14310
Feldspathic Basalt ?
3439 grams

Figure 1: Photograph of 14310 before cutting. Scale is 1 cm, cube is 1 inch. NASA photo # S71-30340.

Introduction
Sample 14310 was found as a separate sample without adhering matrix and thus, may or may not have been a clast within the Fra Mauro Formation. It was apparently not photographed on the lunar surface, but it was apparently half buried and the soil line separating the cratered and uncratered surfaces can be easily distinguished.

The following observations are from Hörz et al. (1972): "Approximately 60% of the rock surfaces are completely uncratered, extremely fresh and essentially dust free" (figure 1). On these surfaces "small-scale surface relief features, such as cracks, depressions, and protruding mineral grains are well preserved". One surface of the rock is heavily cratered with features rounded off (figure 2, also see S71-21828). "The cratered surface displays a multitude of unambiguous cratering events with central, glass-lined pits and halo and spall zones". The overall shape of the rock and "clear-cut relationship between cratered and uncratered areas is highly indicative of a simple surface history. It is suggested that the rock never tumbled after is was deposited on the lunar surface." That is to say, 60% of the rock was buried in the soil and protected from micrometeorite bombardment.

Lunar sample 14310 has received more study than any other KREEP basalt (Brown and Peckett 1971, Gancarz et al. 1971, Ridley et al. 1972, Longhi et al. 1972, Hollister et al. 1972, Bence and Papike 1972, James 1973, Crawford and Hollister 1974, Meyer 1977 and others). It is a holocrystalline igneous basalt with fine-grained subophitic to intergranular texture. However, 14310 has high Ni and Ir contents as well as Fe-Ni-P-S melt globules indicating that it is not of "pristine" igneous origin. In fact, Schonfeld and Meyer 1972 showed that the composition of 14310 can be modeled as a mixture of other lunar components (~8% mare, ~65% KREEP, ~25% anorthosite, ~3% meteorite), in a manor similar to a lunar soil!

Figure 2: PET photograph of rounded and cratered top surface of 14310. Scale is 1 cm. NASA# S71-28229.

Petrography

Thin sections of 14310 show that it is a fine-grained feldspathic basalt with intersertal texture consisting of lath-like plagioclase and anhedral pyroxene (LSPET 1972, Kushiro et al. 1972, Ridley et al. 1972, James 1973 and others). Numerous large (2 mm) blocky phenocrysts of plagioclase are found in the interlocking network of randomly-oriented laths (~200 micron) of plagioclase (figure 3). Pyroxene is found interstitial to the plagioclase. The cores of pyroxene crystals are orthopyroxene which zone to pigeonite (figure 4). Augite sometimes forms epitaxial overgrowths on the pigeonite. Ilmenite occurs in the interstices and is intergrown with the outer margins of the pyroxene. The mesostasis contains globules of Fe-Ni-schreibersite-troilite, Ba-K feldspar, baddeleyite, tranquillityite, Ca-phosphate and patches of devitrified silica-rich glass.

Several investigators report "cognate" inclusions within 14310. LSPET (1972) initially illustrated one such fine-grained "cognate" inclusion. Kushiro et al. (1972) found that one small patch (~1 mm) with distinct boundary, consisted of plagioclase and pyroxene crystals about one-fifth to one-tenth the size of the main portion. James (1973) also reported cognate inclusions.

Mineralogical Mode

	Gancarz et al. 1972	**Carlson et al. 1978**	**Ridley et al. 1972**	**Brown et al. 1972**	**Longhi et al. 1972**
Plagioclase	59 % vol.	68	66	54.1	56.6
Pyroxene		31	31	42.2	
Ortho	18.6				13.8
Pigeonite	12				21
Augite	6.9				
Opaque	2.9	0.5	2	1.8	2.9
Mesostasis	3.9	0.5	0.5	1.9	5.9
Phosphate	0.3				

Figure 3 : Photomicrograph of thin section (crossed Nicols) of 14310. Field of view ~ 5 mm.

The wide modal variation almost certainly confirms that 14310 is not a homogeneous rock, which should also apply to chemistry (Ridley et al. 1972).

