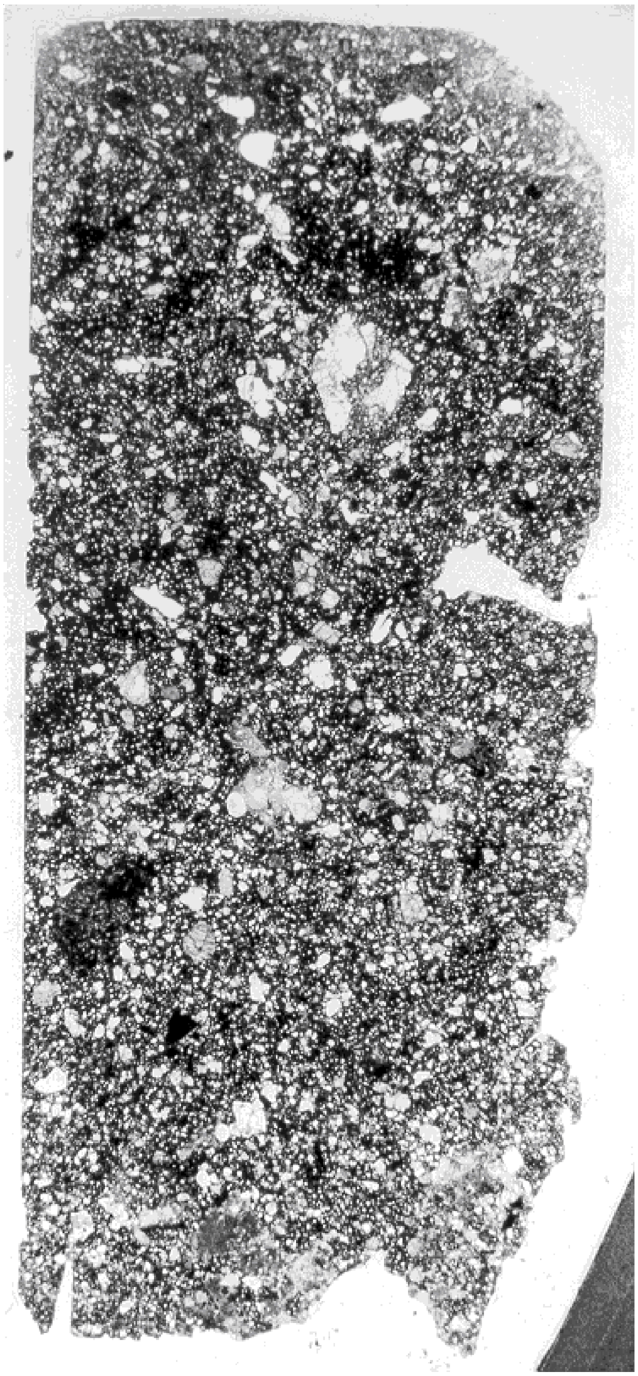


Figure 4: Thin section photo of 14311,180 showing clastic nature of rock. Section is 1.2 cm wide and 3.5 cm long. NASA S71-40507.

