14301
Regolith Breccia
1360.6 grams

Figure 1: Photo of 14301 showing side with striations in packed dirt. NASA S71-32473. Sample is 10 cm.

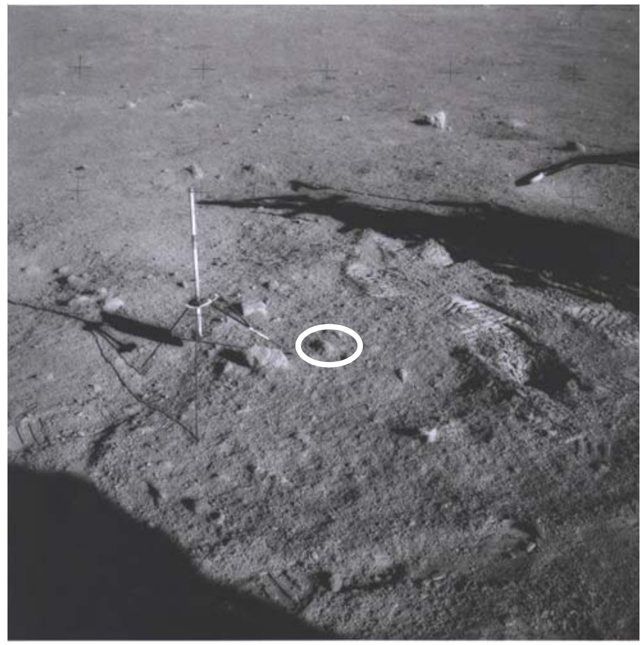


Figure 2: Photo of 14301 before it was collected (AS14-68-9466).

LMP We're approaching Triplet from the east, that's North Triplet from the east. There's a little rock field down here – a small boulder field, Al, to get a documented sample from.
CDR Man, that pile of rocks – beautiful, right to your left. Oh, just the right size. Don't walk over them!
LMP No, I'm trying to stay away from them. Yes _ _ it's' bigger than we thought. Al, we'll grab sample that one; I'll get you another one here.
CDR Okay, bag 27 Nancy. (#14313)
LMP And another documented sample – a larger documented sample than we thought we were getting here, Fredo. Again, it was a burried rock: and it's too big for the sample bag; so, it'll go into the weigh bag. (#14301)

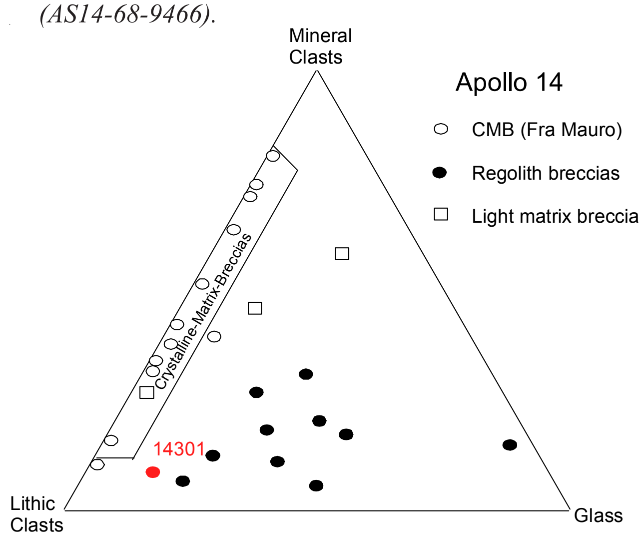


Figure 3: Ratio of clast abundance in Apollo 14 breccia samples with 14301 (Simonds et al. 1977).

Introduction:

14301 and 14313 were collected at station G1 on the rim of North Triplet Crater about 150 meters east of the LM. 14301 is a large rock that was mostly buried (figure 2). A small portion of one side of 14301 was exposed and had abundant micrometeorite craters (Horz et al. 1972; Morrison et al. (1972); Swann et al. 1977). Other surfaces, which were buried at time of collection, had surface coatings with striations (slickensided) with a lesser number of microcraters. The sample is relatively rounded with some craters on various sides indicating it may have had previous exposure.

Figure 4: Photo of 14301,24 showing large dark clast. NASA S77-23456. Sample is 12 cm end-to-end.

14301 is a fragmental breccia with about 20% clasts >1 mm, abundant glass and a fine matrix. It has some agglutinates and is considered a regolith or soil breccia (Chao et al. 1972; Fruland 1983; Simon et al. 1989). However, in various poroperties (C content, ^{4}He, Al etc.) it is transitional between the Fra Mauro breecia and typical Apollo 14 regolith breccia.

14301 has an exposure age of 102 m.y. for cosmic rays. It is one of the lunar samples that contains ^{244}Pu-derived fission Xe and radiogenic ^{129}Xe in excess of what may be expected by in-situ production and it has ^{40}Ar/^{36}Ar ratio that indicates the breccia was formed ~ 4 b.y. ago. 14301 also contains trapped solar wind gases that allow determination of isotopic ratios of the Sun in the past.

