Luna 20

Drill Core

~50 grams

DRAFT

Introduction

"The Luna 20 core, weighing 50 grams exhibited no stratification when placed on a tray. The soil was light gray and has a median grain size of about 70 microns. The sample allocated to NASA was 2.036 g from the 19 to 27 cm level of the sample tray (from certificate). The sample was sieved by the NASA Curator into the following fractions: greater than 500 microns, 0.192 g; 250 – 500 microns, 0.183 g; 125 – 250 microns, 0.235 g; and fines less than 250 microns, 1.426 g." (from Heiken and McEwen 1972). *(that is not the depth in the core, but rather the position on the extrusion tray)*

Figure 1: A 20 cm portion of the Luna 20 core. NASA S73-17207.

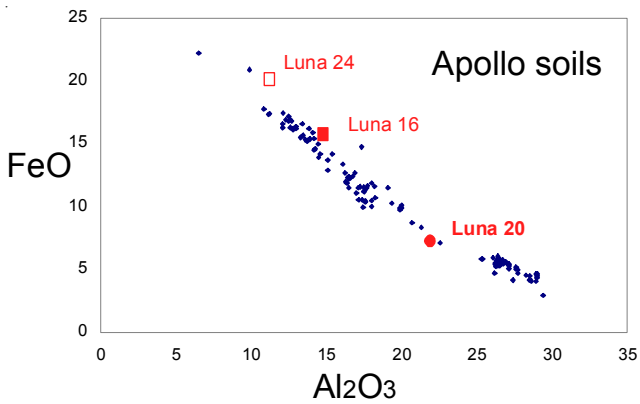


Figure 2: Composition of lunar soil collected by remotely operated Russian robots (1970-1976).

The geologic setting for Luna 20 is outlined in Heiken and McEwen (1972) and Florensky et al. (1979)(*in Cyrillic*). The landing site was in the lunar "highlands" about 160 km north of the Luna 16 site, and about 33 km from the contact with the "shoreline" of Mare Fecunditatis. "The complexly faulted terrain at this site has probably been involved in many generations of shattering and uplift produced by impacts which formed the large basin ring structures"(Heiken and McEwen (1972).

Although Luna 20 collected samples from the "lunar highlands", they were not as anorthositic as might be expected. The largest component is made of impact breccias. The Luna 20 soil also contains more iron-rich pyroxene, than other highland soils (Simon et al. 1981). This may be due to the relative close proximity of mare basalt (33 km).

Petrography

The Luna 20 soil sample contains crystalline lithic fragments of mare basalt, the anorthosite-norite-troctolite group and feldspathic basalt (Crawford and

Mineralogical Mode for 22001

Simon et al. 1981	90-20	20-10 micron
Lithic fragments	28.2	21.5 %
Agglutinates and DMB	28.4	24.8
Pyroxene	11.4	14.1
Plagioclase	22	27.3
Olivine	2.8	4.8
Opaques		
Silica	0.2	
Mare Glass	0.4	1.6
Highland Glass	5.4	5.1

Weigand 1973, Taylor et al. 1973, Cameron et al. 1973, Kridelbaugh and Weill 1973, Prinz et al. 1973, Tarazov et al. 1973 and others). Mineral and glass fragments in the soil and microbreccias are consistent with their origin from comminution of the crystalline lithic fragments. Simon et al. (1981) give the mode.

Albee et al. (1973), Laul and Schmitt (1973) and Podosek et al. (1973) studied two small fragments (22006, and 22007,) that they termed "metaigneous". From what is now known, these are probably impact melt rocks. The carefully planned work on small lunar rock fragments showed how much can be learned from a coordinated study. The age is shown in figure 11,

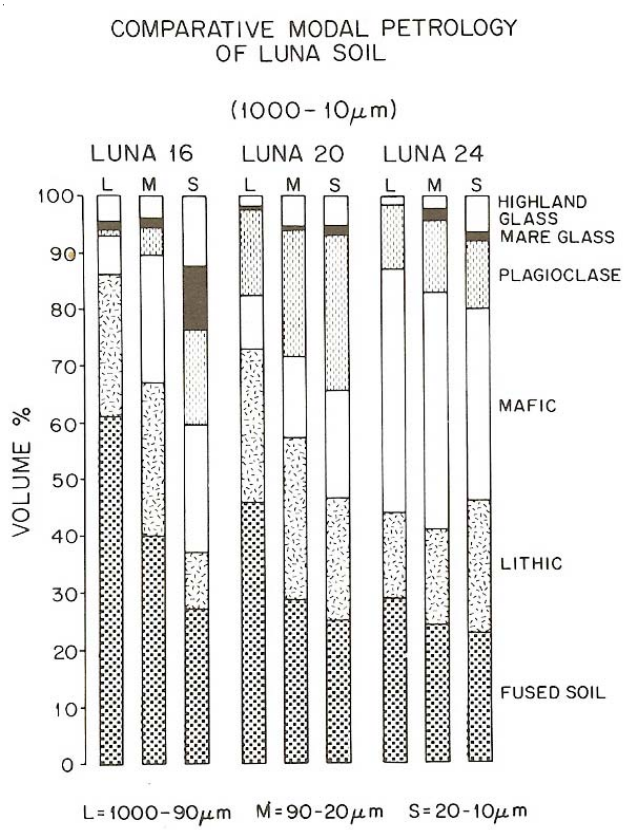


Figure 3: Comparison of mineral modes for the three Luna misssions (Simon et al. 1981).

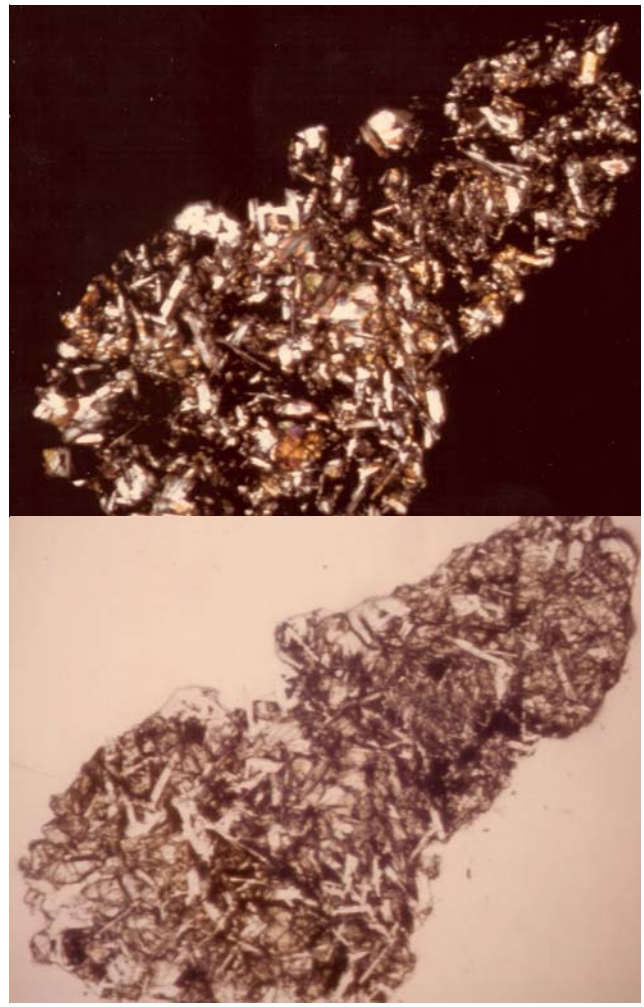


Figure 4: Pictures of a thin section of a basalt fragment from Luna 20 (crossed-polarized and plane-polarized light). About 3 mm across.