Mineralogy

Pyroxene: Kushiro et al. (1972), Brown et al. (1972), Ridley et al. (1972), Gancarz et al. (1972), Bence and Papike (1972) have determined the composition of pyroxene in 14310 (figure 4). The crystal structure of pyroxenes in 14310 were determined by Takeda and Ridley (1972) and orthopyroxene was confirmed. Ghose et al. (1972) studied the structure and exsolution of clinopyroxene.

Plagioclase: Ridley et al. (1972) reported unusual zoning patterns in plagioclase in 14310 (An_{94-58}) and suggested "that many of the crystals are broken fragments". Wenk et al. (1972) reported the structure of plagioclase in 14310. Brown and Peckett (1971) determined that 14310 experienced alkali loss during crystallization of plagioclase.

Opaque: Ridley et al. (1972) estimate that ~72% of the opaques in 14310 are ilmenite, 8% ulvöspinel, 16% troilite, and 4% Fe-Ni. Globules of Fe-Ni-P-S containing schreibersite and troilite have been reported (El Goresy et al. 1972, James 1973). El Goresy et al. give analyses of Fe-Ni (figure 5), ilmenite and ulvöspinel.

Phosphates: Whitlockite in 14310 was analyzed by Gancarz et al. (1971).

Tranquillityite: Brown et al. (1972) reported the Zr-rich minerals in 14310. El Goresy et al. (1972) give an analysis of tranquillityite in 14310 (12% ZrO_2).

Chemistry

A large number of chemical analyses have been made of 14310 (tables 1a, 1b and 2). Figure 6 shows the rare-earth-element pattern. Kushiro et al. (1972) reported an analysis of 14310 by Haramura using the "conventional wet-chemical method" (table 1b). Ni and Ir are high, indicating a meteoritic component (non-pristine).