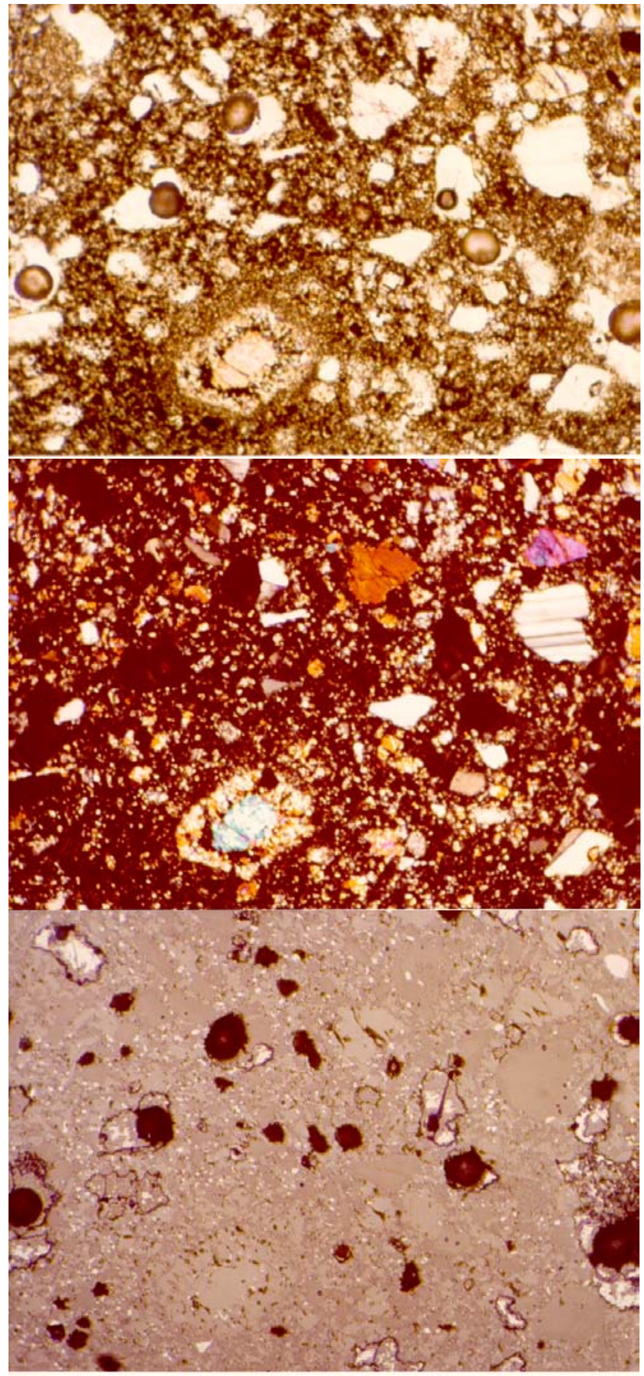


Figure 5: Photomicrographs of thin section 14311,93. Top view is plane polarized light, middle is crossed polarized and bottom is reflected. NASA S79-27477, 27476 and 27375. Note reaction relations of olivine clast with breccia melt. Note also the vesicles.

Gabbronorite ,96

Hunter and Taylor (1983) also reported mineral analysis (An_{85}; En_{63}) for a small clast of gabbronorite found in thin section.

Mineralogy

Olivine: Quaide and Wrigley (1972) and Wilshire and Jackson (1972) noted that olivine in 14311 formed a reaction relation with melt (figure 8). Cameron and Fischer (1975) found that there was a systematic

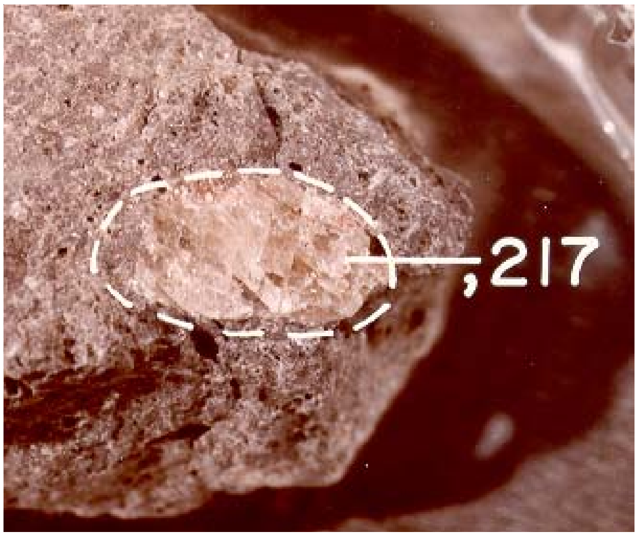


Figure 6: Closeup photo of coarse plagioclase clast in 14311,216. NASA S80-552. Clast is about 0.9 cm.

Figure 7: Closeup photo of mottled white clast (,213) in on N1 face of 14311. Clast is about 1.4 cm. NASA S77-22155.

relationship between the composition of an olivine clast and the mineralogy of its reaction corona in 14311. They found that olivine more Fe-rich than Fo_{58} is mantled by pigeonite plus ilmenite; olivine Fo_{58-61} is mantled by orthopyroxene, pigeonite, ilmenite and minor plagioclase; olivine Fo_{61-65} is mantled by orthopyroxene, ilmenite and plagioclase and olivine Fo_{65} and above is mantled by orthopyroxene with higher Mg content. Sue Kesson (1975) was able to reproduce these effects in laboratory experiments, proving that they could take place in the time and temperature conditions of a hot ejecta blanket, such as that of the Fra Mauro Formation.