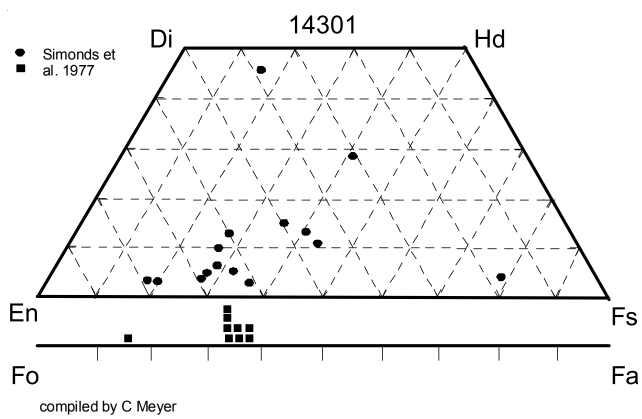


Figure 5: Mineral compositions in matrix of 14301 (Simonds et al. 1977).

Petrography

14301 has been much studied (Carlson and Walton 1978; McGee et al. 1977; Fruland 1983; Simon et al. 1989). Chao et al. (1972), King et al. (1972), Simon et al. (1981, 1989) and Simonds et al. (1977) all recognized that it was a fragmental breccia, with abundant glass (even chondrules) with an included soil component.

The Apollo 14 regolith breccias (vitric matrix breccias) are slightly more aluminous than the Fra Mauro breccias (crystalline matrix breccias). 14301 is on the boundary (figure 7). It has several large clasts (figures 4, 6, and 11).

The maturity index for 14301 has not been measured. However, the amount of ^{4}He and carbon content is intermediate indicating that this regolith breccia is not

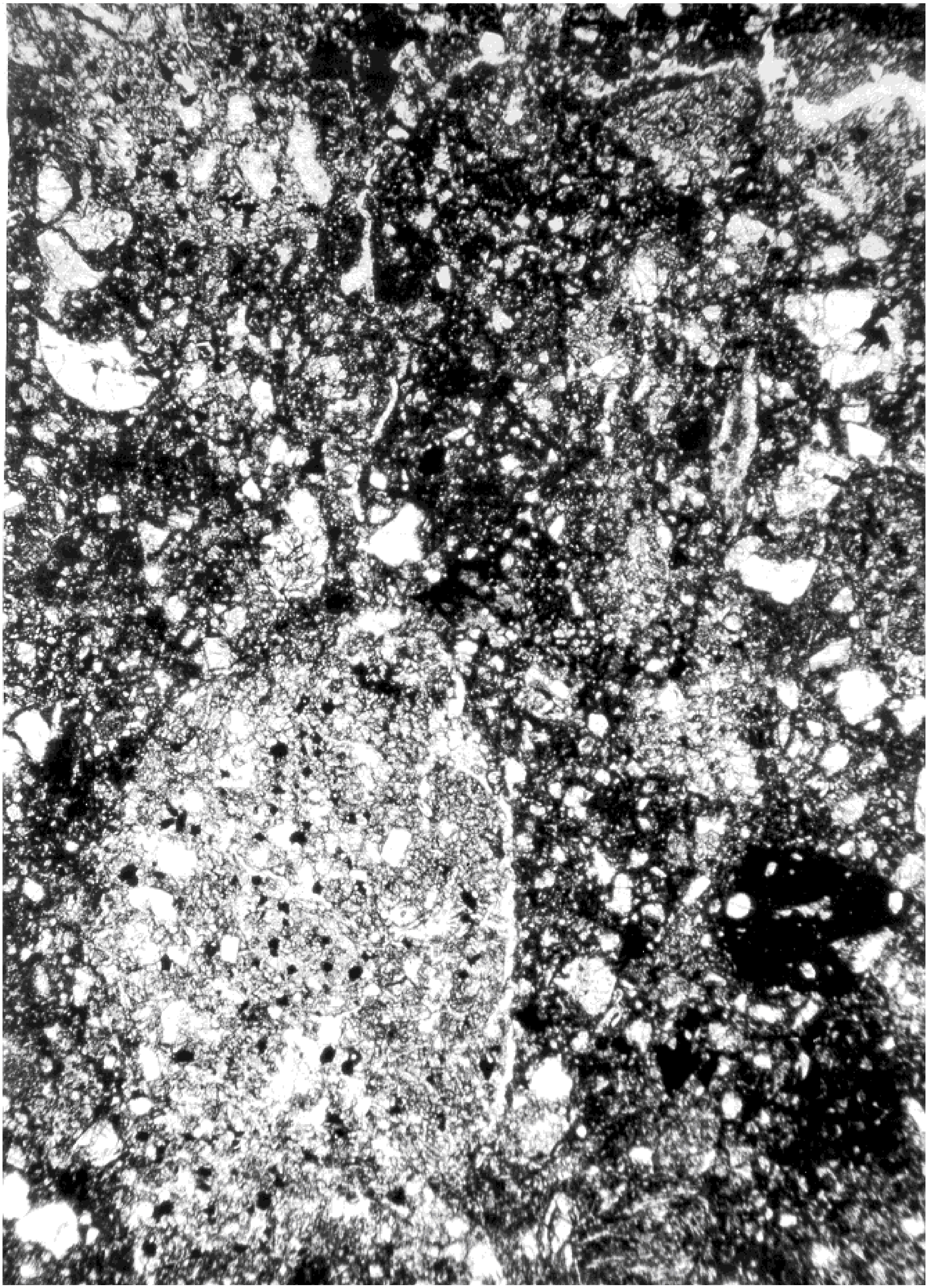


Figure 6: Photomicrograph of thin section 14301,13. Scale is about 500 microns across. NASA S71-25490.

