76535

Troctolite
155.5g, ~5 x 5 x 5 cm

INTRODUCTION

Troctolite 76535 is without doubt the most interesting sample returned from the Moon! It is a colorful, pristine, coarse-grained, plutonic rock that has had a slow cooling history. It is interesting to note that it was collected as a random sample as part of the rake sample collected at Station 6. It has been widely distributed and much studied, but its origin is still debated.

Fig. 1 shows the main mass of 76535 before processing. The sample is friable, separating easily at the grain boundaries. Closeup photos of small pieces show the granular texture of the olivine and plagioclase (Fig. 2). White plagioclase grains (0.2-0.7 mm) are translucent to slightly milky, while lustrous olivine grains (0.2-0.3 mm) occur in clusters and are honey-yellow brown in color. Plagioclase shows nice striations on flat cleavage surfaces.

PETROGRAPHY

Gooley et al. (1974) and Dymek et al. (1975) describe lunar sample 76535 as a coarse-grained, olivine-plagioclase cumulate that shows evidence of extensive annealing and re-equilibration (Fig. 3). Gooley reports the mode as 58% plagioclase (An_{96}), 37% olivine (Fo_{88}), and 4% orthopyroxene (Wo 1 $En_{86}FS_{13}$), while Dymek finds 35% plagioclase, 60% olivine, and 5% low-Ca pyroxene. Warren (1993) wisely puts it at 50% plagioclase! Other trace minerals reported include Ca-rich pyroxene ($Wo_{48}En_{50}FS_4$), Cr-spinel, Ca-phosphates (apatite and whitlockite), baddeleyite, "pyrochlore," "K-Ba feldspar," and metallic iron. These minor phases occur in "mesostasis areas" and in symplectite intergrowths.

This rock has a granular polygonal texture with smooth, curved grain boundaries and abundant 120 deg junctions resulting from the slow process of grain coarsening leading to a mineral fabric with minimum surface area (Fig. 3). Stewart (1975) used the grain size of 76535 (2 to 3 mm) and various assumptions to calculate the interval of annealing (108 y.) in the temperature range 1100°C to 600°C. Stewart termed this "Apollonian" metamorphism.

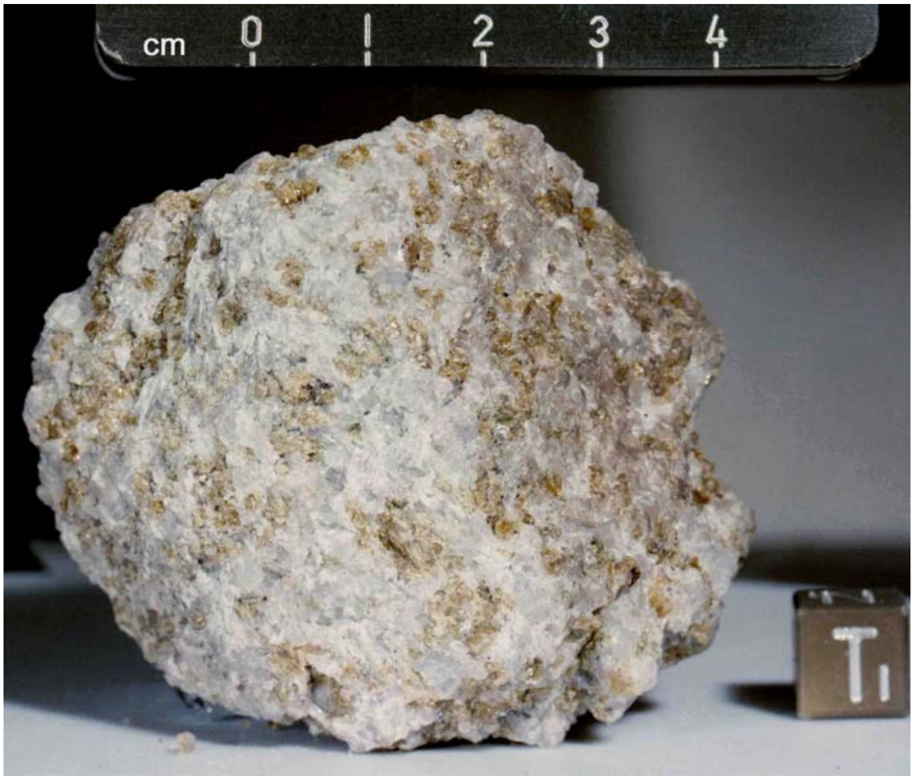

Figure 1: Photograph of lunar troctolite 76535. Cube is 1 cm. S73-19459.

Figure 2: Photograph of lunar troctolite 76535,2. Scale bar is marked in mm. S73-19601.

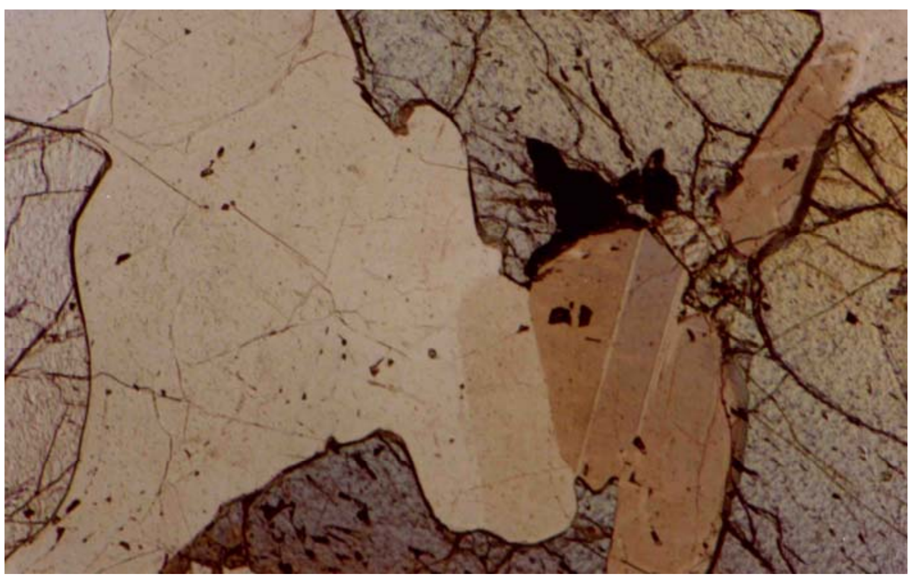

Figure 3: Photomicrograph of thin section 76535 in partially cross-polarized light.
Field of view is 2 x 3 mm. S76-20796.