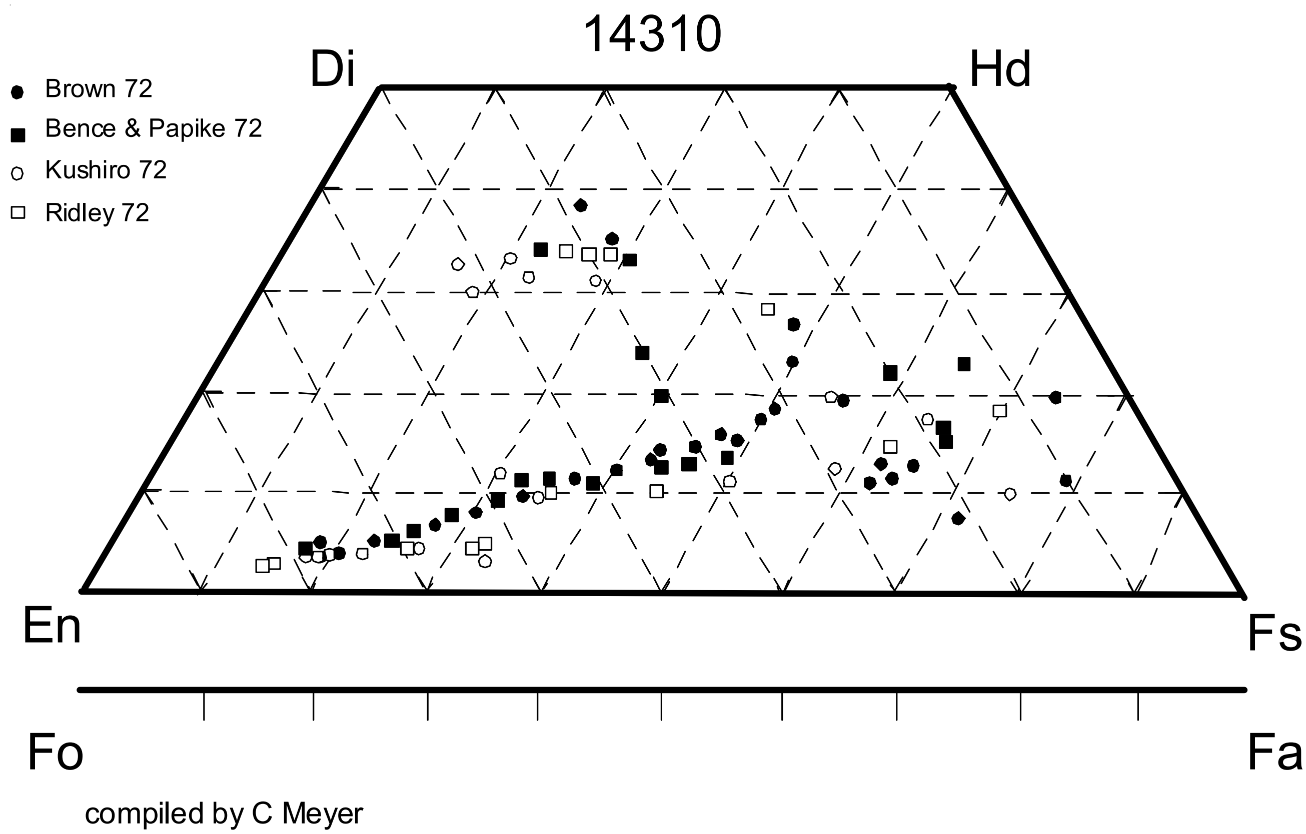

Figure 4: Pyroxene composition of 14310 from Brown et al. 1972; Ridley et al. 1972, Kushiro et al. 1972 and Bence and papike 1972. Additional pyroxene data can be found in Gancarz et al. 1972 (not plotted).

Radiogenic age dating

Numerous investigators determined the age of 14310 with considerable agreement (see table). However, 14310 proved difficult to date by the U-Pb method (Tatsumoto et al. 1972, Tera and Wasserburg 1972).

Cosmogenic isotopes and exposure ages

Rancitelli et al. (1972) and others determined the radionuclide concentrations of 14310 as soon as it was available, because of the large Solar Flare Event of 25 January 1971. Indeed, the top surface of 14310 was found to have significant ^{56}Co (half life, 77 days)

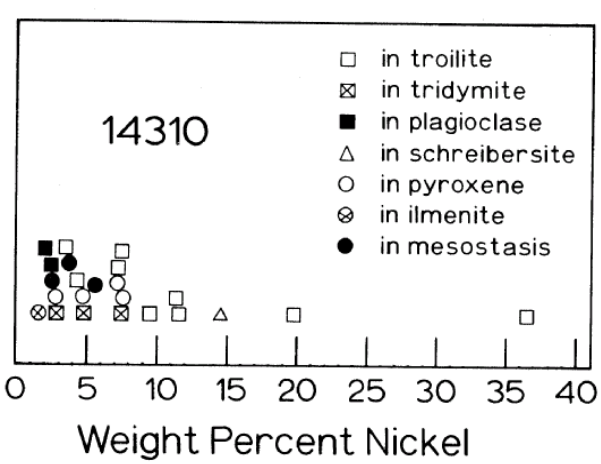

Figure 5: Composition of metal grains in 14310 (from El Goresy et al. 1972).

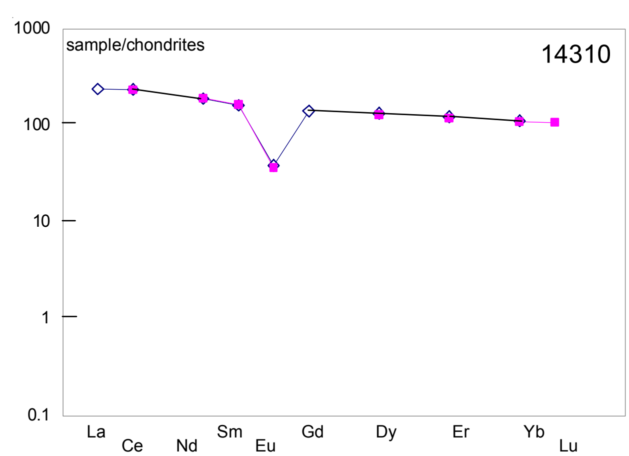

Figure 6: Normalized rare-earth-element diagram for 14310 (isotope dilution mass spectroscopy data only, from Wiesmann and Hubbard 1972 and Phillpotts et al. 1972).