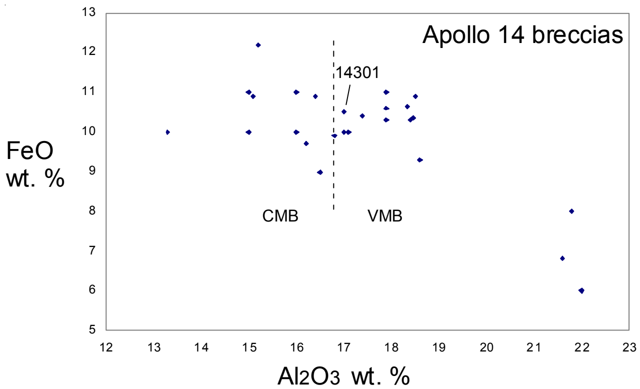


Figure 7: Composition of Apollo 14 breccias with 14301 on the transition line.

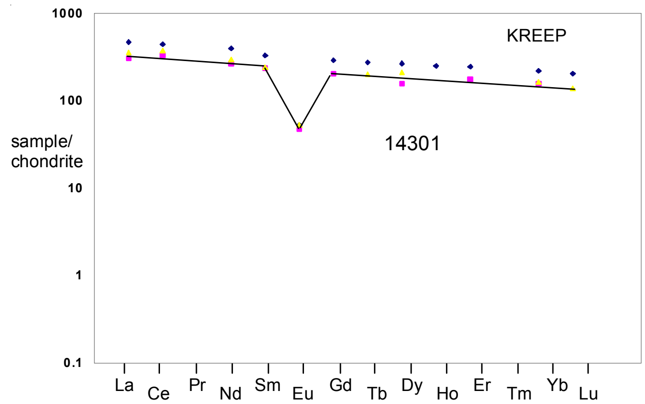


Figure 8: Normalized rare-earth-element diagram showing bulk analysis for 14301 is about 60 % KREEP.

Mineralogical Mode for 14301

	Simonds et al. 1977	Simon et al. 1989
Matrix	46 %	43
Clasts		
Plagioclase	2	4.9
Mafic	2.5	5.7
Breccia	33	~25
Glass	1	9.7
Granulite	10	2
Mare basalt	3.5	0.1
Agglutinate		4 %

Mineralogical Mode for 14301

	Drozd et al. 1977
Mineral fragments	18 %
Lithic fragments	67.4
Colored glass	4.7
Agglutinate glass	8.5
Colorless glass	0.3
Chondrules	0.5
Devitrified glass	0.6

as mature as other regoltih breccias or as soil. Agglutinates are present in 14301, but they are relatively rare when compared with lunar soils (see modes).

A portion of the surface of 14301 has been described as "glassy slickensided" and has a low density of micrometeorite pits (Morrison et al. 1972).

Based on different glass populations, 14301 is inferred to have a closure age sometime during the epoch of mare volcanism, while other regolith breccias at Apollo 14 site include mare basalt glass from the whole range of mare volcanism (Delano 1987). Chao et al. (1972b), Wentworth and McKay (1991) and Simon et al. (1989) also studied glass from 14301.

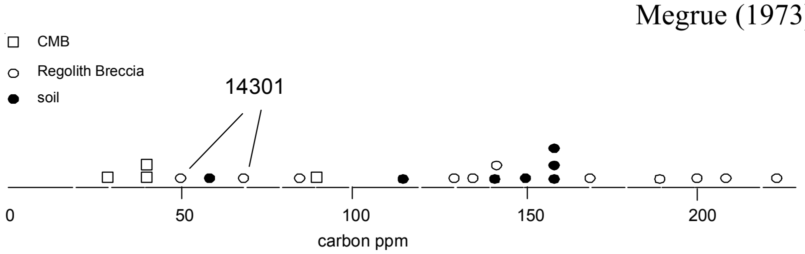


Figure 9: Carbon content of Apollo 14 samples showing 14301 (data from Moore et al. 1972).

Chemistry

LSPET (1971), Hubbard et al. (1972), Rose et al. (1972), Simon et al. (1981) and Keith et al. (1972) have provided analyses of 14301 (table 1). Detailed chemical compositions of grain size fractions are found in Bernatowicz et al. (1980), Swindle et al. (1985) and Papike et al. (1981).

Carbon contents were reported by Moore et al. (1972) and Holland et al. (1972)(figure 9). Cr and Be analyses were made by Eisenstaut et al. (1972).

Radiogenic age dating

Alexander and Kahl (1974) determined the Ar-Ar release pattern of a sample of 14301 (figure 10), but could not obtain an "age" of this breccia from this data. Excess Ar is released at low temperature – see also Megrue (1973).