Gooley et al. (1974) used the enstatite content of the high-Ca pyroxene coexisting with low-Ca pyroxene in the symplectites to calculate an equilibrium temperature of 1000 °C and a minimum pressure of about 0.6 kb, which would be about 12 km deep in the Moon. Dymek et al. (1975) agreed that this rock formed deep in the Moon, but not with the calculation of the depth! Finnerty and Rigden (1981) argue that the high-Ca pyroxene in the symplectite is secondary and not in equilibrium.

The plagioclase has striations (Fig. 2) reportedly due to twinning (LSPET 1973; Phinney et al., 1974; Gooley et al., 1974). Oriented rows of fine elongate metal particles are also reported in the plagioclase (Gooley et al., 1974), but Bell et al. (1975) report that these elongate inclusions are another form of symplectite. Using high resolution TEM techniques, Nord (1976) found that the inclusions in the plagioclase are augite, pigeonite, orthopyroxene, and holes (or an unidentified phase which is preferentially thinned out during-sample preparation). Ni-Fe metal particles are also present but constitute a small volume of the inclusions. These elongate inclu - sions in the plagioclase of 76535 appear to be the result of unmixing of unwanted components in the plagioclase that have nucleated on dislocations, subboundaries, and twin boundaries during solid-state exsolution. The geometric distribution of these rows of small inclusions precludes entrapment of melt droplets during crystallization.

MINERAL CHEMISTRY

Minerals in 76535 are homogeneous in composition. Dymek et al. (1975) and Gooley et al. (1974) present detailed mineral compositions (Fig. 4). High Ca-pyroxene and Cr-spinel are only minor phases. Fig. 5 shows the position of 76535 on the plagioclase vs. pyroxene diagram. It is the end-member of the "Mg-suite" of lunar magmatic rocks in James and Flohr (1983).

Hansen et al. (1979) have determined the Na, K, Fe, and Mg distribution by electron probe in plagioclase from 76535, and Steele et al. (1980) have determined Li, Mg, Ti, K, Sr, and Ba in plagioclase by ion probe. Smith et al. (1980) have determined the trace element contents of olivine

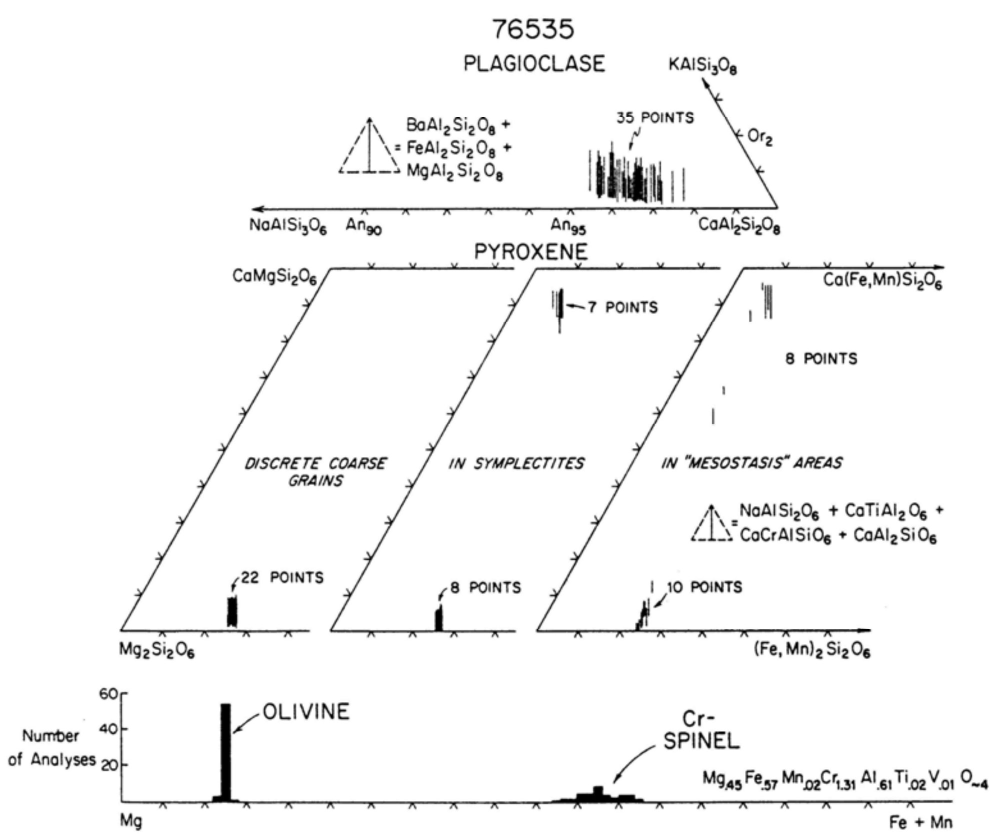

Figure 4: Pyroxene diagrams and mineral compositions of 76535 (from Dymek et al., 1975). Plagioclase and olivine are main minerals.

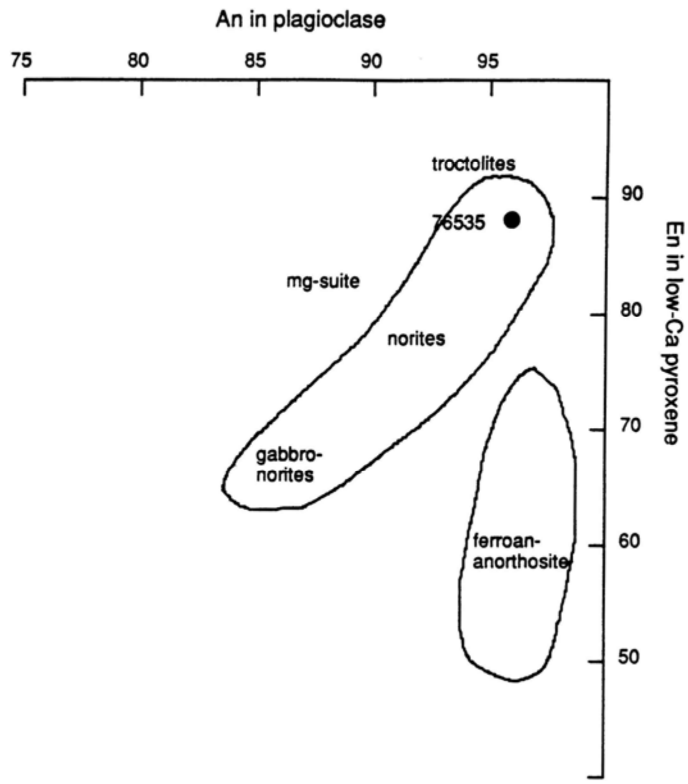

Figure 5: Plagioclase vs. low-Ca pyroxene composition of 76535 troctolite, showing that it is the end-member of the Mg-suite of plutonic lunar rocks. Fields are from James and Flohr (1983).

from 76535. Precise mineral compositions for olivine and low-Ca pyroxene are also given in Bersch et al. (1991). Haskin et al. (1974) determined the rare earth contents of plagioclase and olivine separates by isotope dilution mass spectroscopy (Fig. 6). Heavilon and Crozaz (1989) have also used the ion microprobe technique to determine the rare earth elements in plagioclase and pyroxene.