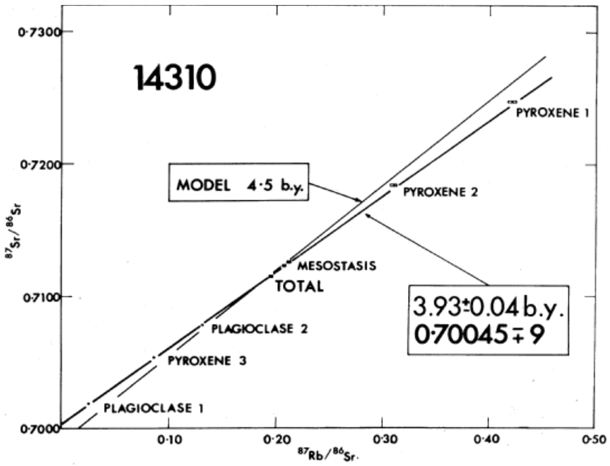

Figure 7: Rb-Sr isochron diagram for 14310 (from Compston et al. 1972).

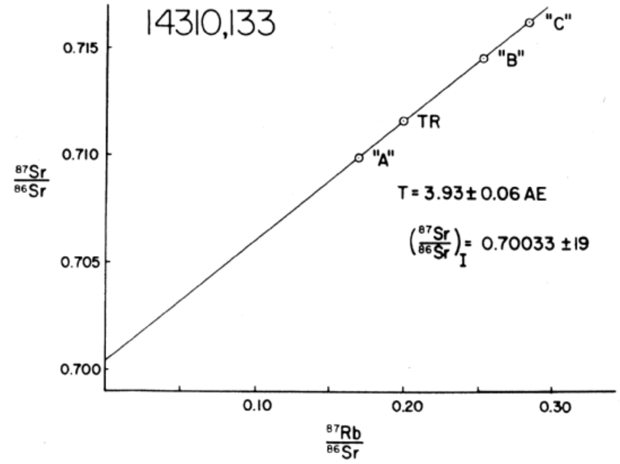

Figure 11: Rb-Sr isochron diagram for 14310 (from Murthy et al. 1972).

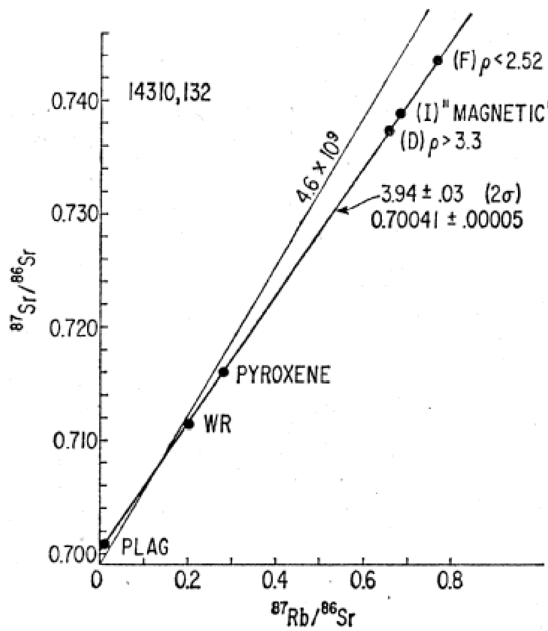

Figure 9: Internal Rb-Sr isochron for 14310 by Mark et al. 1972.

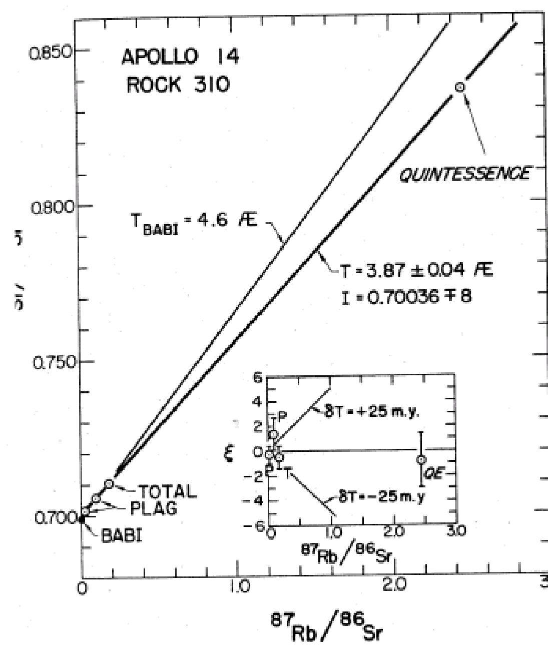

Figure 10: Internal Rb-Sr diagram for 14310 determinded by Papanastassiou and Wasserburg 1972.