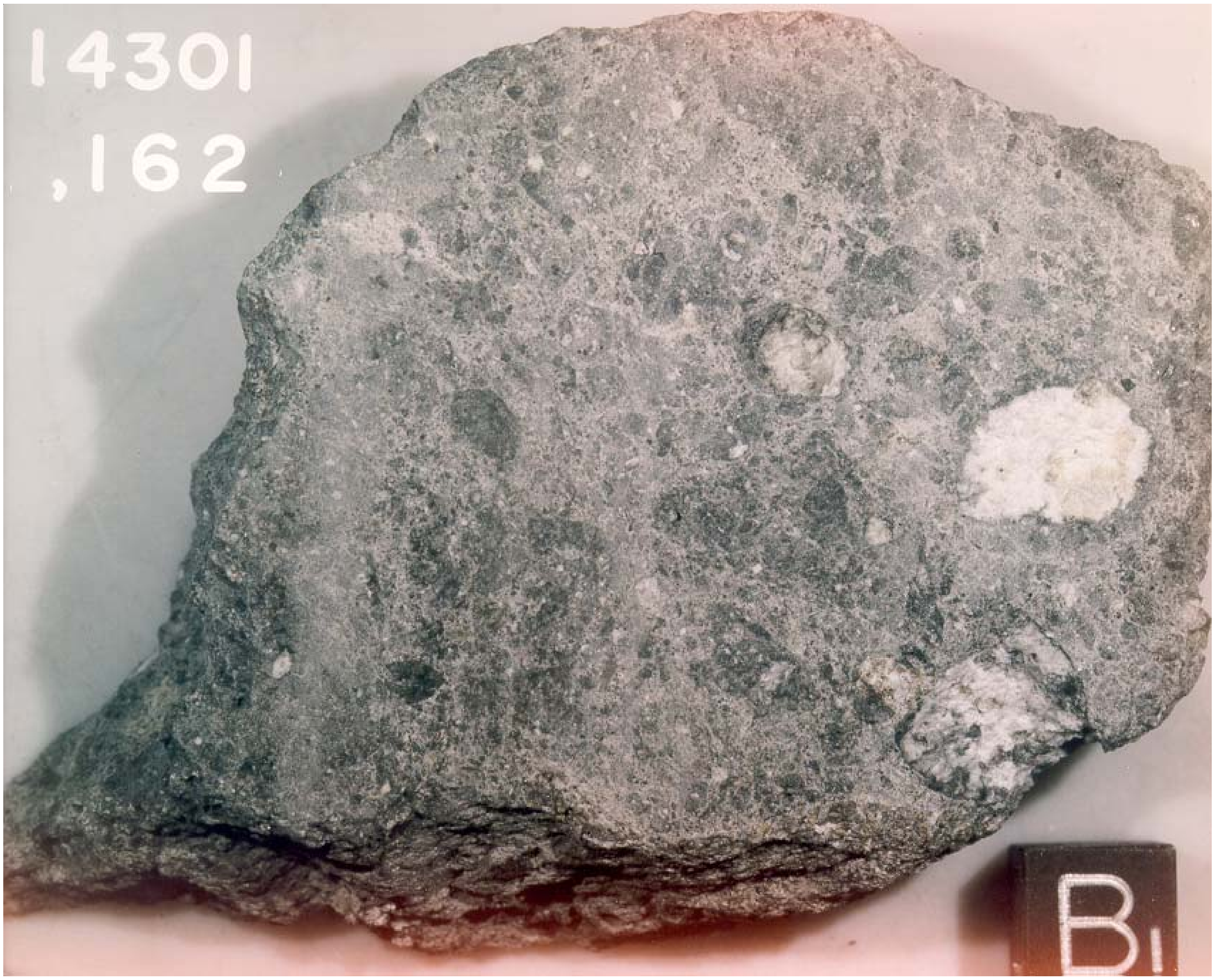


Figure 11: Photo of sawn surface of 14301 showing white clasts. Cube is 1 cm. NASA S92-44057.

Cosmogenic isotopes and exposure ages

14301 was found to have ^{26}Al activity of 62 dpm/kg, ^{22}Na = 27 dpm/kg and ^{56}Co = 8 dpm/kg (Keith et al. 1972).

Drozd et al. (1974) and Crozaz et al. (1972) determined the exposure age of 102 ± 30 m.y. by the ^{81}Kr method (figure 12), while Bhandari et al. (1972) reported a track age (subdecimeter) of only 8 m.y. Crozaz et al. (1972) give a long discussion.

Other Studies

LSPET (1971), Bogard and Nyquist (1972) and Swindle et al. (1985) reported rare gas analyses of 14301. Becker R.H. and Clayton R.N. (1975) determined the He and nitrogen contents and isotopic ratio of nitrogen in 14301. Bernatowitz et al. (1979,

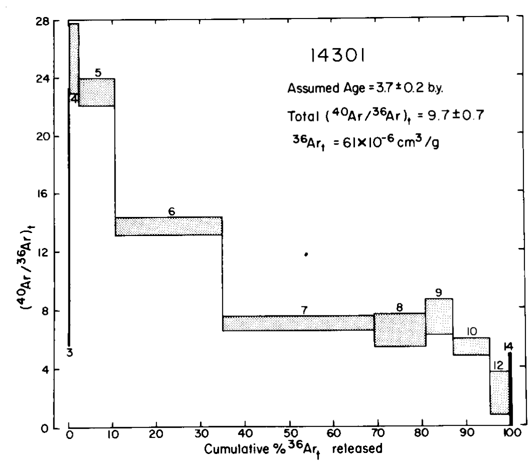


Figure 10: Ar-Ar release pattern for 14301 (Alexander and Kahl 1974).