76535 has symplectite intergrowths along some but not all of the grain boundaries (Gooley et al., 1974; Albee et al., 1975; Bell et al., 1975). Bell et al. discuss in detail several types of symplectites in 76535. Gooley et al. (1974) and Ryder et al. (1980) report the composition of metal grains in 76535. Haggerty (1975) gives the composition of chromite in 76535.

Smyth (1986) performed a crystal structure refinement of anorthite using plagioclase from 76535 to determine the position of the cations in the structure.

Based on identical mineral chemistry, Warren et al. (1987) apparently have found at least two additional pieces of troctolite i.imilar to 76535 in the "coarse fines" from the soil samples (76504, 12 and 76034,90).

WHOLE-ROCK CHEMISTRY

Rhodes et al. (1974a), Wiesmann and Hubbard (1975), and Haskin et al. (1974) have determined the bulk chemical composition (Table I and Fig. 6). Morgan et al. (1974),and Wolf et al. (1979) report the siderophile and volatile trace elements (Table 2). The low siderophile content indicates its pristine composition with no meteorite contribution.

Haskin et al. used the whole-rock composition and known distribution coefficients to calculate the probable parent liquid (Fig. 7). They concluded that this rock may have had ~16% trapped liquid when it originally crystallized from the melt.

RADIOGENIC ISOTOPES

Heroic efforts have been made to date troctolite 76535. Most recently, Premo and Tatsumoto (1992) have carefully considered the age of 76535 and conclude that it was formed between 4.23 and 4.26 b.y. Note that Hinthorne et al. (1975) originally determined 4.27 ± 0.03 b.y. using the $^{207}Pb/^{206}Pb$,

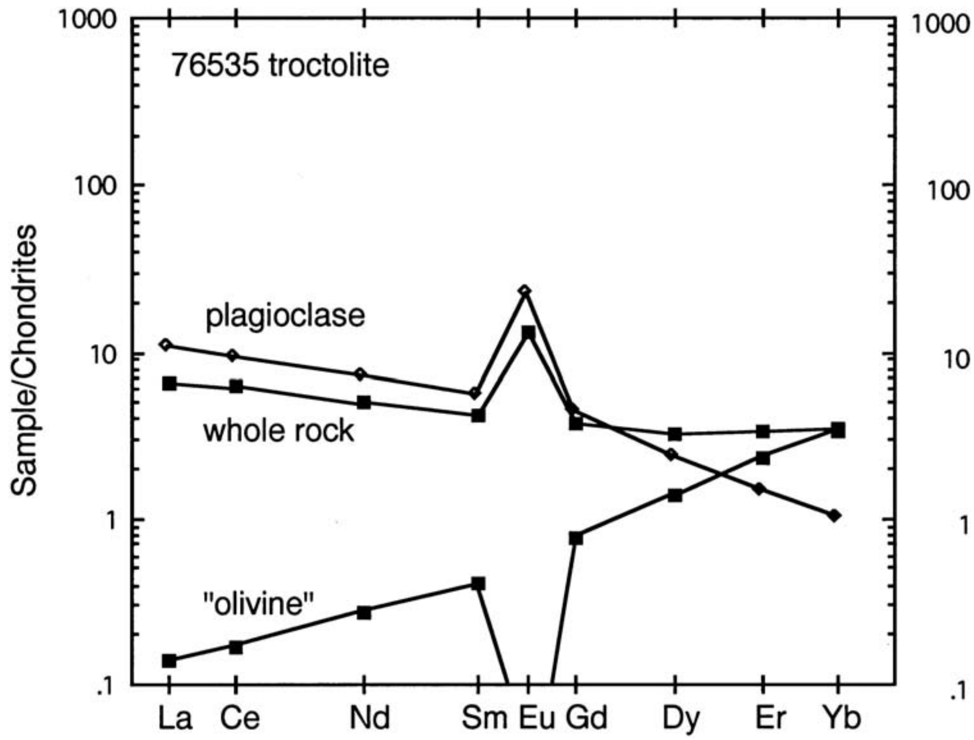

Figure 6: Normalized rare earth element diagram for lunar troctolite 76535. Data are from Haskin et al. (1975.)

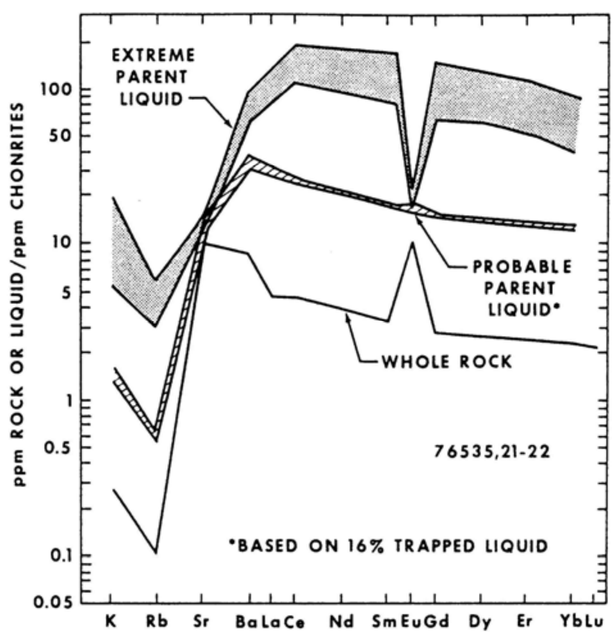

Figure 7: Calculated liquids for parental magma of 76535. Figure is from Haskin et al. (1975).

ion microprobe technique to date U-rich phases.

The various age dating studies of troctolite 76535 provide an interesting study in the preservation of radiogenic information through the course of major metamorphic change (Table 3). Careful study of the Rb-Sr, Sm-Nd, and $^{4O}Ar/^{39}Ar$ systematics has yielded a broad range of apparent isotopic closure ages, 4.61 ± 0.07, 4.26 ± 0.06, and 4.23-4.34 b.y., respectively, for troctolite 76535 (Papanastassiou and Wasserburg, 1976; Lugmair et at., 1976; Lugmair and Marti, 1978; Husain and Schaeffer, 1975; Bogard et al., 1975; Huneke and Wasserburg, 1975). The Rb-Sr isochron (Table 4 and Fig. 8) is based on Rb-rich inclusions in the olivine (one point was excluded), whereas the Sm-Nd isochron (Table 5 and Fig. 9) is based on pyroxene, plagioclase, and accessory phases, exclusive of olivine. The Rb-Sr isochron presumably dates the isolation of Rb-rich inclusions in olivine and is apparently insensitive to the metamorphism that produced the texture of the rock, while the Sm-Nd and $^{4O}Ar/^{39}Ar$ isochrons involve a variety of lower temperature mineral phases that are more sensitive to subsequent metamorphism and closure to movement of radiogenic elements at a later time. The study of rare gases by Caffee et al. (1981) also shows that the different minerals in 76535 have different, mineral-specific, isotopic closure ages.