the pyroxene composition is in figure 5b and the chemical composition is given in table 2.

Swindle et al. (1991) studied 6 additional fragments (table 2) and were able to get an age for one of them (figure 12).

Mineralogy

There is an abundance of iron-rich pyroxene in Luna 20 samples, which must mean there is a large component of mare material (figure 5). There is also some Mg-rich pyroxene form true highland rocks. The plagioclase form Luna 20 is very calcic (Steele and Smith 1973, bell and Mao 1973).

Brett et al. (1973), Haggerty (1973), Goldstein and Blau (1973) and others studied the opaque minerals. Glass (1973), Warner et al. (1973), Meyer (1978) and Simon

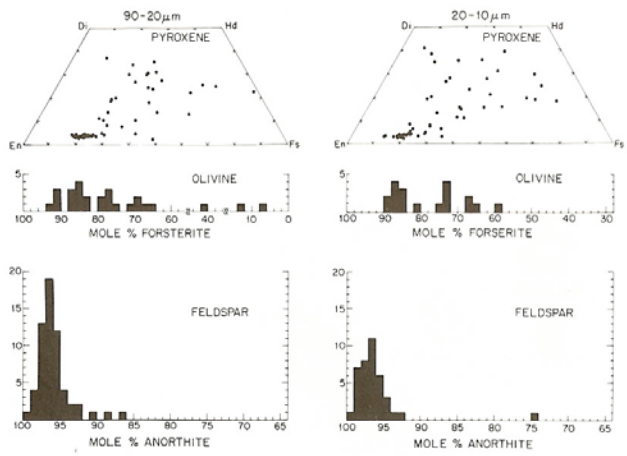


Figure 5a: Mineral compositions of Luna 20 soil (Simon et al. 1981).

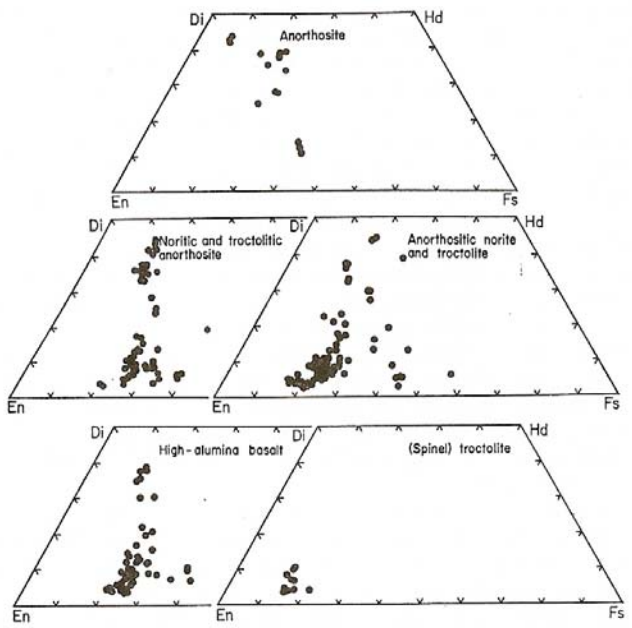


Figure 5c: Pyorxene composition of various small rock fragments from Luna 20 (Prinz et al. 1973).

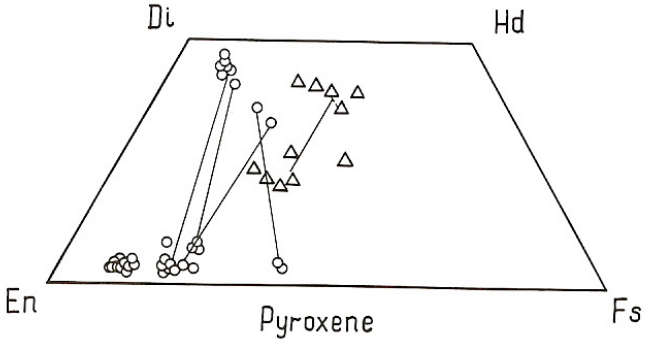


Figure 5e: Pyroxene in Luna 20 fragments (circle for anorthosite, triangle for basalt)(from Tarasov et al. 1973).

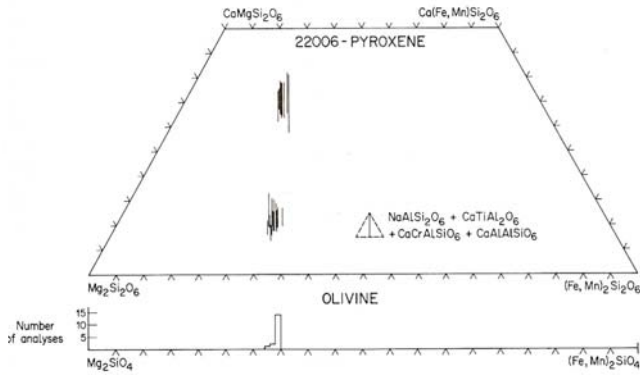


Figure 5b: Composition of pyroxene and olivine in lithic fragment 22006 (Albee et al. 1973).

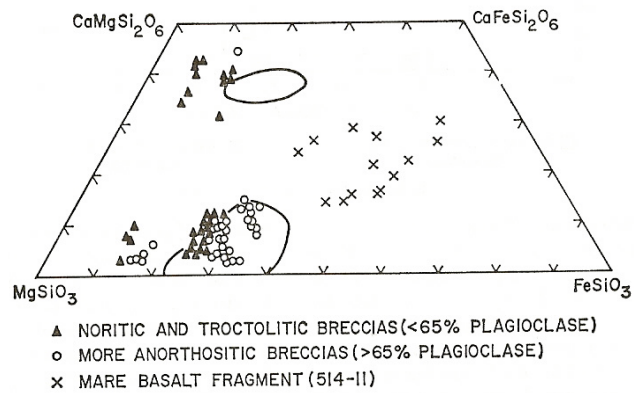


Figure 5d: Composition of pyroxene is Luna 20 rock fragments (Taylor et al. 1973).