Pyroxene: Pyroxene analyses for grains in the matrix were tabulated by Simonds et al. (1977) and McGee et al. (1979)(figure 10).

Plagioclase: Simonds et al. (1977) reported plagioclase An_{85}.

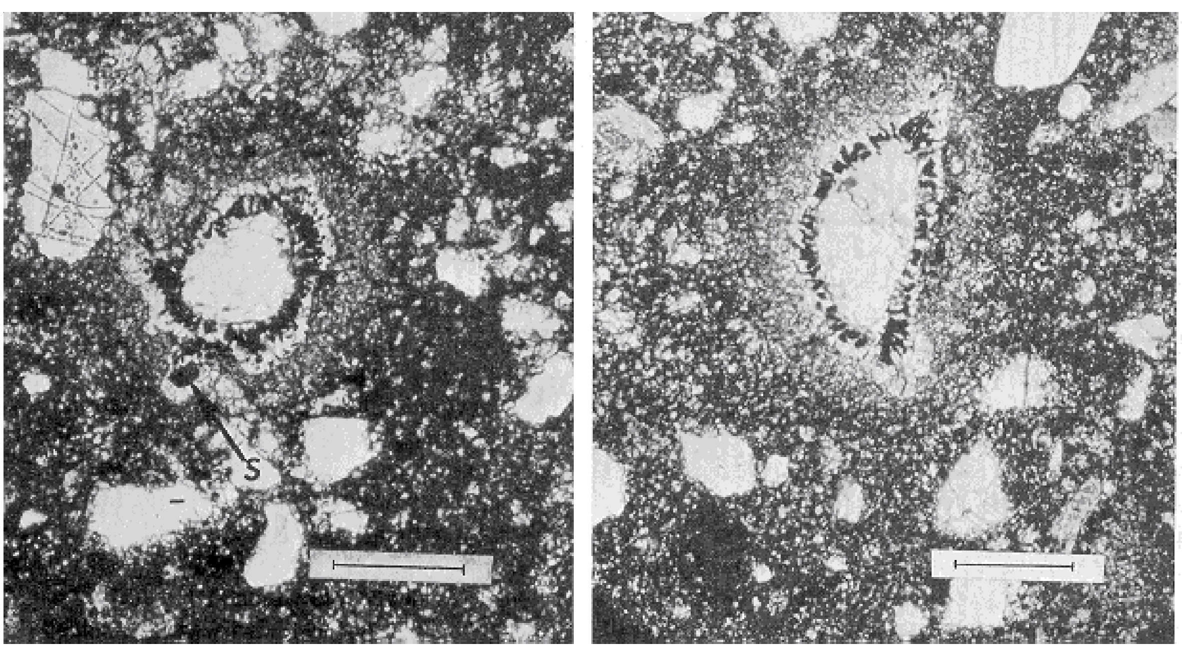


Figure 8: Olivine clasts with "corona". Scale bar is 100 micron (from Cameron and Fischer 1975).