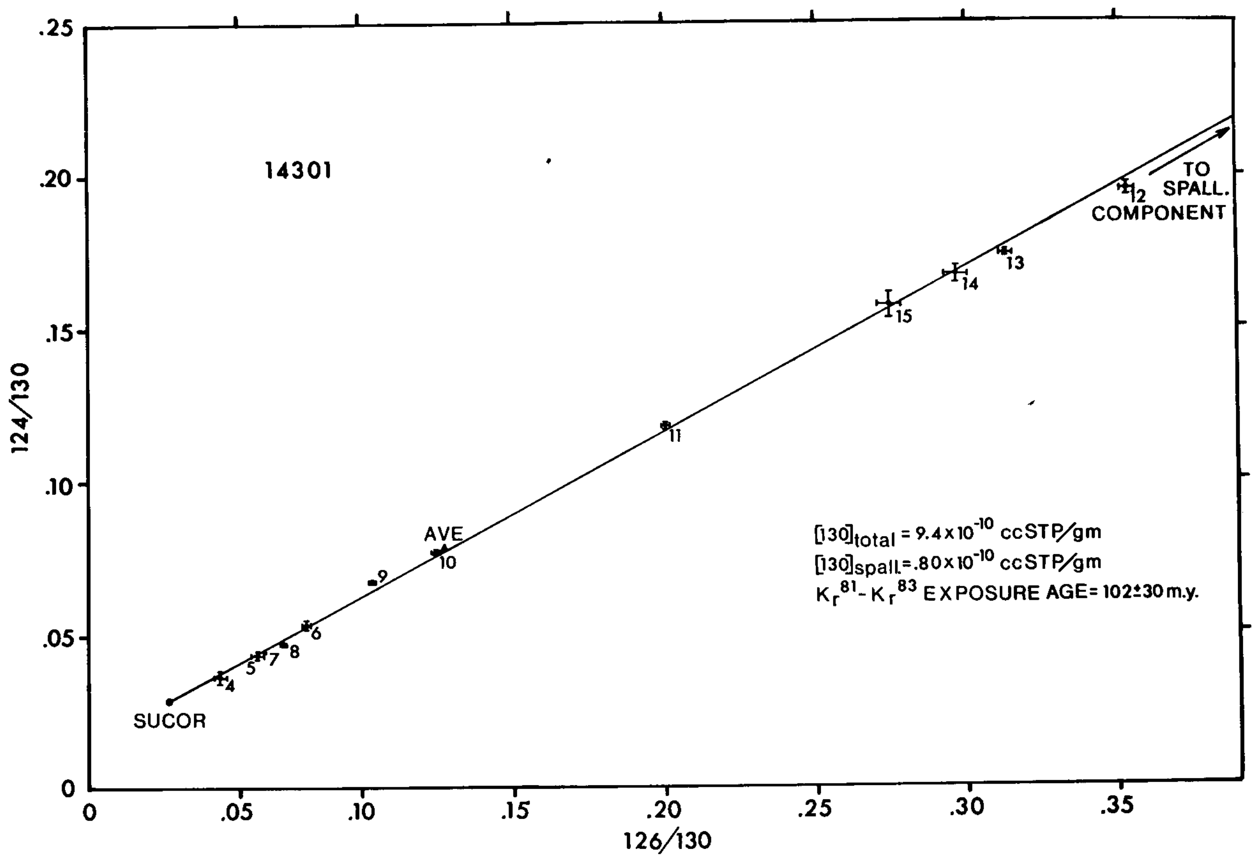


Figure 12: Xenon isotopes in 14301(Crozaz 1972).

1980) discuss the significance of excess Xe from extinct ^{129}I and ^{244}Pu, found in 14301.

Numerous authors had found that the $^3He/^4He$ ratio was apparently different in the past, using 14301 and other samples, however Heber et al. (2003) have made arguments that this may due to the way the sample was handled, and not, as previously thought, an indication of a change in the isotopic composition of the Sun. Eugster et al. (2001) used the 40Ar/36Ar ratio to calibrate the age of regolith breccias (figure 13), with 14301 about 4.0 b.y.

Hart et al. (1972), Hutcheon et al. (1972), Bhandari et al. (1972) studied the density of tracks in 14301.

Dunn and Fuller (1972), Nagata et al. (1972, 1975), Schwerer and Nagata (1976) and Brecher (1977) studied the magnetic properties of 14301 and other breccias. Chung et al. (1972) determined the dielectric properties, and Gibb et al. (1972) and Huffman et al. (1974) determined Mossbauer spectra.

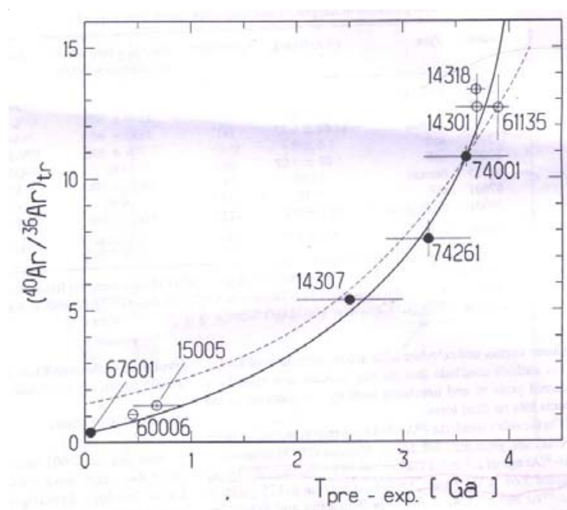


Figure 13: Calibration curve for Ar data from ancient regolith breccias (from Eugster et al. 2001).