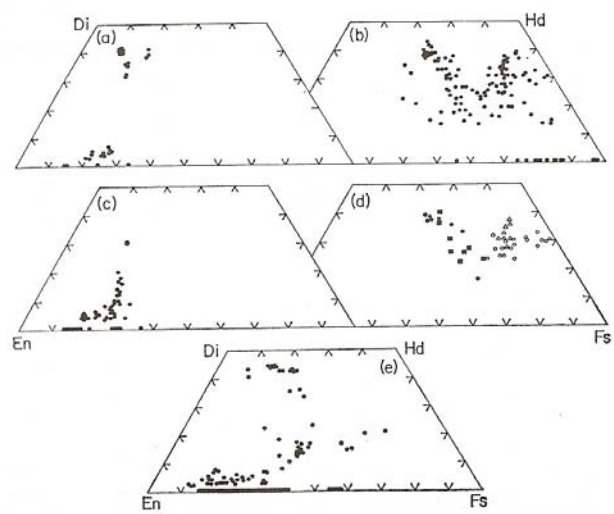


Figure 5f: Pyroxene and olivine composition in various different rock fragments from Luna 20 a) anorthosite, b) basalt, c) recrystallized microbreccia, d) basalt trends, e) microbreccias (Kridelbaugh and Weill 1973).

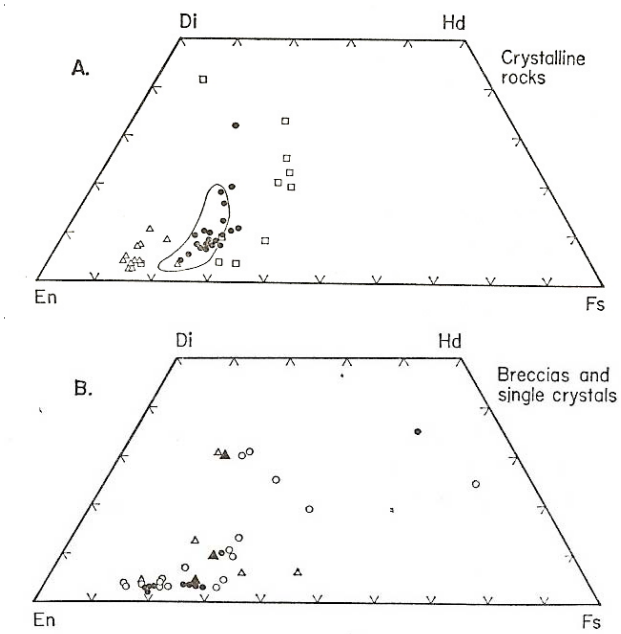


Figure 5g: Pyroxenes in rock fragments and breccias from Luna 20 soil (Cameron et al. 1973).

et al. (1981) determined the composition of numerous glass particles (figures 6 and 7). There are some glass particles from mare regions. A major cluster at about 26% Al_2O_3 has the same average composition as for other sites and is termed "highland basalt" (which may be a misnomer).

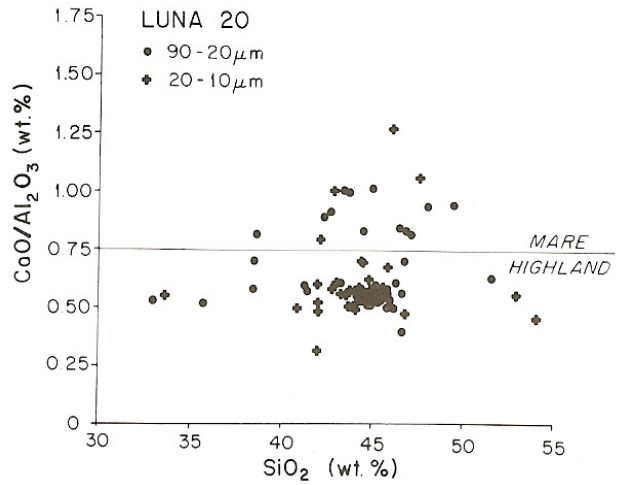


Figure 6: Composition of glass in Luna 20 sample (from Simon et al. 1981).

Chemistry

Bansal et al. (1973), Vinogradov (1973), Nava et al. (1973), Philpotts et al. (1972), Morgan et al. (1973), Laul et al. (1973, 1981) and others reported analyses of the Luna 20 core from different depths – finding it relatively uniform (table 1). The overall trace element content of the soil was lower than for other missions (figure 8).

Laul and Schmitt (1973), Helmke et al. (1973), Vinogradov (1973) and Swindle et al. (1991) analyzed several small fragments (tables 2 and 3). Laul et al.