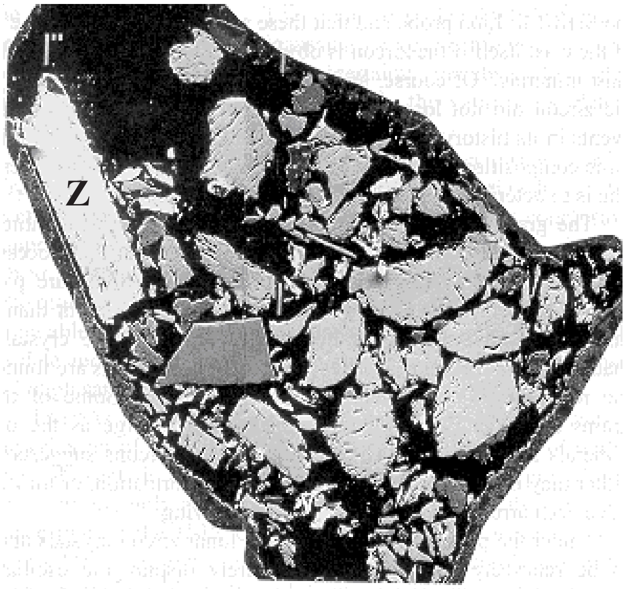


Figure 9: Large zircon (Z) with numerous ilmenite grains in vug in 14311,90 (Meyer et al. 1996). Scale bar at tip of zircon is 100 microns.

Zircon: Meyer et al. (1996) studied a large, euhedral zircon (200-800 micron). Crozaz et al. (1972) reported the U content of zircon in 14311 (90-300 ppm).

Baddeleyite: Crozaz et al. (1972) reported U = 270 ppm in baddelyite.

Whitlockite: Crozaz et al. (1972) reported that fission tracks in phophates in 14311 were annealed !! This apparent anomoly has not been explained.

Chemistry

Scoon (1972) determined the major element composition (Table 1). It is interesting that the bulk analysis plots outside the field of the CMB (figure 11). The matrix has not been analyzed for trace elements. Figure 12 shows the composition of a feldspathic clast, compared with average KREEP. 14311 is very poor in carbon (figure 13), proving that it is not related to regolith breccias.

Radiogenic age dating

Stadermann et al. (1991) determined an Ar plateau age of 3.82 ± 0.03 b.y. for 14311 (figure 14).

Meyer et al. (1996) used the ion microprobe U/Pb method to precisely date the large zircon in a clast at 4.250 ± 0.002 b.y.

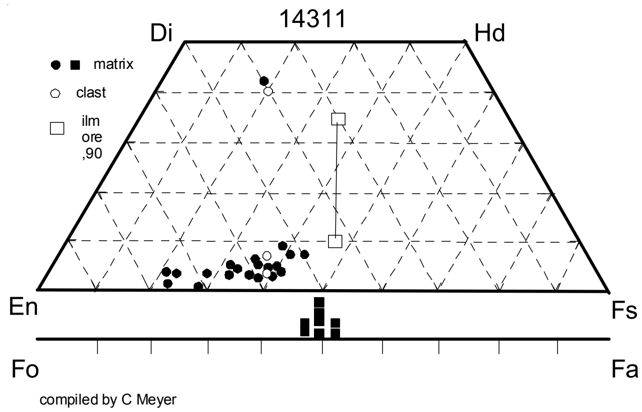


Figure 10: Olivine and pyroxene composition for matrix and clasts in 14311 (data from Simonds et al. 1977 , Warren et al. 1983 and Meyer et al. 1996).

Cosmogenic isotopes and exposure ages

Crozaz et al. (1972) determined a cosmic ray exposure age of 661 ± 72 m.y. by ^{81}Kr, while Stadermann et al. (1991) determined an exposure age of 528 m.y. by the Ar method. Bhandari et al. (1972) reported a track age (subdecimeter) of only 12 m.y.

Other Studies

Mitzutani et al. (1972) determined the wave velocity (figure 15). Nagata et al. (1972, 1975) and Schwerer and Nagata (1976) have reported the magnetic porperties of 14311.

Processing

14311 broke along penetrating fractures, but the pieces could be fit together (figure 1, 2, 18). A cm thick slab was cut from the end (figure17) and most thin sections are from the potted butts from this end. A portion of 14311 is used for public display.

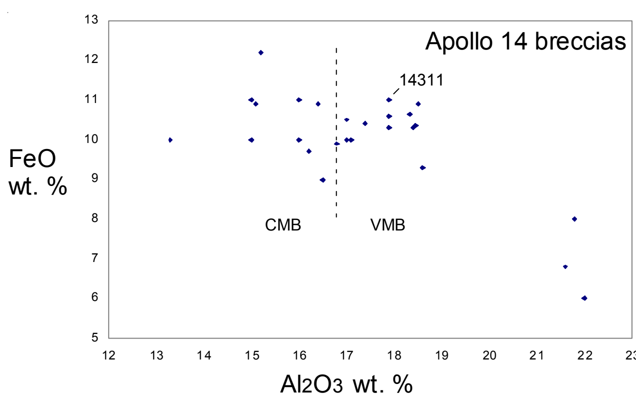


Figure 11: Composition of breccia samples from Apollo 14 showing 14311.