Processing

14301 was large and was returned in a "weigh bag". It broke during sawing - see diagram and figures 14 and 15.

Table 1. Chemical composition of 14301.

reference	Hubbard72		Hubbard72 Wiesmann75		Rose72		Keith72		Bernatowicz80			Simon 89		LSPET71	
weight	*sawdust*						1370 g		>~0.6 cm	0.5-0.6cm		143 mg			
SiO2 %	47.6	(b)			48.26	(d)								49	(f)
TiO2	1.77	(b)	1.73	(c)	2.06	(d)			1.5	1.5	(e)	1.74	(e)	1.7	(f)
Al2O3	15.9	(b)			16.52	(d)			16	17.2	(e)	17	(e)	17	(f)
FeO	11.9	(b)			10.29	(d)			11.2	10.7	(e)	10.5	(e)	9.8	(f)
MnO	0.14	(b)			0.14	(d)			0.13	0.128	(e)	0.145	(e)	0.21	(f)
MgO	10.4	(b)	8.84	(c)	9.98	(d)			10.4	9.5	(e)	9.8	(e)	11	(f)
CaO	10.1	(b)	10.3	(c)	10.29	(d)			9.4	10.8	(e)	10.1	(e)	8.8	(f)
Na2O	0.74	(b)			0.84	(d)			0.88	0.89	(e)	0.83	(e)	0.78	(f)
K2O	0.69	(b)	0.83	(c)	0.75	(d)	0.73	(a)	0.81	0.7	(e)	0.64	(e)	0.72	(f)
P2O5	0.58	(b)			0.64	(d)									
S %	0.09	(b)													
sum															
Sc ppm					26	(d)			22	21.6	(e)	21	(e)	31	(f)
V					49	(d)			35	35	(e)	41	(e)	63	(f)
Cr	1368	(b)			1437	(d)			1347	1266	(e)	1230	(e)	1200	(f)
Co					27	(d)			28.1	30.4	(e)	30	(e)	44	(f)
Ni	203	(b)			255	(d)			260	290	(e)	400	(e)	230	(f)
Cu					43	(d)								17	(f)
Zn					39	(d)									
Ga					7.7	(d)									
Ge ppb															
As															
Se															
Rb	18	(b)	21.7	(c)	17	(d)						26	(e)	17	(f)
Sr	175	(b)	185	(c)	195	(d)						80	(e)	240	(f)
Y	238	(b)			335	(d)								260	(f)
Zr	1215	(b)			940	(d)			1270	1100	(e)	900	(e)	1000	(f)
Nb	73	(b)			64	(d)								63	(f)
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb															
Cd ppb															
In ppb															
Sn ppb															
Sb ppb															
Te ppb															
Cs ppm												0.99	(e)		
Ba			959	(c)	1280	(d)			1100	1100	(e)	1000	(e)	920	(f)
La			71.8	(c)	92	(d)			100	82.4	(e)	84.1	(e)	92	(f)
Ce			201	(c)					260	220	(e)	226	(e)		
Pr															
Nd			121	(c)					150	120	(e)	134	(e)		
Sm			34.7	(c)					41.5	35.3	(e)	35.5	(e)		
Eu			2.69	(c)					2.72	2.75	(e)	2.96	(e)		
Gd			40.3	(c)											
Tb									9.1	7.6	(e)	7.3	(e)		
Dy			46	(c)					54	48	(e)	52	(e)		
Ho									13	11	(e)				
Er			28	(c)											
Tm									5	4.2	(e)				
Yb			25.5	(c)	23	(d)			30.8	23.9	(e)	26.7	(e)	33	(f)
Lu									4.4	3.66	(e)	3.37	(e)		
Hf									32.9	28.8	(e)	25.7	(e)		
Ta									4.5	3.9	(e)	3.4	(e)		
W ppb															
Re ppb															
Os ppb															
Ir ppb												5	(e)		
Pt ppb															
Au ppb												2	(e)		
Th ppm	15	(b)					13.2	(a)	18.6	15.2	(e)	15.1	(e)		
U ppm			4.32	(c)			3.6	(a)	4.8	4.2	(e)	3.9	(e)		