Summary of Age Data for 14310

	Rb-Sr	**Ar-Ar**	**figure #**
Murthy et al. (1972)	3.93 ± 0.06 m.y.		8
Compston et al. (1972), DeLaeter et al. (1972)	3.93 ± 0.04		7
Papanastassiou and Wasserburg (1972)	3.87 ± 0.04		10
Tatsumoto et al. (1972)	3.84 ± 0.04		
Mark et al. (1974)	3.94 ± 0.03		9
Turner et al. (1971)		3.89 ± 0.04 m.y.	12
York et al. (1972)		3.91 ± 0.05	11
Stettler et al. (1973)		3.88 ± 0.06	10

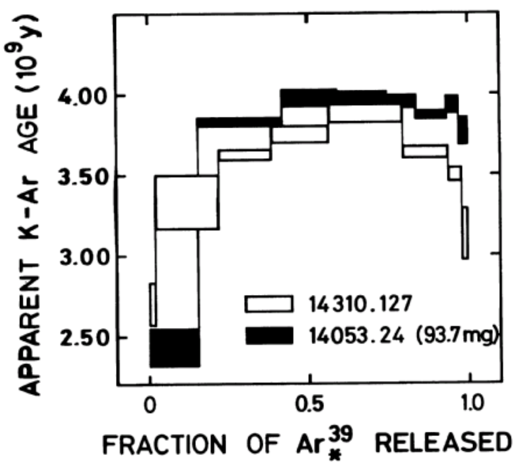

Figure 10: Ar-Ar plateau age for 14310 (from Stettler et al. 1973).

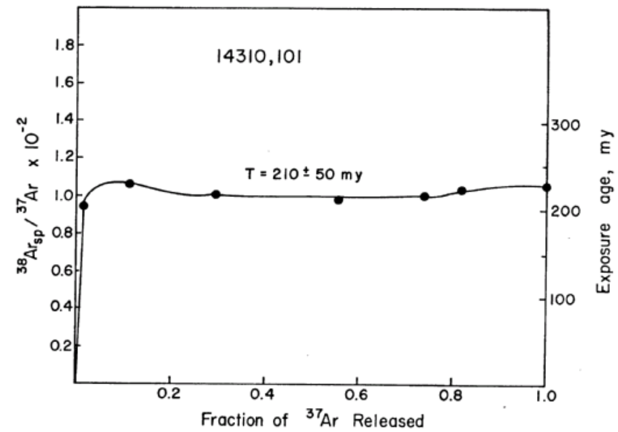

Figure 13: Exposure age of 14310 (from Husain et al. 1972).

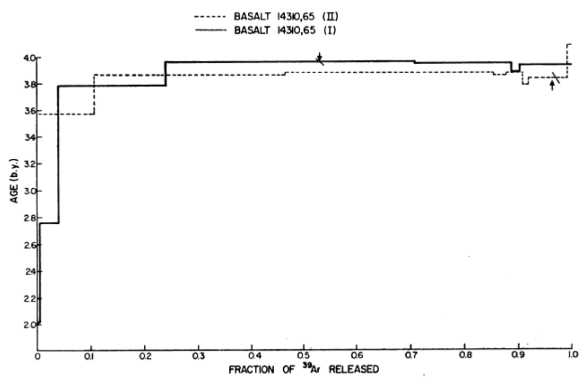

Figure 11: Ar-Ar plateau age for 14310 from York et al. (1972).

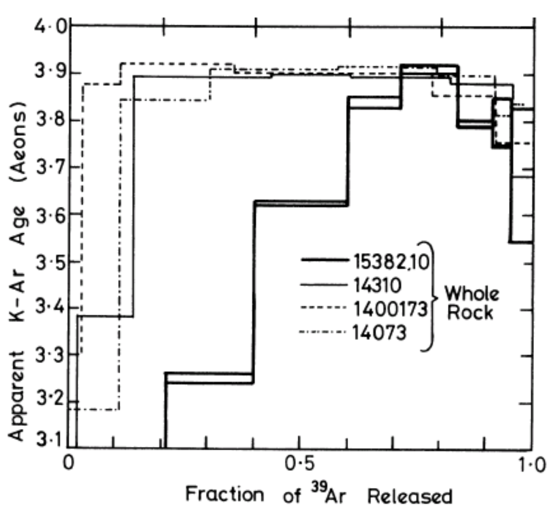

Figure 12: Ar-Ar plateau diagram for 14310 (from Turner et al. 1973).