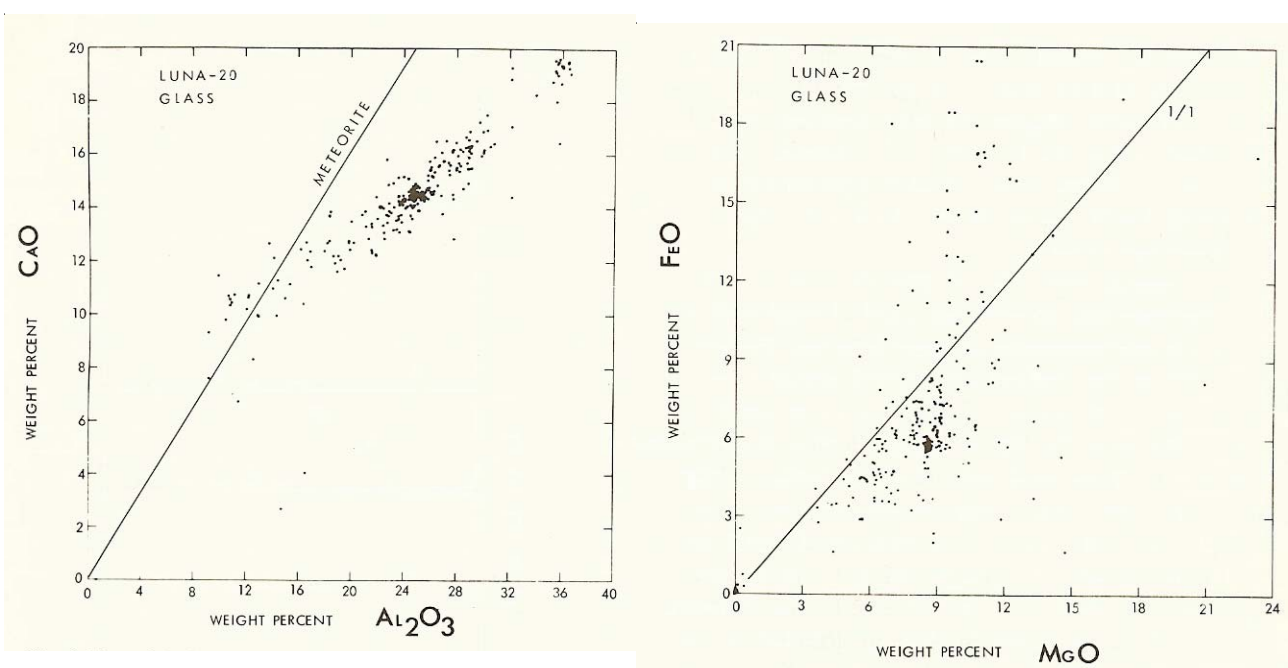


Figure 7: Composition of glass particles from Luna 20 as determined by Apollo Soil Survey (Warenr et al. 1973). The cluster at about 26% Al2O3, 6% FeO and 9% MgO was the evidnce for "Highland Basalt".

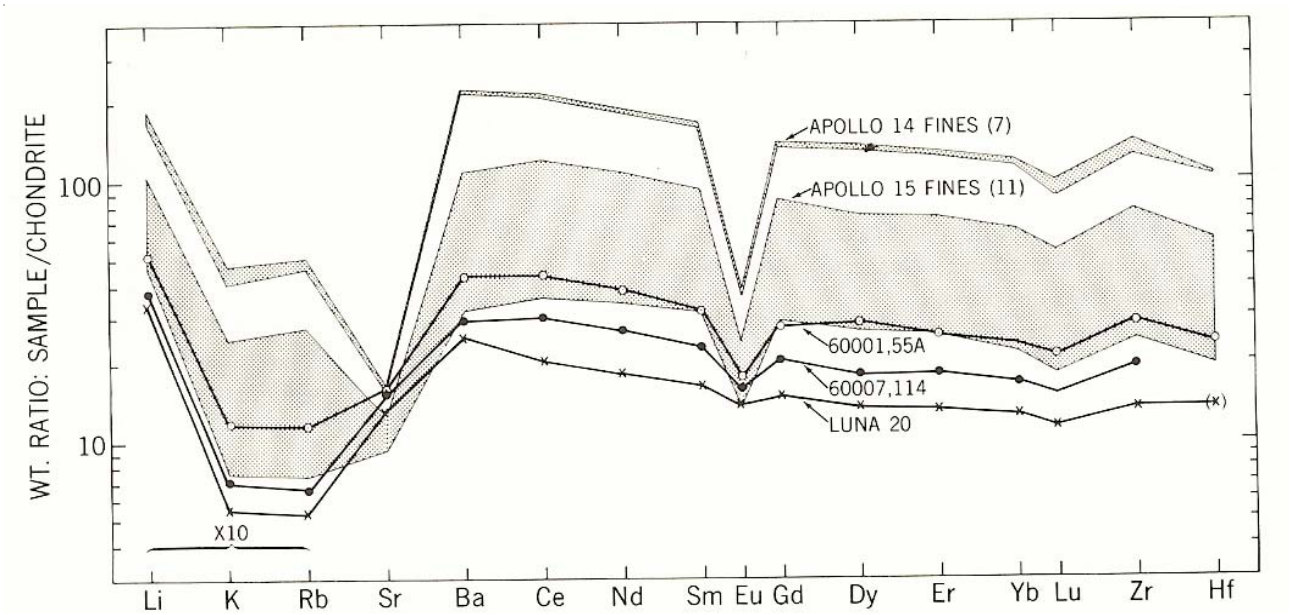


Figure 8: Spider diagram for lunar soils showing that Luna 20 has the absolute lowest trace element content (from Philpotts et al. 1972).

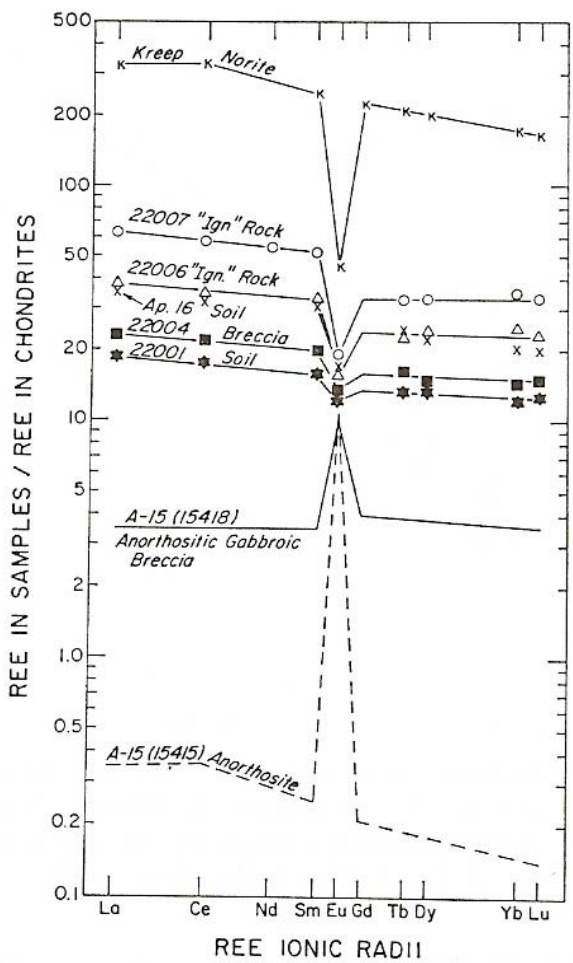


Figure 9: Normalized rare-earth-element diagram for two metaigneous rocks from Luna 20 compared with KREEP, Luna 20 soil and anorthosites from other sites (Laul and Schmitt 1973).

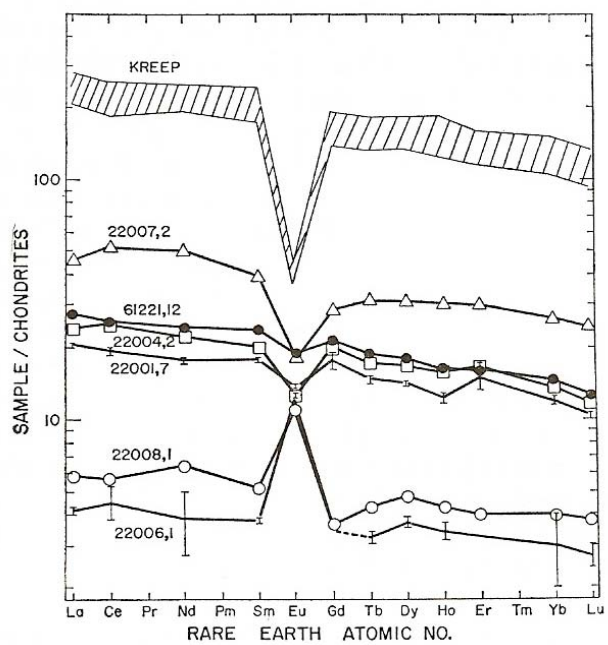


Figure 10: Normalized rare-earth-element diagram for Luna 20 soil and selected particles compared with Apollo 16 soil and KREEP (Helmke et al. 1973).