Premo and Tatsumoto (1992) performed careful leaching experiments on mineral separates from 76535 and determined a "probable age" of 4.236 ± 0.015 b.y., with a young "disturbance" at about 62 rn.y. (Table 6 and Fig. 10). This requires a high U/Pb in the source region. Tera and Wasserburg (1974) had previously tried to date 76535 by U-Pb systematics, but found that their techniques did not give go& data for this rock, even after careful leaching of mineral surfaces. The: discordant data by Tera and Wasserburg are presented in Figs. 11 and 12.

Bogard et al. (1975) and Premo avid Tatsumoto (1992) have measured additional Rb-Sr and Sm-Nd data on 76535 (Tables 7 and 8).

Hohenberg et al. (1980) and Caffee et al. (1981) have carefully studied "excess" fission xenon and trapped solar wind noble gases in troctolile 76535 (Fig. 13). Stepwise heating of separated olivine and plagioclase showed evidence for *in-situ* decay of ^{244}Pu leading to fission Xe ages of 4.50 b.y. and 4.25 b.y., respectively (consistent with Rb-Sr and Sm-Nd ages above). Ne, Ar, Kr and "parentless" fission Xe are loosely bound (Fig. 14). These rare gases are apparently located at the grain boundaries and apparently due to trapped solar wind located in this sample!

Braddy et al. (1975) reported a fission track age of 4.07 b.y., which they say may record a metamorphic age. However, fission tracks in apatite are easily annealed over a long time, and it is unlikely that they would be fully preserved.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Bogard et al. (1975), Crozaz et al. (1974), and Lugmair et al. (1976) reported cosmic ray exposure ages of 195 ± 10 m.y., 211 ± 7 m.y., and 223 ± 16 m.y., respectively. Premo and Tatsumoto (1992) show a hint of a lower intercept age at 62 ± 320 m.y., suggesting Pb disturbance at the time of excavation.

SPECTRAL REFLECTANCE

Charette and Adams (1977) have recorded the spectral reflectance of 76535 and note the minimum near 1.1 pm due to olivine as well as the absorption at 0.9 µm due to pyroxene (Fig. 15).

PROCESSING

This sample was extremely friable and had already broken into many separate fragments by the time of the preliminary examination. There may be additional pieces of it in the residue from the collection bag (76530, 70 g).

The largest remaining piece (, 0) weighs 26 g. A 20-gram piece is at Brooks Air Force Base, and a 10-gram piece is at the California Institute of Technology.

There are 14 thin sections. Sample 76535 was cut with the band saw!

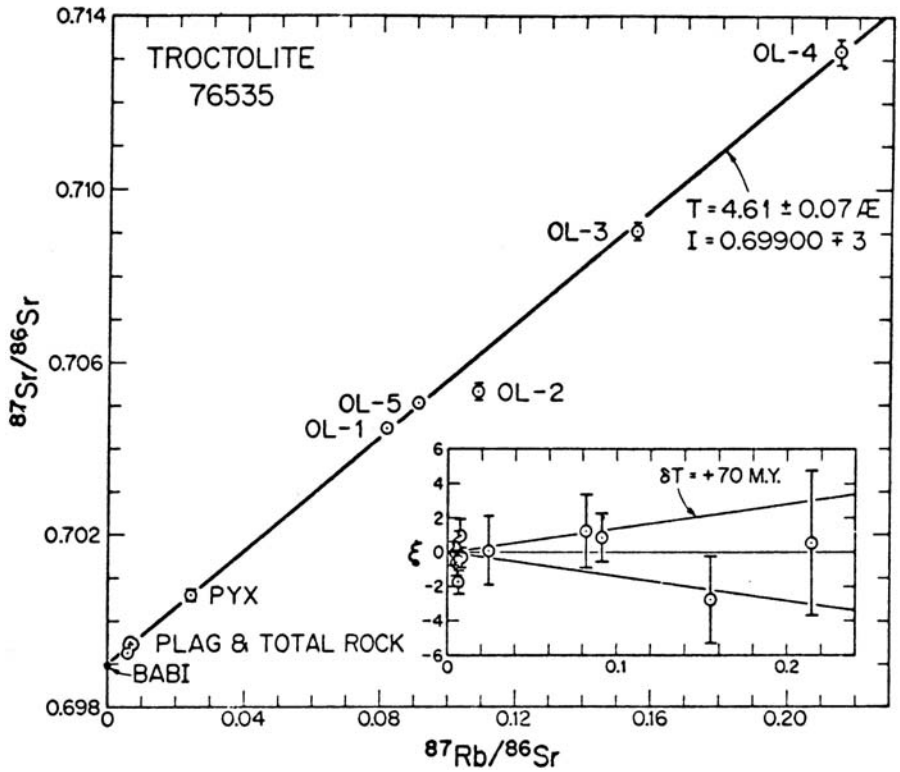

Figure 8. Rb-Sr isochron diagram for lunar troctolite 76535. From Papanastassiou and Wasserburg (1976).