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

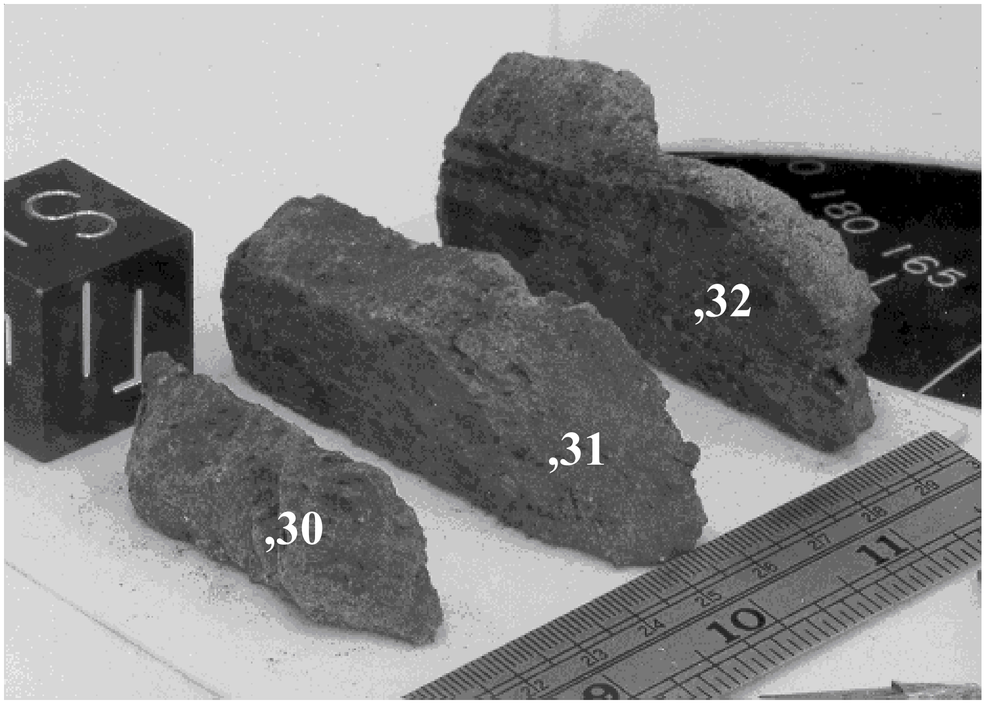
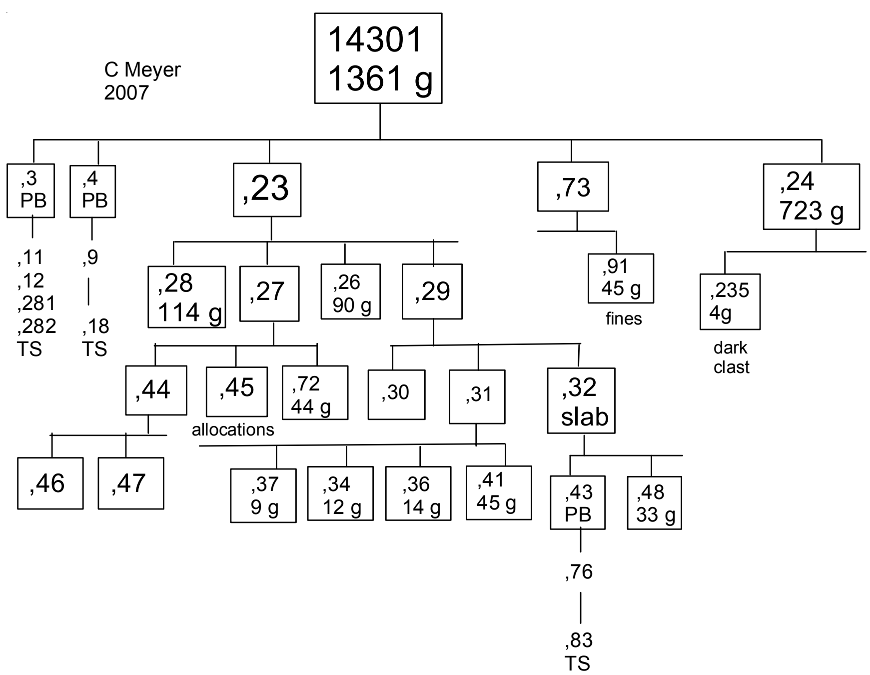
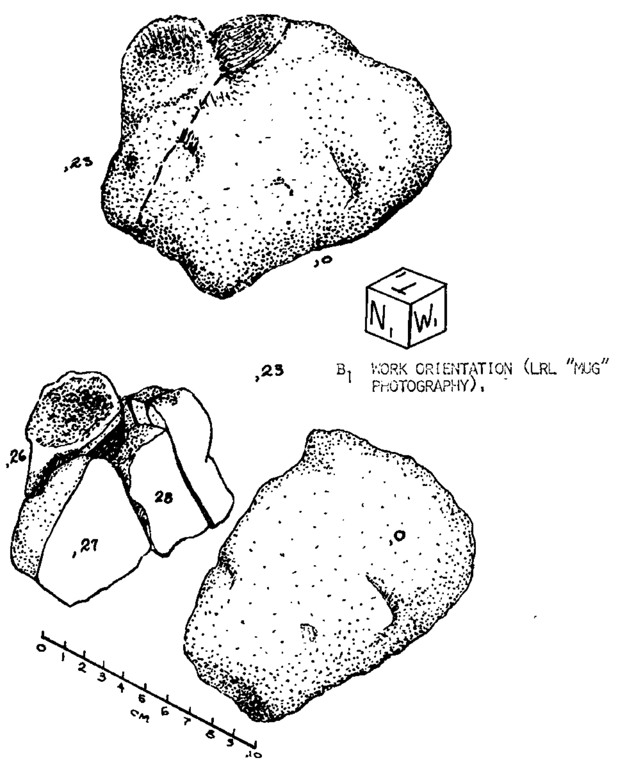
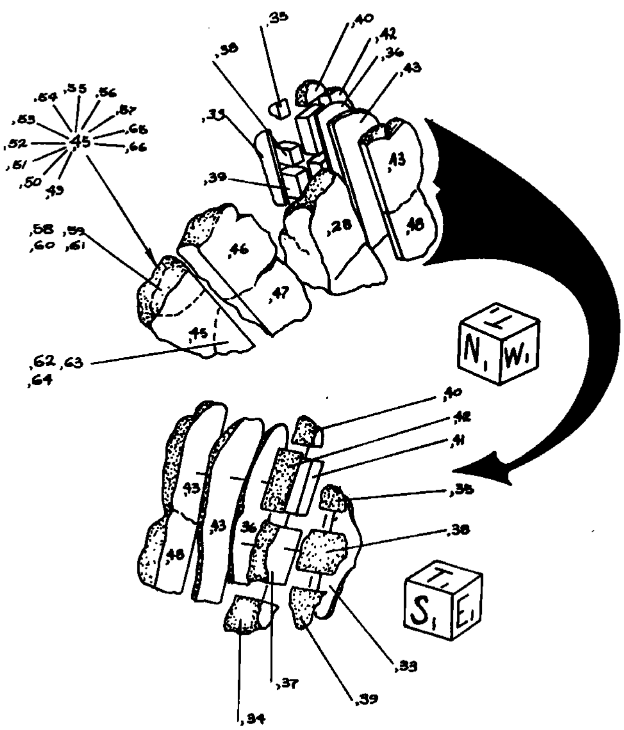