Table 1. Chemical composition of 14311.

			clast	
reference	Scoon 72		Warren 83	
weight			,220	
SiO2 %	47.24	(a)		
TiO2	1.81	(a)		
Al2O3	18.05	(a)		
FeO	11.13	(a)	7.07	(b)
MnO	0.14	(a)	0.1	(b)
MgO	9.59	(a)		
CaO	10.16	(a)	15.4	(b)
Na2O	0.85	(a)	1.2	(b)
K2O	0.81	(a)	0.11	(b)
P2O5	0.76	(a)		
S %	0.06	(a)		
sum				
Sc ppm			15.1	(b)
V				
Cr	1779	(a)	720	(b)
Co			5.2	(b)
Ni			<120	(b)
Cu				
Zn				
Ga			10.3	(b)
Ge ppb				
As				
Se				
Rb			<30	(b)
Sr			370	(b)
Y				
Zr			1240	(b)
Nb				
Mo				
Ru				
Rh				
Pd ppb				
Ag ppb				
Cd ppb				
In ppb				
Sn ppb				
Sb ppb				
Te ppb				
Cs ppm				
Ba			750	(b)
La			25.8	(b)
Ce			65	(b)
Pr				
Nd			39	(b)
Sm			10.2	(b)
Eu			4.8	(b)
Gd				
Tb			2.24	(b)
Dy			15.2	(b)
Ho			3.3	(b)
Er				
Tm				
Yb			10.6	(b)
Lu			1.68	(b)
Hf			28.3	(b)
Ta			0.85	(b)
W ppb				
Re ppb				
Os ppb				
Ir ppb			<5	(b)
Pt ppb				
Au ppb				
Th ppm			3.6	(b)
U ppm			1.12	(b)

technique: (a) wet chem. (b) INAA

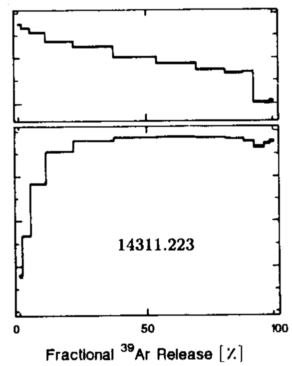


Figure 14: Argon plateau diagram for 14311 (from Stadermann et al. 1991).

Summary of ages for 14311

	Ar/Ar	U/Pb
Stadermann et al. 1991	3.82 b.y.	
Meyer et al. 1996		4.25 b.y.

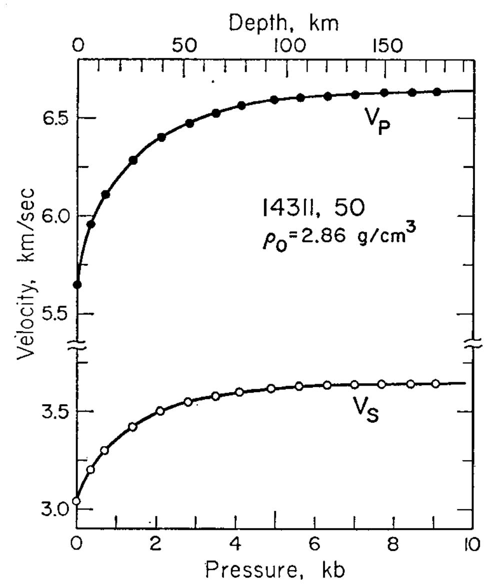


Figure 15: Wave velocity determined by Mizutani et al. (1972) for 14311.