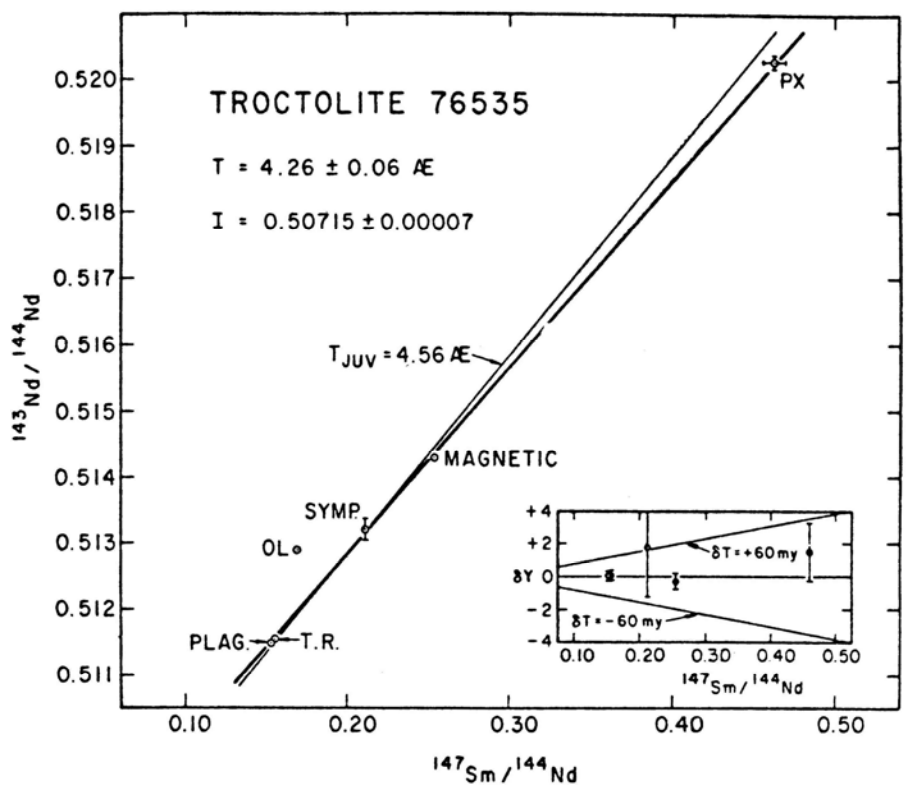

Figure 9. Sm-Nd isochron diagram for 76535. From Lugmair et al. (1976).

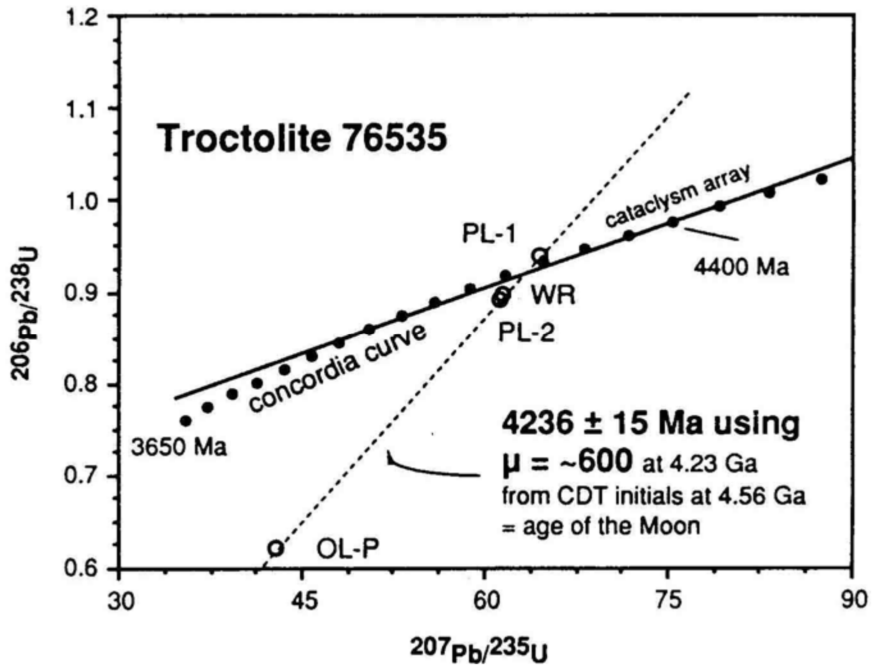

Figure 10: U-Pb concordia diagram for 76535. From Premo and Tatsumoto (1992).

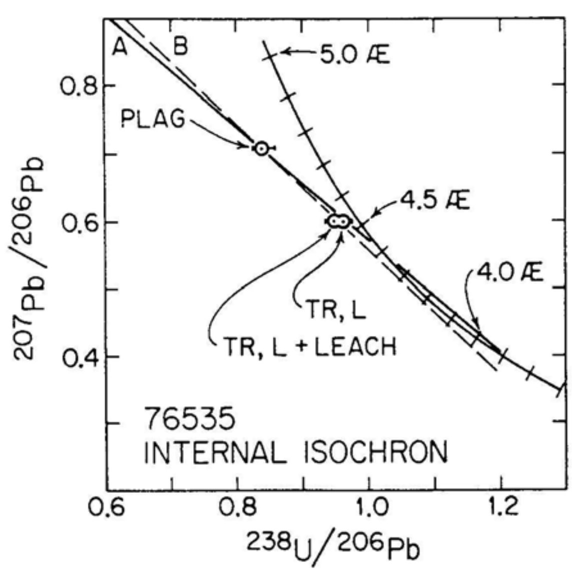

Figure 11: U-Pb concordia diagram for 76535. From Tera and Wasserburg (1974).

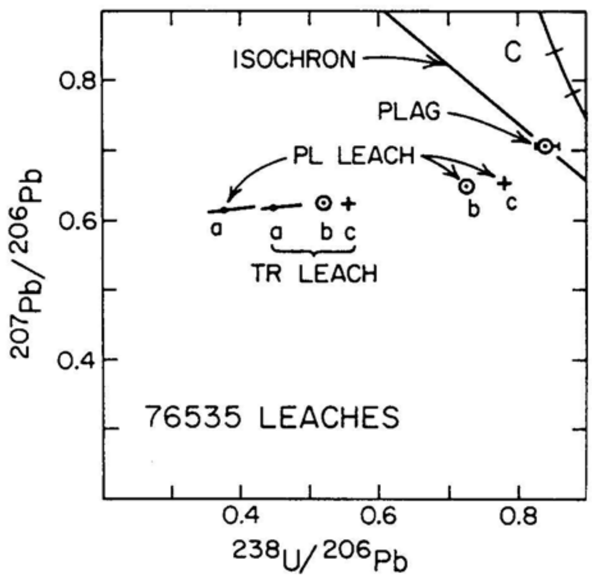

Figure 12: U-Pb concordia diagram showing the Pb data for the leached fractions. From Tera and Wasserburg (1974).