LSPET (1971). Wahlen et al. (1972) reported the ^{55}Fe, ^{22}Na, ^{26}Al, ^{53}Mn, ^{36}Cl and ^{10}Be activity of an interior piece of 14310. The depth profile of ^{53}Mn is reported in Imamura et al. (1974).

Turner et al. (1971), York et al. (1972) and Stettler et al. (1973) determined ^{38}Ar exposure ages of 300 m.y., 333 m.y., 347 m.y. and 250 m.y. Husain et al. (1972) determined 210 m.y. (figure 13). Lugmair and Marti (1972) determined an ^{81}Kr exposure age of 259 ± 7 m.y.

Other Studies

Noble gas concentrations of 14310 were determined by Husain et al. (1972).

Green et al. (1972) and Walker et al. (1972) conducted experiments with powders prepared from 14310 to see what phases coexist at various temperatures and pressures (figure 14). Ford et al. (1972) studied the effect of H_2O and oxygen fugacity on the crystallization of 14310.

Berdot et al. (1972), Yuhas et al. (1972) and Crozaz et al. (1972) determined the density (number) of nuclear tracks near the surface of 14310. The "suntan" age appears to be only 2-3 m.y.

Processing

Two slabs were cut thru sample 14310 (figures 15 and 16). An exploded parts diagram for 14310 is also illustrated in Rancitelli et al. (1972) and Hörz et al. (1972).

Table 1a. Chemical composition of 14310.

reference	LSPET 71		Wiesmann 73		Hubbard 72		Brunfelt 72		Rose 72	Taylor 72		Willis 72		Helmke 72		Philpotts 72	
weight																	
SiO2 %	50				47.2	(d)			47.81	47.14	(f)	47.16	(d)			48.3	(g)
TiO2	1.3				1.24	(d)	1.22	(e)	1.11	1.23	(f)	1.25	(d)			1.25	(g)
Al2O3	20				20.1	(d)	20.8	(e)	21.54	20	(f)	20.35	(d)			20.74	(g)
FeO	7.7				8.38	(d)	7.93	(e)	7.62	8.37	(f)	8.31	(d)			7.78	(g)
MnO	0.14				0.11	(d)	0.11	(e)	0.1	0.12	(f)	0.113	(d)	0.1	(e)	0.11	(g)
MgO	8		7.3	(c)	7.87	(d)	8.8	(e)	7.48	7.88	(f)	7.83	(d)			8	(g)
CaO	11		12.5	(c)	12.3	(d)	12.6	(e)	12.92	12.29	(f)	12.43	(d)			11.61	(g)
Na2O	0.63		0.71	(c)	0.63	(d)	0.73	(e)	0.68	0.63	(f)	0.72	(d)			0.76	(g)
K2O	0.53		0.512	(c)	0.49	(d)	0.46	(e)	0.48	0.49	(f)	0.485	(d)			0.52	(g)
P2O5					0.34	(d)			0.43	0.34	(f)	0.385	(d)			0.38	(g)
S %					0.02	(d)						0.066	(d)				
sum																	
Sc ppm	20	(a)					16.7	(e)	25					18.7	(e)		
V	35	(a)					56	(e)	38	36	(f)						
Cr	1100	(a)			1231	(d)	1160	(e)	1710	1080	(f)	1163	(d)	1440	(e)	1163	(c)
Co	31	(a)					15.1	(e)	17	17	(f)			16.1	(e)		
Ni	165	(a)			64	(d)			120	20	(f)			150	(e)		
Cu	11	(a)					3.8	(e)	9								
Zn							1.6	(e)	<4								
Ga							3.7	(e)	3.2	3.2	(f)			4.3	(e)		
Ge ppb																	
As							0.03	(e)									
Se																	
Rb	15	(a)	12.8	(c)	13	(d)	15	(e)	15	12	(f)	12.1	(d)			12.7	(c)
Sr	250	(a)	188	(c)	193	(d)	220	(e)	175	185	(f)	177	(d)			180.9	(c)
Y	180	(a)			174	(d)			185	160	(f)	174	(d)				
Zr	930	(a)			842	(d)			610	890	(f)	852	(d)			893	(c)
Nb	43	(a)			52	(d)			29	36	(f)						
Mo																	
Ru																	
Rh																	
Pd ppb																	
Ag ppb																	
Cd ppb																	
In ppb							30	(e)									
Sn ppb																	
Sb ppb							4	(e)									
Te ppb																	
Cs ppm							0.4	(e)		0.7	(f)						
Ba	630	(a)	617	(c)			595	(e)	780	610	(f)	666	(d)			649	(c)
La	36	(a)	56.4	(c)			53	(e)	59	72	(f)			57	(e)		
Ce			144	(c)						207	(f)			135	(e)	143	(c)
Pr							17	(e)		23	(f)						
Nd			87	(c)						91	(f)			93	(e)	87.9	(c)
Sm			24	(c)			22.7	(e)		23	(f)			25.6	(e)	24.6	(c)
Eu			2.15	(c)			2.4	(e)		2.28	(f)			2.08	(e)	2.09	(c)
Gd			28	(c)						29	(f)						
Tb							5.1	(e)		4.2	(f)			5.3	(e)		
Dy			32.7	(c)			27.3	(e)		29	(f)			36.2	(e)	31.7	(c)
Ho							6.5	(e)		6.8	(f)			6.7	(e)		
Er			19.7	(c)			16	(e)		19	(f)			20	(e)	19.3	(c)
Tm										3	(f)						
Yb	30	(a)	18.4	(c)			12.5	(e)	16	15	(f)			18.6	(e)	18.1	(c)
Lu														2.76	(e)	2.66	(c)
Hf							17.2	(e)		16	(f)			18	(e)	21	(c)
Ta							2.3	(e)									
W ppb							1200	(e)		600	(f)						
Re ppb			Reed 72														
Os ppb			12														
Ir ppb																	
Pt ppb																	
Au ppb							0.3	(e)									
Th ppm	13.7	(b)	Reed 72		11	(d)	8.6	(e)		12	(f)						
U ppm	3.7	(b)	3.5				2.9	(e)		3	(f)						