Figure 14: Processing photo of 14301,29. Cube is 1 cm. NASA S??







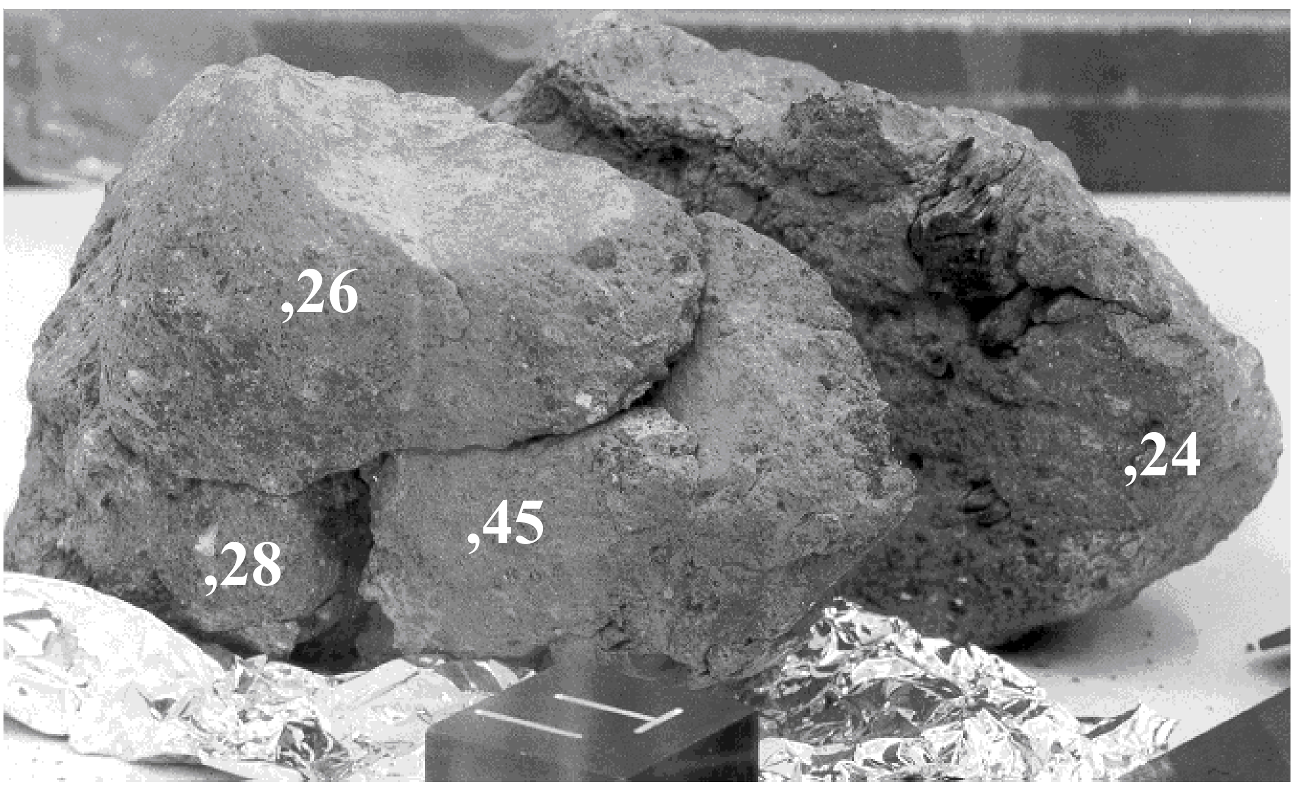


Figure 15: Photo of 14301 after cutting. Cube is 1 inch. NASA S71-??

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