(1981) analyzed the different grain size fractions, finding that the finest fraction (<10 microns) had the highest content of trace elements, as is the case for other lunar soils.

Simoneit et al. (1973) reported 380 ppm carbon and 80 ppm nitrogen in soil sample 22001,3.

Radiogenic age dating

Podosek et al. (1972) obtained precise ages for two impact melt rocklets from Luna 20 by the Ar/Ar plateau technique (figure 11). Swindle et al. (1991) also obtained a precise age of another (figure 12). Turner et al. (1973) could not get a well defined age on the very small fragments they studied (4.0 ± 0.3 b.y.). However, Andersen and Hinthorne (1973) reported older ages for a phosphate and a "Y,Zr phase" by the ion probe Pb/Pb method.

Tatsumoto (1973), Tera and Wasserburg (1973), studied the U-Th-Pb systematic finding excess Pb (unsupported by U, Th) in these Luna 20 samples. Papanastassiou and Wasserburg (1973) and Nyquist et al. (1973) reported Rb-Sr results.

Cosmogenic isotopes and exposure ages

Turner et al. (1973) reported an exposure age for L2015 of 340 m.y. from ^{38}Ar measurements. Heymann et al. (1973) reported ^{21}Ne exposure ages of 260 m.y. and ^{38}Ar ages of 200-600 m.y. for the Luna 20 soil while Podosek et al. (1973) reported 900 – 1300 m.y. exposure ages by ^{38}Ar for the two metaigneous particles they studied from the soil. This is understood as due to volatile release of comminuted soil over time.

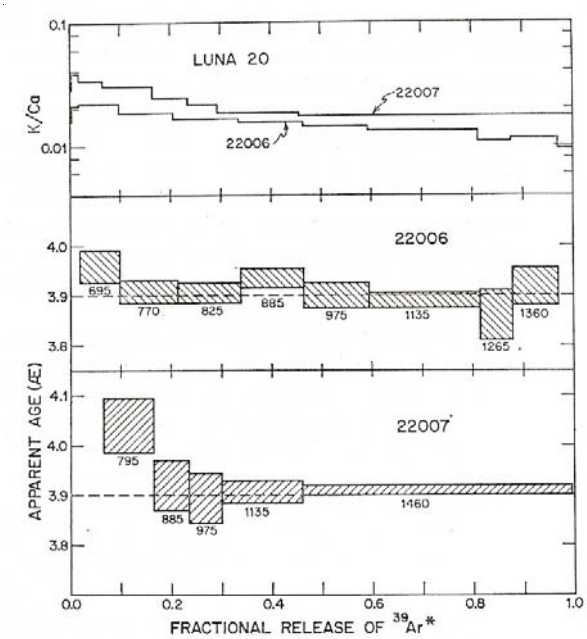


Figure 11: Ar/At plateau diagram for lithic fragments 22006 and 22007 (Podosek et al. 1972).

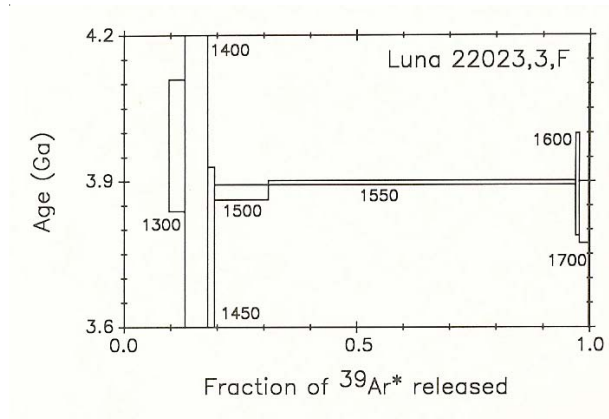


Figure 12: Ar/Ar plateau diagram for 22023,3 (Swindle et al. 1991).

Summary of Age Data for Luna 20

	Ar/Ar
Podsosek et al. 1972	3.84 ± 0.04 b.y.
	3.84 ± 0.04
Cadogen and Turner 1977	3.84 ± 0.1
Swindle et al. 1991	3.895 ± 0.017
Andersen and Hinthorne 73	4.12 ± 0.04
	4.42 ± 0.11

Corrected ages

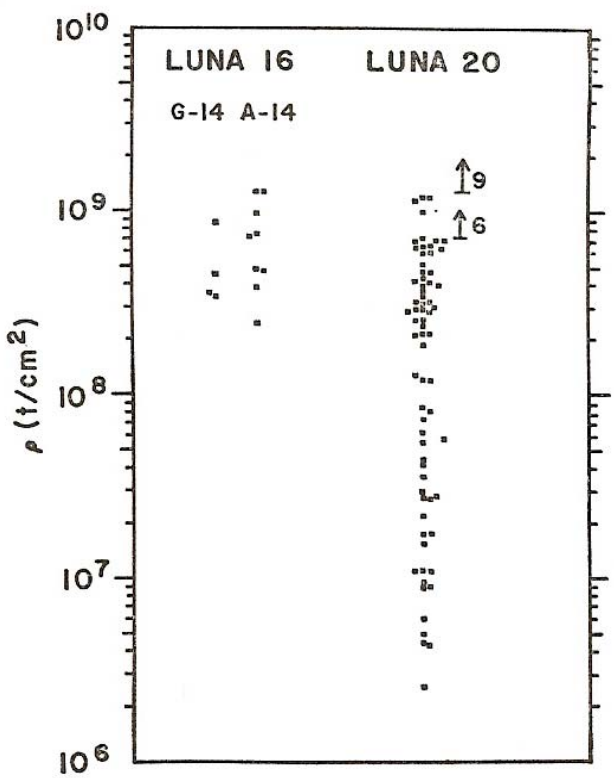


Figure 13: Track densities measured in Luna 20 plagioclase compared with Apollo 16 (Crozaz et al. 1973).