technique (a) emiss. spec., (b) radiation counting, (c) IDMS, (d) XRF, (e) INAA, (f) spark source mass spec., (g) AA-Coul.

Table 1b. Chemical composition of 14310.

reference	Masuda 72		Baedecker 72		Morgan 72		Haramura 72		Longhi 72	Chi 73
weight							Kushiro 72			
SiO2 %							46.88	(h)	48.27	
TiO2							1.19	(h)	1.27	
Al2O3							21.68	(h)	20.26	
FeO							8.22	(h)	8.11	
MnO							0.13	(h)		
MgO							7.42	(h)	7.76	
CaO							12.55	(h)	12.25	
Na2O							0.72	(h)	0.81	
K2O							0.5	(h)	0.55	
P2O5							0.17	(h)		
S %										
sum										
Sc ppm										
V										
Cr							1710	(h)		
Co										
Ni			210	(e)						
Cu										
Zn			1.5	(e)	2.3	(e)				
Ga			4.2	(e)						
Ge ppb			90	(e)	130	(e)				
As										
Se					120	(e)				
Rb					11.8	(e)				
Sr										
Y										
Zr										1230
Nb										
Mo										
Ru										
Rh										
Pd ppb										
Ag ppb										
Cd ppb			8.4	(e)	2.6	(e)				
In ppb			20	(e)	130	(e)				
Sn ppb										
Sb ppb					4.5	(e)				
Te ppb					4	(e)				
Cs ppm					0.54	(e)				
Ba										
La	54.9	(c)								
Ce	151.1	(c)								
Pr										
Nd	88.8	(c)								
Sm	25.06	(c)								
Eu	2.33	(c)								
Gd	29.04	(c)								
Tb										
Dy	33.62	(c)								
Ho										
Er	20.28	(c)								
Tm										
Yb	18.65	(c)								
Lu	2.6	(c)								
Hf										27
Ta										
W ppb										
Re ppb					1.2	(e)				
Os ppb										
Ir ppb			7.8	(e)	10.5	(e)				
Pt ppb										
Au ppb					4.31	(e)				
Th ppm										
U ppm										

technique (a) emiss. spec., (b) radiation counting, (c) IDMS, (d) XRF, (e) INAA, (f) spark source mass spec., (g) AA-Coul., (h) wet chemistry