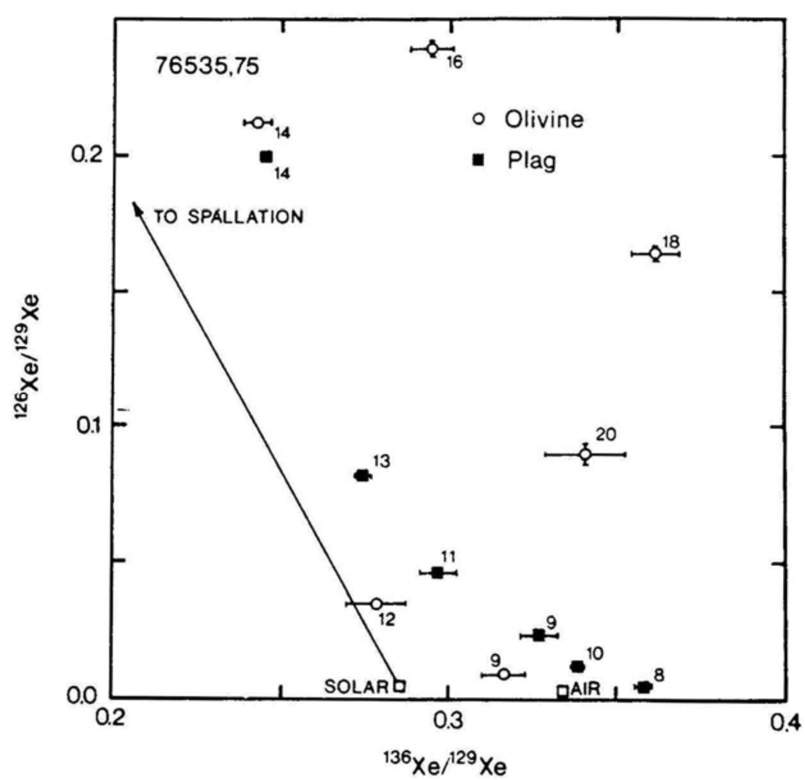

Figure 13: Xe isotope data from olivine and plagioclase in 76535. From Caffee et al. (1981).

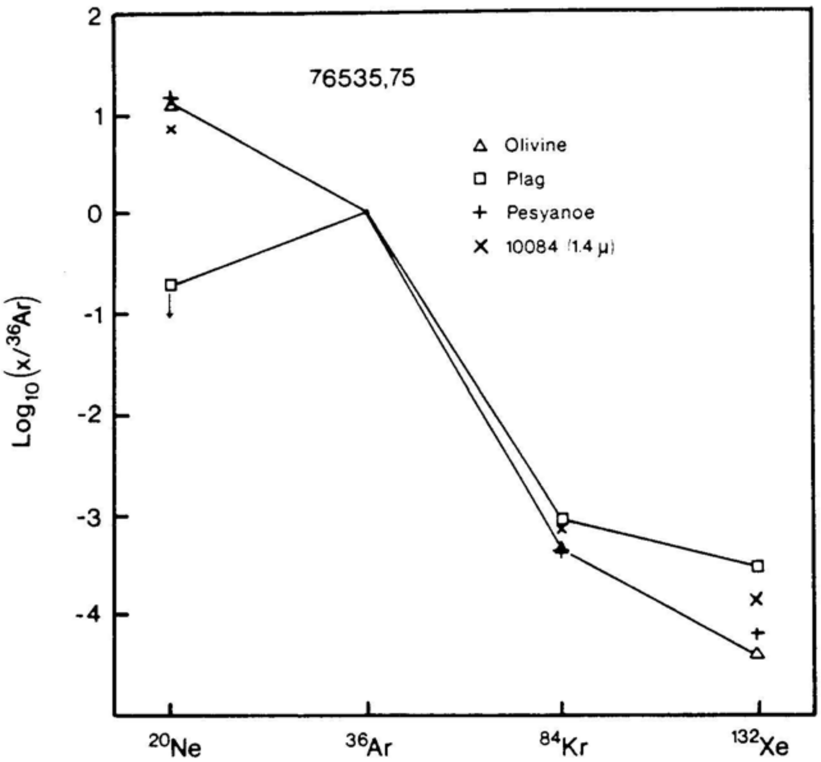

Figure 14: Relative abundances of trapped rare gases in 76535. From Caffee et al. (1981).

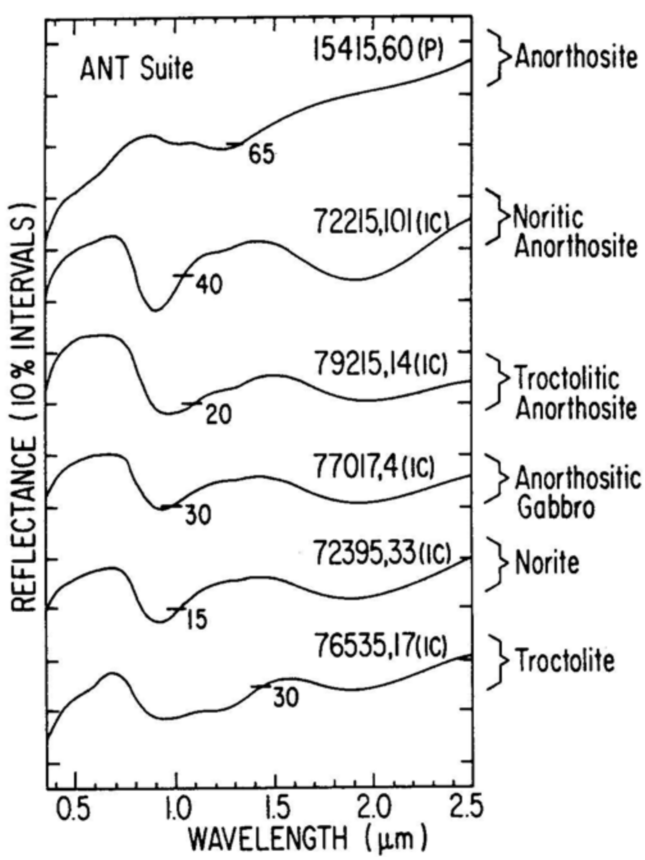

Figure 15: Reflectance spectra of 76535 compared with other lunar samples. From Charette and Adams (1977).

Table 1: Whole-rock chemistry of 76535.
a) Rhodes et al. (1974a); Haskin et al. (1974); Wiesmann and Hubbard (1975)

Split Technique	,21 (a) XRF, IDMS
SiO_2 (wt%)	42.88
TiO_2	0.05
Al_2O_3	20.73
Cr_2O_3	0.11
FeO	4.99
MnO	0.07
MgO	19.09
CaO	11.41
Na_2O	0.23
K_2O	0.03
P_2O_5	0.03
S	0.00
Nb (ppm)	1.2
Zr	24
Hf	0.52
U	.056
Th	0.16
Y	4.4
Sr	114
Rb	0.24
Li	3.0
Ba	32.7
Zn	1
Ni	25
La	1.51
Ce	3.81
Nd	2.30
Sm	0.61
Eu	0.73
Gd	0.73
Dy	0.80
Er	0.53
Yb	0.56
Lu	0.079

Table 2: Trace element composition of 76535. Concentrations in ppb.
Data from Morgan et al. (1974) and Wolf et al. (1979).

	Sample 76535,20
Ir	0.0054
Os	
Re	0.0012
Au	0.0025
Pd	
Ni (ppm)	44
Sb	0.014
Ge	1.7
Se	4.1
Te	0.28
Ag	0.12
Br	3.2
In	
Bi	0.037
Zn (ppm)	1.2
Cd	0.6
Tl	0.012
Rb (ppm)	0.2
Cs	14
U	19.4

Table 3: Summary of age data for 76535.