Table 1a. Chemical composition of Luna 20 soil.

reference	**Korotev81**	Laul72	Morgan72	Laul81		McKay Sourcebook		Philpotts72		Loubet72		Bansal72		Jerome72	
weight	**average**	22001,9	22001,10	22001,35		ave.		Nava72		Birck72					
SiO2 %	**45.6**					45.1	(b)	45.4							
TiO2	**0.46**	0.49		0.48	(a)	0.55	(b)	0.47				0.47	(c)	0.43	(a)
Al2O3	**22.9**	22.8		23.5	(a)	22.3	(b)	23.44				22.1	(c)	22.7	(a)
FeO	**7.5**	8.1		7.27	(a)	7	(b)	7.37				7	(c)	7.8	(a)
MnO	**0.106**	0.104		0.1	(a)	0.13	(b)	0.1						0.11	(a)
MgO	**9.15**	10		9.7	(a)	9.8	(b)	9.19				8.4	(c)		
CaO	**14.5**	14.2		14.1	(a)	15.1	(b)	13.38				13.6	(c)	15.8	(a)
Na2O	**0.4**	0.334		0.35	(a)	0.5	(b)	0.29				0.41	(c)	0.38	(a)
K2O	**0.069**	0.076		0.068	(a)	0.1	(b)	0.067	(c)	0.066	(c)	0.07	(c)		
P2O5						0.16	(b)	0.06							
S %						0.08	(b)								
sum															
Sc ppm	**16.4**	16.5		15.4	(a)	16	(b)							16.2	(a)
V	**48**	47		40	(a)										
Cr	**1310**	1231		1231	(a)			960				1668	(c)	1250	(a)
Co	**31**	27		31.6	(a)									34	(a)
Ni	**221**	260		300	(a)										
Cu															
Zn		21	21.5		(d)										
Ga					(d)										
Ge ppb			430		(d)										
As					(d)										
Se		0.2	0.209		(d)										
Rb	**1.6**	1.6	1.5		(d)			1.6	(c)	1.864	(c)	1.6	(c)		
Sr	**141**			130				144	(c)	139.5	(c)	140	(c)		
Y	**24**														
Zr	**110**							94	(c)			115	(c)		
Nb															
Mo														26	(a)
Ru															
Rh															
Pd ppb															
Ag ppb		720	*3080*		(d)										
Cd ppb		19400	1.74		(d)										
In ppb		10	3.9		(d)										
Sn ppb															
Sb ppb		760	9.8		(d)										
Te ppb			21.5		(d)										
Cs ppm		0.07	0.07		(d)										
Ba	**90**			100	(a)			93.8	(c)	92	(c)	87.3	(c)		
La	**6.71**	6.2		7.2	(a)	5				7.4	(c)	6.13	(c)	6.4	(a)
Ce	**16.6**	16		17	(a)			16.1	(c)	16.7	(c)	17.7	(c)	20.3	(a)
Pr															
Nd				12	(a)			10.6	(c)	11.3	(c)	10.3	(c)	11.1	(a)
Sm	**2.97**	3.1		3.2	(a)			2.98	(c)	2.91	(c)	2.97	(c)	3.2	(a)
Eu	**0.95**	0.92		0.9	(a)			0.94	(c)	1.01	(c)	0.92	(c)	0.96	(a)
Gd								3.81	(c)	3.8	(c)	3.8	(c)		
Tb	**0.65**	0.63		0.65	(a)									0.66	(a)
Dy		4		4.2	(a)			4.08	(c)	4.23	(c)	4.23	(c)		
Ho															
Er								2.4	(c)	2.61	(c)	2.66	(c)		
Tm				0.37	(a)									0.35	(a)
Yb	**2.41**	2.6		2.55	(a)			2.36	(c)	2.48	(c)	2.54	(c)	2.3	(a)
Lu	**0.38**	0.43		0.35	(a)			0.38	(c)	0.315	(c)	0.38	(c)	0.37	(a)
Hf	**2.55**	2.5		2.3	(a)			*2.7*	(c)					2.1	(a)
Ta	**0.3**	0.3		0.28	(a)										
W ppb														82	(a)
Re ppb			5.34		(d)										
Os ppb															
Ir ppb			9.5		(d)										
Pt ppb															
Au ppb		7.8	3.59		(d)										
Th ppm	**1.01**	1		1.32	(a)	0.85								0.95	(a)
U ppm	**0.34**	0.5	0.31		(d)	0.29						0.37	(c)		

technique : (a) INAA, (b) Russian data, (c) IDMS, (d) RNAA

Table 1b. Chemical composition of Luna 20 soil (cont.).

	zone 2002			zone 2004											
reference	Vinogradov73		Vinogradov73		Cimbalnikova77		Ganapathy73		Helmke73						
weight		Hubbard77		Hubbard77					22001	22004	22005	22006	22007	22008	
SiO2 %	45.8		44.4		42.8	(a)			fines	frag	frag	frag	frag	frag	
TiO2	0.533		0.56		0.47	(a)									
Al2O3	21.6		22.9		23.6	(a)									
FeO	7.02		7.03		6.6	(a)				7.1	7	4	13.3	6.1	(a)
MnO	0.13		0.12		0.1	(a)				0.08	0.12	0.06	0.1	0.08	(a)
MgO	9.85		9.7		9.5	(a)									
CaO	14.9		15.2		14.4	(a)									
Na2O	0.46		0.55		0.35	(a)									
K2O	0.1		0.1		0.06	(a)									
P2O5	0.17		0.14												
S %	0.08		0.08												
sum															
Sc ppm	17	15	48	15.5	15	(a)			16	11.7	15.8	7.4	20.5	8	(a)
V	23		70		43	(a)									
Cr	720		700		1095	(a)			1370	920	1370	540	1290	1090	(a)
Co	53	40	70	18.6	28	(a)			26	24	28	12.4	162	11	(a)
Ni	170	262	194	280									1900		(a)
Cu	11		27												
Zn	39	21.4	76	28			21.5	(d)	35	52	3	8	6	10	(a)
Ga	3.4		4.5						3.2	4.8	2.3	1.3	3.4	2.7	(a)
Ge ppb							430	(d)							
As	0.25		0.3												
Se	0.2		0.7												
Rb	1	1.31	1	0.86			1.5	(d)	2						
Sr	250	150	230	162	120	(a)									
Y	43	15.8	54	18											
Zr	230	109	400	167											
Nb	6.8	15.8	16												
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb		0.18	1	0.22			*3080*	(d)							
Cd ppb		1.8		0.61			1740	(d)							
In ppb	<0.4		<0.03				3.9	(d)							
Sn ppb	3		0.8												
Sb ppb			<9				9.8	(d)							
Te ppb	0.5														
Cs ppm	0.2		0.1		0.24	(a)	0.07	(d)	0.5						
Ba	110	116	120	85	170	(a)									
La	4.5	5.8	4.9	4.3	8	(a)			6.7	7.9	7	1.39	15	1.93	(a)
Ce	1.2	19.7	1.4	14.8	18	(a)			15.8	22	17.5	3.6	47	5.1	(a)
Pr	3.4		4.5												
Nd	14		13		20	(a)			10.5	13	11.2	2.3	30	3.9	(a)
Sm	3.5		5.3		3.5	(a)			3.23	3.59	3.48	0.68	7.04	0.93	(a)
Eu	0.74	0.93	0.9	0.71	1	(a)			0.94	0.86	0.99	0.86	1.2	0.76	(a)
Gd	2.5		2.9						4.4	5	5		7	0.9	(a)
Tb	0.52		0.47		0.6	(a)			0.68	0.8	0.72	0.15	1.5	0.2	(a)
Dy	3.9		4.5		5	(a)			4.48	5.3	5.5	1.2	9.7	1.53	(a)
Ho	0.8		1						0.85	1.1	1.2	0.24	2.1	0.3	(a)
Er	1.8				1.3	(a)			3	3.3	3.5	1.1	6	0.8	(a)
Tm	0.27		0.6												
Yb	1.6		1.6		2.5	(a)			2.38	2.7	2.8	0.6	5.2	0.8	(a)
Lu	0.28		0.38		0.4	(a)			0.349	0.39	0.42	0.09	0.81	0.13	(a)
Hf	1.6		4.5						2.9	1.9	2.7	0.7	8	0.77	(a)
Ta															
W ppb															
Re ppb							5.3	(d)							
Os ppb															
Ir ppb							9.5	(d)							
Pt ppb															
Au ppb							3.59	(d)							
Th ppm															
U ppm							0.31	(d)							