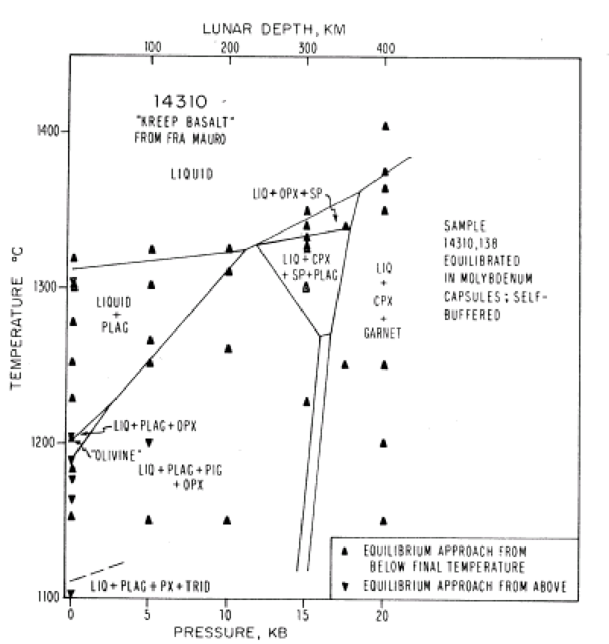

Figure 14: Pressure-temperature phase diagram for 14310 (from Walker et al. 1972).

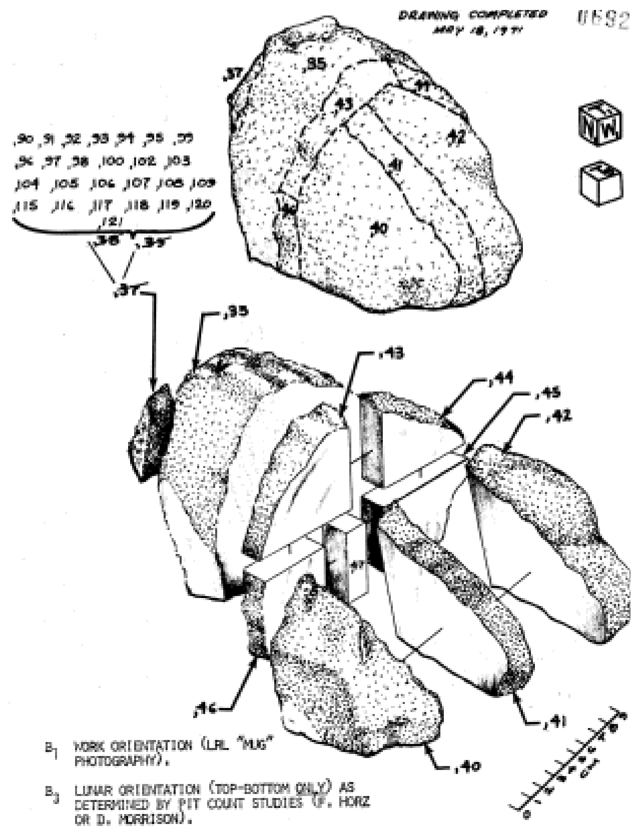

Figure 15: Cutting plan for 14310.

Figure 16: Group processing photo of 14310. Compare with figures 1 and 15.

List of Photos #
S71-21827-21832 – B & W photos, PET
S71-28214-28245 – B & W
S71-30340-30345 – color
S86-32009-32010 – color

Table 2. Light and/or volatile elements for 14310.

reference	LSPET 71	Reed 72	Goel 72	Brunfelt 72		Rose 72	Taylor 72	Gibson 72	Morgan 72		Philpotts 72
Li ppm	19	27				23	22				27.5
Be						4.2					
B											
C	35							35			
S											
N ppm			21								
F ppm											
Cl		5.9		22	(e)						
Br ppb		850							235	(e)	
I ppb		4.7									
Pb ppm						13					
Hg ppb		42									
Tl									10	(e)	
Bi									2.5	(e)	

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