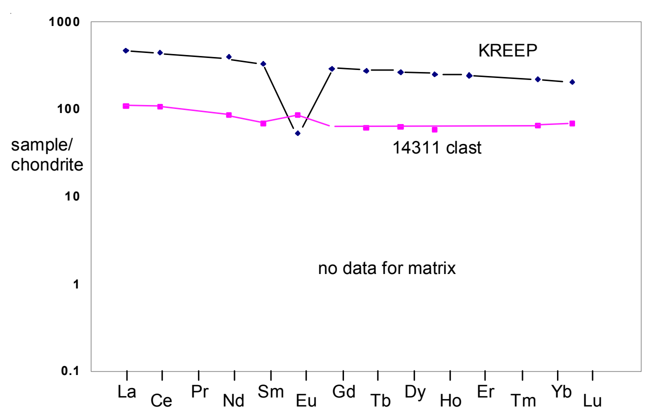


Figure 12: Composition of clast ,220 in 14311 (data from Warren et al. 1983). Matrix composition has not been determined (2007).

Figure 16: Photo of freshly broken surface of 14311 showing fine grained melt rock texture different from that of typical Apollo 14 breccia (note the vugs). Cube is 1 cm. NASA S77-22158.

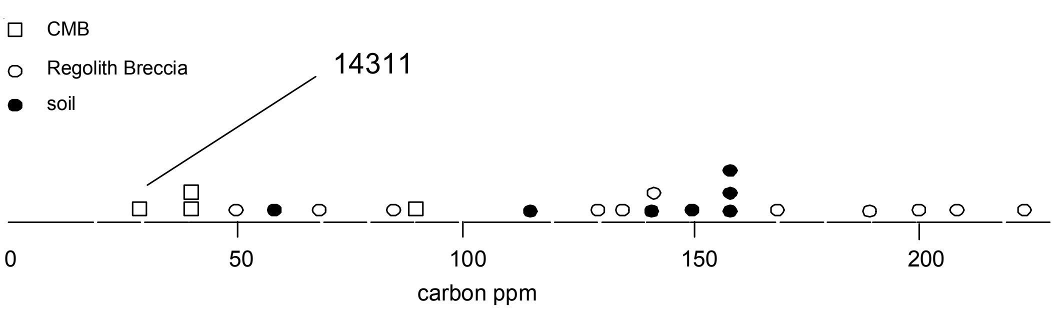


Figure 13: Carbon content in 14311 compared with other Apollo 14 samples.