technique : (a) INAA, (b) Russian data, (c) IDMS, (d) RNAA

Table 2. Chemical composition of L20 particles.

reference	Vinogradov73		Swindle et al. 1991							Laul and Schmitt 1973			Ganapathy73		
weight	anorthosite		22023					18F		22007-1	22006-1		anor.	soil brec.	
SiO2 %	44.2	(a)											22006,3	22005,3	
TiO2	0.52									0.76	0.63	(b)			
Al2O3	19.1									21.4	21.9	(b)			
FeO	6.91		3.73	6.21	6.91	4.62	6.28	6.85	(b)	8	9.9	(b)			
MnO	0.12									0.096	0.121	(b)			
MgO	13.37									13	11	(b)			
CaO	13.3		15.5	14.6	12.9	16.7	15.3	13.3	(b)	13	12.4	(b)			
Na2O	0.48		0.457	0.389	0.441	0.315	0.183	0.459	(b)	0.485	0.408	(b)			
K2O	0.47									0.21	0.12	(b)			
P2O5	0.17														
S %															
sum															
Sc ppm	36		4.81	13.7	9.66	9.9	10.2	12.5	(b)	15.3	21	(b)			
V	30									35	40	(b)			
Cr	1224		698	1000	1360	733	962	1110	(b)	1190	1170	(b)			
Co	27		19.6	17.6	26.4	10.7	29.2	26.4	(b)	51	40	(b)			
Ni	189		226	130	245	99	350	155	(b)				230	295	(c)
Cu	7														
Zn	6												2.1	12	(c)
Ga	3.2														
Ge ppb	170												53	485	(c)
As	0.2														
Se													49	234	(c)
Rb													0.9	1.7	(c)
Sr	86		170	127	139	152	153	149	(b)						
Y															
Zr	50		31	80	100	87	80	255	(b)						
Nb	9.3														
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb													7	29	(c)
Cd ppb													12	48	(c)
In ppb															
Sn ppb															
Sb ppb													0.68	1.5	(c)
Te ppb													31	30	(c)
Cs ppm			0.06	0.11	0.15	0.06	0.15	0.1	(b)				0.14	0.14	(c)
Ba	66		37	38	21	55	64	198	(b)						
La			2.55	2.97	1.44	4.47	4.53	16.9	(b)	21.4	12.9	(b)			
Ce	5.2		6.4	7.8	3.9	11.5	11.8	43.2	(b)	53	32	(b)			
Pr	1.5														
Nd	3.1		4			6	8	25	(b)	35		(b)			
Sm	1.5		1.17	1.43	0.71	2.1	2.15	7.42	(b)	10.1	6.4	(b)			
Eu	0.53		0.95	0.81	0.67	0.9	0.81	1.29	(b)	1.41	1.11	(b)			
Gd	0.9														
Tb			0.24	0.34	0.16	0.44	0.44	1.51	(b)	1.6	1.1	(b)			
Dy	1.5									9.8	7.2	(b)			
Ho	0.3														
Er	0.75														
Tm															
Yb	0.68		0.97	1.39	0.65	1.66	1.73	5.45	(b)	7.8	5.6	(b)			
Lu	0.13		0.136	0.193	0.094	0.234	0.246	0.776	(b)	1.13	0.78	(b)			
Hf			0.9	0.94	0.53	1.71	1.62	5.88	(b)	8.5	4.2	(b)			
Ta			0.123	0.1	0.07	0.21	0.22	0.67	(b)	0.7	0.5	(b)			
W ppb						2		3	(b)						
Re ppb													1.19	1.04	(c)
Os ppb															
Ir ppb			8.8	3.5	9.4	5.3	21	6.2	(b)				11.7	9.52	(c)
Pt ppb															
Au ppb			2.4	3.5	4.8	10	4.8	4.2	(b)				3.37	3.29	(c)
Th ppm			0.54	0.48	0.17	0.77	0.81	2.7	(b)	3.4	1.7	(b)			
U ppm			0.14	0.22	0.15	0.2	0.29	0.77	(b)				0.077	0.34	(c)