4.19 ± 0.02	K-Ar	Husain and Schaeffer (1975)
4.16 ± 0.04	K-Ar	Huneke and Wasserburg (1975)
4.27 ± 0.08	K-Ar	Bogard et al. (1975)
4.61 ± 0.07	Rb-Sr	Papanastassiou and Wasserburg (1976)
4.26 ± 0.02	Sm-Nd	Lugmair et al. (1976)
4.330 ± 0.064	Sm-Nd	Premo and Tatsumoto (1992)
4.27 ± 0.03	Pb-Pb	Hinthorne et al. (1975)
4.236 ± 0.015	U-Pb	Premo and Tatsumoto (1992)

Table 4: 76535 analytical results.
From Papanastassiou and Wasserburg (1976).
(Footnotes may refer to material not included in this catalog.)

Sample[a]		Weight (mg)	K (ppm)	Rb^{b} 10^{-8} mole/g	$^{88}Sr^{b}$	$^{87}Rb/^{86}Sr$ x 10^{2}	$^{87}Sr/^{86}Sr^{c}$	
Plagioclase								$I^{d}_{4.6\ AE}$
1.	25	8	400	0.509	185.9	0.639 ± 3	0.69946 ± 5	0.69904 ± 5
2.	25	2[e]	374	0.521	182.0	0.669 ± 7	0.69951 ± 7	0.69907 ± 7
3.	25	2[e]	371	0.563	177.4	0.741 ± 7	0.69947 ± 4	0.69898 ± 4
4.	13	13	392	0.522	186.7	0.653 ± 3	0.69939 ± 5	0.69896 ± 5
Olivine								T^{d}_{BABI}(AE)
1.	25	192	5.6	0.03231	0.925	8.15 ± 5	0.70448 ± 15	4.70 ± 0.13
2.	14	90	2.2	0.01623	0.3486	10.86 ± 8	0.70534 ± 18	4.09 ± 0.12
3.	14	67	3.0	0.02029	0.3050	15.52 ± 13	0.70907 ± 18	4.53 ± 0.09
4.	13	112	2.6	0.01393	0.1518	21.41 ± 22	0.7132 ± 3	4.63 ± 0.10
5.	13 + 25	92	9.4	0.0492	1.262	9.08 ± 5	0.70507 ± 10	4.67 ± 0.08
Pyroxene								$I^{d}_{4.6\ AE}$
1.	13 + 14 + 25	26	6.7	0.02973	2.878	2.41 ± 4	0.70060 ± 14	0.69901 ± 14
Total (25)								
A.	Leach	–	0.48%[f]	4.0%[f]	0.29%[f]	7.38 ± 15	0.7044 ± 3	
	Residue	–	292	0.3268	140.5	0.543 ± 3	0.69924 ± 5	
	Combined	1.04 g	293	0.3397	140.9	0.563 ± 3	0.69925 ± 5	0.69888 ± 5
B.	-300 µm	100	209	0.2469	100.1	0.575 ± 3	0.69937 ± 5	0.69899 ± 5

[a]Subsample number (assigned by Curator) from which separate was obtained.
[b]Concentrations calculated using normal compositions $^{85}Rb/^{87}Rb = 2.591$; $^{86}Sr/^{88}Sr = 0.1194$; and $^{84}Sr/^{88}Sr = 0.006748$.
[c]Errors are $\pm 2\sigma_{mean}$ and correspond to last figures given.
[d]Initial $^{87}Sr/^{86}Sr$ using the isochron age $T = 4.61$ AE. Model ages are relative to BABI = 0.69898.
[e]Concentrations uncertain by ~5% due to small weight; element ratios are not affected by this uncertainty.
[f]Amount in leach given as percentage of the amount in the combined total rock.

Table 5: 76535 analytical results.
From Lugmair et al. (1976).
(Footnotes may refer to material not included in this catalog.)

Sample Subsample no.		Weight[a] (mg)	[Sm][b] 10^{-9} mole/g	[^{144}Nd][b]	$^{147}Sm/^{144}Nd$ [c]	$^{143}Nd/^{144}Nd$ [d]
Plagioclase,	66	52.50	5.085	4.975	0.1533 ± 1	0.511 481 ± 15
Total rock,	64	72.02	3.909	3.768	0.1556 ± 1	0.511 556 ± 14
"Symplectite,"	66	47.5[e]	9.31	6.61	0.2111 ± 14	0.513 206 ± 157
"Magnetic,"	64	31.03	1.258	0.743	0.2538 ± 14	0.514 304 ± 26
Pyroxene,	66	7.87	5.15	1.67	0.462 ± 7	0.520 272 ± 91[f]
Olivine,	66	777.5[e]	0.2200	0.1956	0.1689 ± 2	0.512 889 ± 26

[a]Weights are calculated for aliquants taken from total sample solution for spiking.
[b]Sm concentrations are calculated using measured composition (see text); for Nd normal Nd (see Table 1) was used.
[c]Errors correspond to last figures given and represent 95% C.L. Included are uncertainty in concentration ratio of Sm/Nd in spike solution and 50% of the blank corrections, quadratically added.
[d]Isotope ratios are those given in Table 1 but corrected for a neutron capture effect (1.5 parts in 10^5).
[e]Fractions were totally spiked and isotope ratios corrected for spike contributions.
[f]Isotope ratio corrected for 3% blank of terrestrial composition (Table 1); uncertainty of correction included in error.

Table 6: U-Th-Pb analytical data for 76535.
From Premo and Tatsumoto (1992).
(Footnotes may refer to material not included in this catalog.)