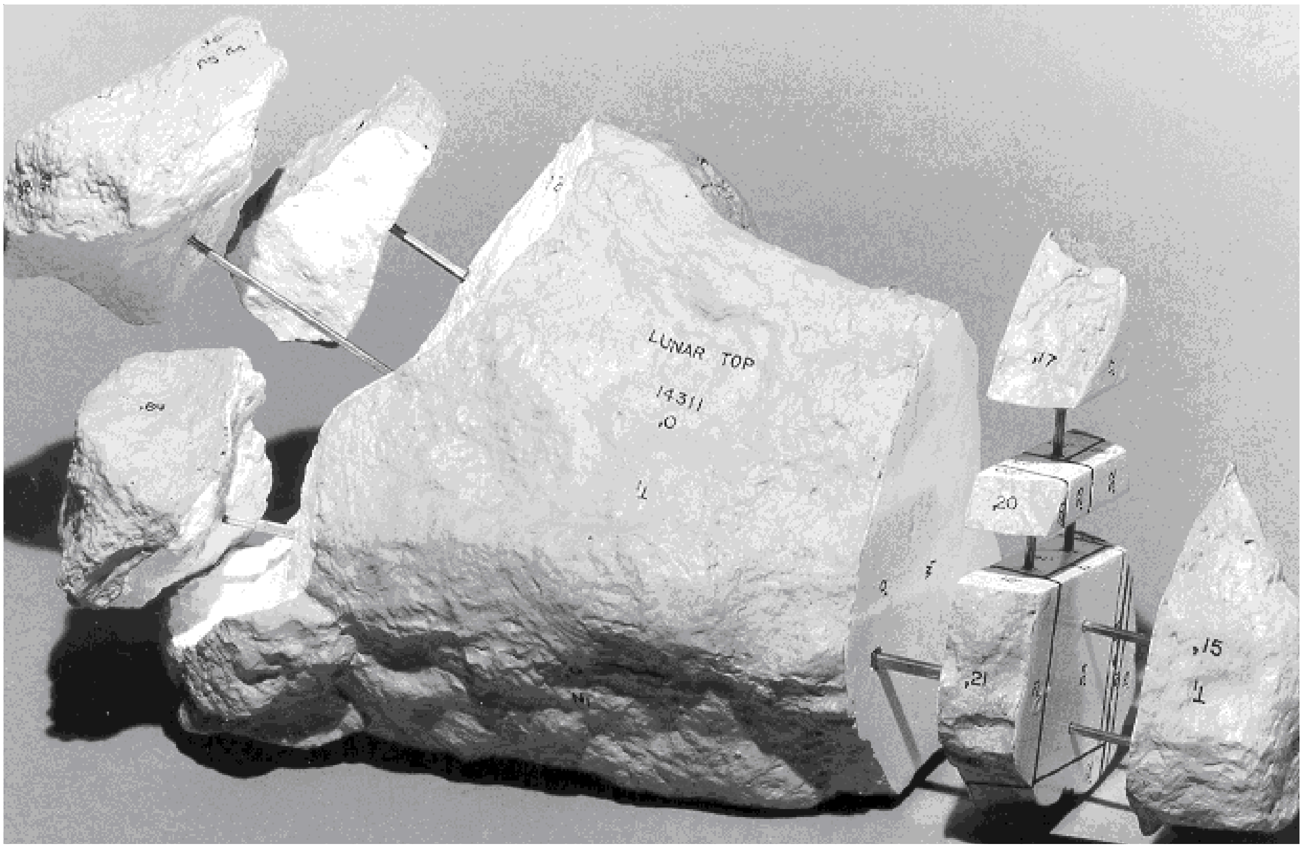
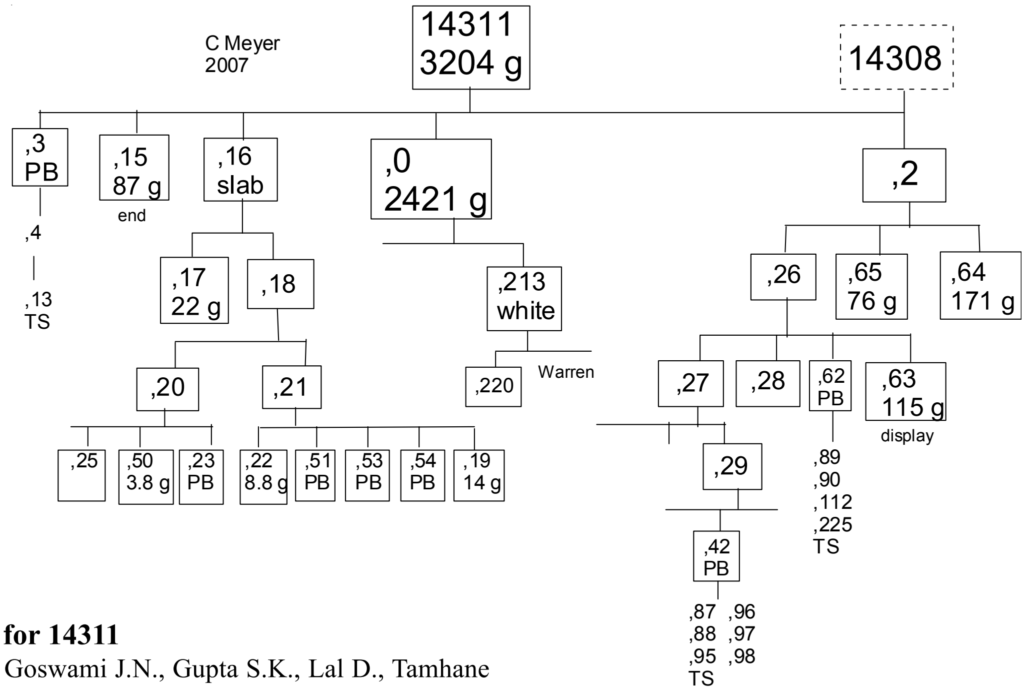


Figure 17: Photo of exploded parts model for 14311. NASA S78-26754.

Figure 18: End view of 14311 (E). Sample about 10 cm wide. NASA S71-22903.



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