technique: (a) "mass spec. and XRF, (b) INAA, (c) RNAA

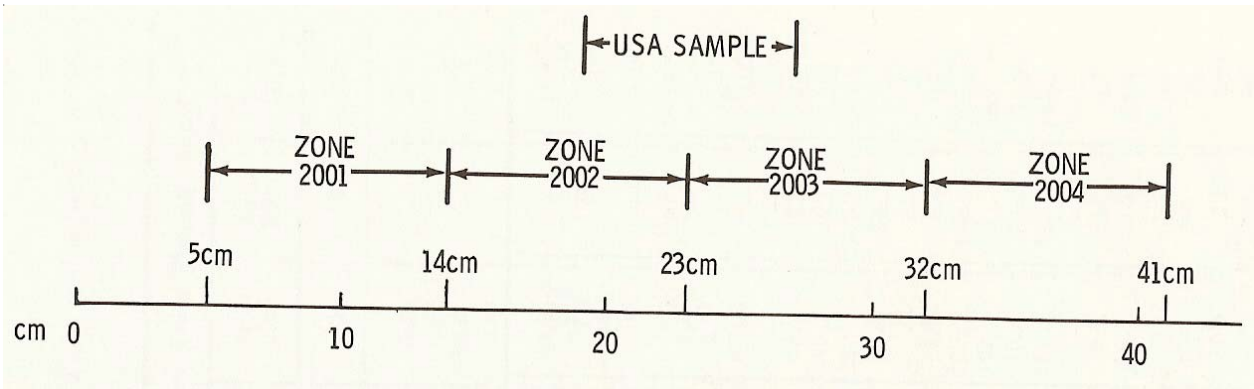
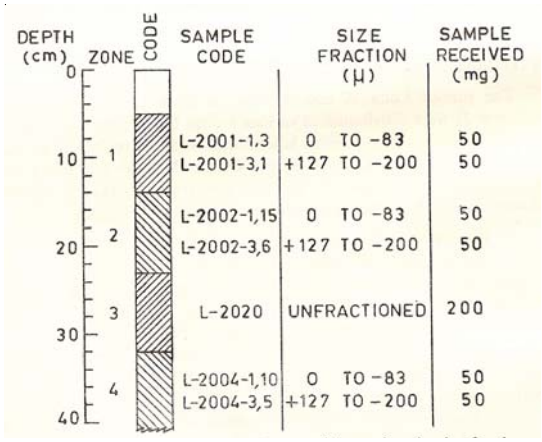


Figure 14: The Luna 20 tray (Hubbard et al. 1977). See figure 1.



DEPTH (cm)	ZONE	CODE	SAMPLE CODE	SIZE FRACTION (μ)	SAMPLE RECEIVED (mg)
0					
10	1		L-2001-1,3	0 TO -83	50
			L-2001-3,1	+127 TO -200	50
20	2		L-2002-1,15	0 TO -83	50
			L-2002-3,6	+127 TO -200	50
30	3		L-2020	UNFRACTIONED	200
40	4		L-2004-1,10	0 TO -83	50
			L-2004-3,5	+127 TO -200	50

Figure 15: Location of Luna 20 samples studied by Indian researchers (Lal 1974).

Other Studies

Clayton (1973) and Taylor and Epstein (1973) determined the isotopic composition of oxygen.

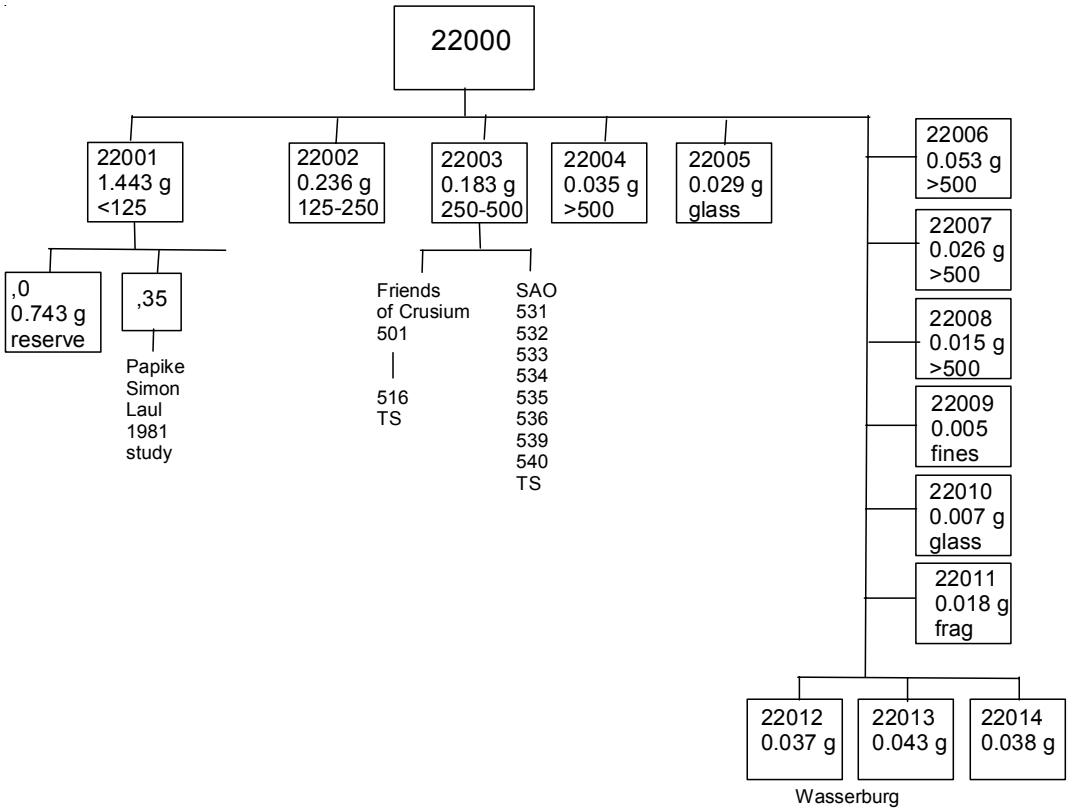
Rare gas analyses were reported by Agrawal et al. (1974), Eugster et al. (1975), Heymann et al. (1973)

Nuclear tracks produced by cosmic rays were studied by Crozaz et al. (1973), Berdot et al. (1972), Phakey and Price (1973) and Russian investigators (figure 13).

Processing

After the sample was returned to Earth (Moscow), it was transferred into a chamber filled with He at the Vernadsky Institute (see figure in Vinogradov 1973) where the Luna 20 core was extruded into a tray, which was divided into zones (figure 14). The details of initial sample processing are given in Surkov 1979, *in Cyrillic*). The depth of the sample in the core does not correspond to the marking on the tray, but the relative position was maintained.

The USSR Academy of Science made samples available to the international science community. The US sample, L2009, from 19-27 cm (2.036 grams), was traded for Apollo core material.
L2015 (0.51 g) was allocated to the Royal Society of London and was from the 27-32 cm zone (Turner et al. 1973). The French CNES also got ~1 gram from 19-23 cm zone (L-2010).
India and Czechoslovakia studied splits from several depths (figure 14)..



List of Luna Samples received from USSR as of 9/25/87

Luna20

US number	weight	date rec
22001	1.443	4/13/72 (as 2.05 inc. 22002-11)
22002	0.236	
22003	0.183	
22004	0.035	
22005	0.029	
22006	0.053	
22007	0.026	
22008	0.015	
22009	0.005	
22010	0.007	
22011	0.018	
22012	0.037	4/13/72 (to Wasserburg)
22013	0.043	4/13/72 (to Wasserburg)
22014	0.038	3/20/79
22023	0.522	3/14/87

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