Sample/ Fraction	Weight (mg)	% Blank Pb	Pb* (ppb)	U* (ppb)	Th* (ppb)	$^{206}Pb/^{204}Pb$†	$^{204}Pb/^{206}Pb$‡	$^{207}Pb/^{206}Pb$‡	$^{208}Pb/^{206}Pb$‡	$^{238}U/^{204}Pb$‡	$^{232}Th/^{238}U$‡
Residues											
WR	91.9	2.0	45.2	21.0	45.2	349.3	0.00223	0.6829	0.6595	421	2.23
						(1.0)§	(4.4)	(0.11)	(0.42)	(4.7)	
PL-1	185.7	1.0	44.2	15.1	64.5	300.2	0.00294	0.7455	1.119	288	4.42
						(0.38)	(2.0)	(0.05)	(0.14)	(2.2)	
PL-2	137.0	2.3	26.8	6.85	25.4	141.3	0.00620	0.9594	1.112	109	3.83
						(1.2)	(2.5)	(0.07)	(0.25)	(2.8)	
OL-P	55.5	3.7	40.1	39.9	28.0	747.7	0.00040	0.5299	0.2861	3890	0.725
						(0.35)	(35)	(0.16)	(1.6)	(36)	
Dilute HNO_3 (1 N) leaches											
A2-WR	–	30.4	2.39	0.094	1.67	23.40	0.03778	0.8435	2.016	3.52	18.3
						(0.14)	(3.0)	(0.20)	(0.22)	(17)	
A2-PL-1	–	11.5	3.95	0.173	2.73	23.02	0.04194	0.8367	2.127	3.61	16.3
						(0.14)	(0.6)	(0.09)	(0.15)	(4.2)	
A2-PL-2	–	33.7	1.38	0.058	0.418	22.61	0.03945	0.8729	1.810	3.41	7.48
						(0.13)	(2.9)	(0.46)	(1.0)	(18)	
A2-OL-P	–	59.9	1.16	0.290	1.49	28.62	0.01430	0.6468	1.147	42.5	5.31
						(0.21)	(65)	(6.7)	(18)	(101)	
Dilute HBr (0.1 N) leaches											
A1-WR	–	11.2	14.7	0.309	4.54	21.06	0.04655	0.8492	2.153	1.58	15.2
						(0.10)	(0.35)	(0.10)	(0.17)	(4.8)	
A1-PL-1	–	19.9	3.66	0.239	6.43	29.04	0.02779	0.7775	3.558	11.0	27.8
						(0.14)	(5.1)	(0.40)	(2.3)	(14)	
A1-PL-2	–	2.7	45.3	0.080	0.546	19.06	0.05230	0.8351	2.014	0.113	7.07
						(0.05)	(0.12)	(0.07)	(0.14)	(9.8)	
A1-OL-P	–	18.5	13.5	0.528	1.77	20.80	0.04668	0.8406	1.964	2.79	3.46
						(0.13)	(0.56)	(0.12)	(0.22)	(7.0)	
Water washes											
W-WR	91.9¶	41.2	1.46	0.026	0.089	19.16	0.05090	0.8420	2.019	1.18	3.54
						(0.07)	(0.8)	(0.31)	(0.34)	(47)	
W-PL-1	186.6	84.3	0.094	0.011	0.105	20.17	0.02809	0.7778	1.878	13.2	9.91
						(0.18)	(350)	(26)	(33)	(815)	
W-PL-2	137.0	8.6	7.33	0.007	0.061	18.95	0.05253	0.8299	2.014	0.063	8.77
						(0.05)	(0.13)	(0.07)	(0.14)	(103)	
W-OL-P	55.5	29.3	4.09	0.159	0.302	19.68	0.04946	0.8248	1.963	2.60	1.96
						(0.21)	(0.68)	(0.18)	(0.33)	(17)	

*Concentrations corrected for blank Pb; ppm for leaches and washes are calculated using the original weight of the sample fraction.
†Measured ratio, uncorrected for blank Pb or mass fractionation.
‡Corrected for blank Pb (amounts are given in the text) using the methods of *Ludwig* (1980, 1985a).
§Numbers in parentheses are 2σ errors given in percent for the values just above them.
¶Original weights before washing and leaching procedure.

Table 7: Rb-Sr composition of 76535.
Data from Bogard et al. (1975)

Sample	76535,21-22
wt (mg)	53.9
Rb (ppm)	0.238
Sr (ppm)	113.9
$^{87}Rb/^{86}Sr$	0.00605 ± 28
$^{87}Sr/^{86}Sr$	0.69950 ± 5

Table 8: Rb-Sr and Sm-Nd analytical data for 76535.
From Premo and Tatsumoto (1992).

Sample	Weight (mg)	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$*	$^{87}Sr/^{86}Sr$*	$^{87}Sr/^{86}Sr$†	εSr†
WR	91.9	0.29	161	0.00520 ± 3	0.699472 ± 33	0.699152 ± 49	-3.53 ± 0.90
PL-1	185.7	0.33	180	0.00530 ± 2	0.699449 ± 17	0.699122 ± 45	-3.96 ± 0.89
PL-2	137.0	0.35	180	0.00570 ± 2	0.699481 ± 20	0.699128 ± 46	-3.87 ± 0.89
OL-P	55.5	0.01	5.14	0.00810 ± 20	0.699598 ± 43	0.699085 ± 53	-4.49 ± 0.91

*Isotopic ratios corrected for blank and mass fractionation. $^{87}Sr/^{86}Sr$ data are normalized to $^{86}Sr/^{88}Sr = 0.1194$ and adjusted for instrumental bias to $^{87}Sr/^{86}Sr = 0.710265$ for NBS SRM 987 standard. Uncertainties correspond to the last significant figure(s) at the 95% confidence level.
†Initial $^{87}Sr/^{86}Sr$ ratios and εSr are calculated using an age of 4.23 Ga; $\lambda = 1.42 \times 10^{-11}$/yr; present day $(^{87}Sr/^{86}Sr)_{UR} = 0.7045$, and $(^{87}Rb/^{86}Sr)_{UR} = 0.0824$, where UR = uniform reservoir.

Sample	Weight (mg)	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$*	$^{143}Nd/^{144}Nd$*	$^{143}Nd/^{144}Nd$†	εNd†
WR	91.9	0.70	2.73	0.15592 ± 14	0.511430 ± 43	0.507025 ± 36	-1.10 ± 0.41
PL-1	185.7	0.69	2.76	0.15134 ± 15	0.511277 ± 14	0.507001 ± 30	-1.57 ± 0.39
PL-2	137.0	0.73	2.97	0.14834 ± 80	0.511220 ± 51	0.507029 ± 123	-1.02 ± 0.72
OL-P	55.5	0.26	0.43	0.36345 ± 25	0.517372 ± 92	0.507104 ± 104	0.45 ± 0.64

*Isotopic ratios corrected for blank and mass fractionation. $^{143}Nd/^{144}Nd$ data are normalized to $^{146}Nd/^{144}Nd = 0.7219$ and adjusted for instrumental bias to $^{143}Nd/^{144}Nd = 0.511860$ for the La Jolla Nd standard. Uncertainties correspond to the last significant figure(s) at the 95% confidence level.
†Initial $^{143}Nd/^{144}Nd$ ratios and εNd are calculated using an age of 4.26 Ga; $\lambda = 6.54 \times 10^{-12}$/yr; present day $(^{143}Nd/^{144}Nd)_{CHUR} = 0.512636$, and $(^{147}Sm/^{144}Nd)_{CHUR} = 0.1967$, where CHUR = chondritic uniform reservoir.

Note: Our ^{149}Sm data were corrected for a 0.43% depletion due to neutron absorption observed in 76535 (*Lugmair et al.*, 1976).