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Catalog of Apollo 17 Rocks

Volume 4 – North Massif

By Charles Meyer

Space and Life Sciences Directorate
Solar System Exploration Division
Office of the Curator #87

August 1994

Index to all Apollo 17 rocks included.

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
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INTRODUCTION*

The Catalog of Apollo 17 rocks is a set of four volumes that characterize each of 334 individually numbered rock samples (79 larger than 100 g) in the Apollo 17 collection, showing what each sample is and what is known about it. Unconsolidated regolith samples are not included. The catalog is intended to be used by both researchers requiring sample allocations and a broad audience interested in Apollo 17 rocks. The volumes are arranged geographically, with separate volumes for the South Massif and Light Mantle; the North Massif; and two volumes for the mare plains. Within each volume, the samples are arranged in numerical order, closely corresponding with the sample collection stations. A sample index is included at the back of Volume 4.

Information on sample collection, petrography, chemistry, stable and radiogenic isotopes, rock surface characteristics, physical properties, and curatorial processing is summarized and referenced as far as it is known up to early 1994. The intention has been to be comprehensive—to include all published studies of any kind that provide information on the sample, as well as some unpublished information. References which are primarily bulk interpretations of existing data or mere lists of samples are not generally included. Foreign language journals were not scrutinized, but little data appears to have been published <u>only</u> in such journals. The reference list included at the end of this volume has been updated.

Much valuable information exists in the original Apollo 17 Lunar Sample Information Catalog (Butler, 1973) based on the intense and expert work of the Preliminary Examination Team. However, that catalog was compiled and published only four months after the mission itself, from rapid descriptions of usually dust-covered rocks, usually without anything other than macroscopic observations, and less often with thin sections and a little chemical data. In the nearly two decades since then, the rocks have been substantially subdivided, studied, and analyzed, with numerous published papers. However, the original Catalog contains more information on macroscopic observations for most samples than does the present set of volumes. Considerably more detailed information on the dissection and allocations of the samples is preserved in the Data Packs in the Office of the Curator.

THE APOLLO 17 MISSION

On December 11, 1972, the Apollo 17 lunar excursion module "Challenger," descending from the Command Service Module "America," landed in a valley near the edge of Mare Serenitatis (Figures 1 and 2). It was the sixth and final landing in the Apollo program. Astronauts Eugene Cernan and Harrison Schmitt spent 72 hours at the site, named Taurus-Littrow from the mountains and a crater to the north. The site was geologically diverse, with the mountain ring of the Serenitatis basin and the lava fill in the valley. The main objectives of the mission were to sample very ancient material such as pre-Imbrian highlands distant from the Imbrium basin, and to sample pyroclastic materials believed pre-mission to be substantially younger than mare basalts collected on previous missions.

The crew spent more than 22 hours on the lunar surface, using the rover to traverse across the mare plains and to the lower slopes of the South and North Massifs, and over a light mantle in the valley that appeared to have resulted from a landslide from the South Massif. The traverses

*Adapted from volume 1.

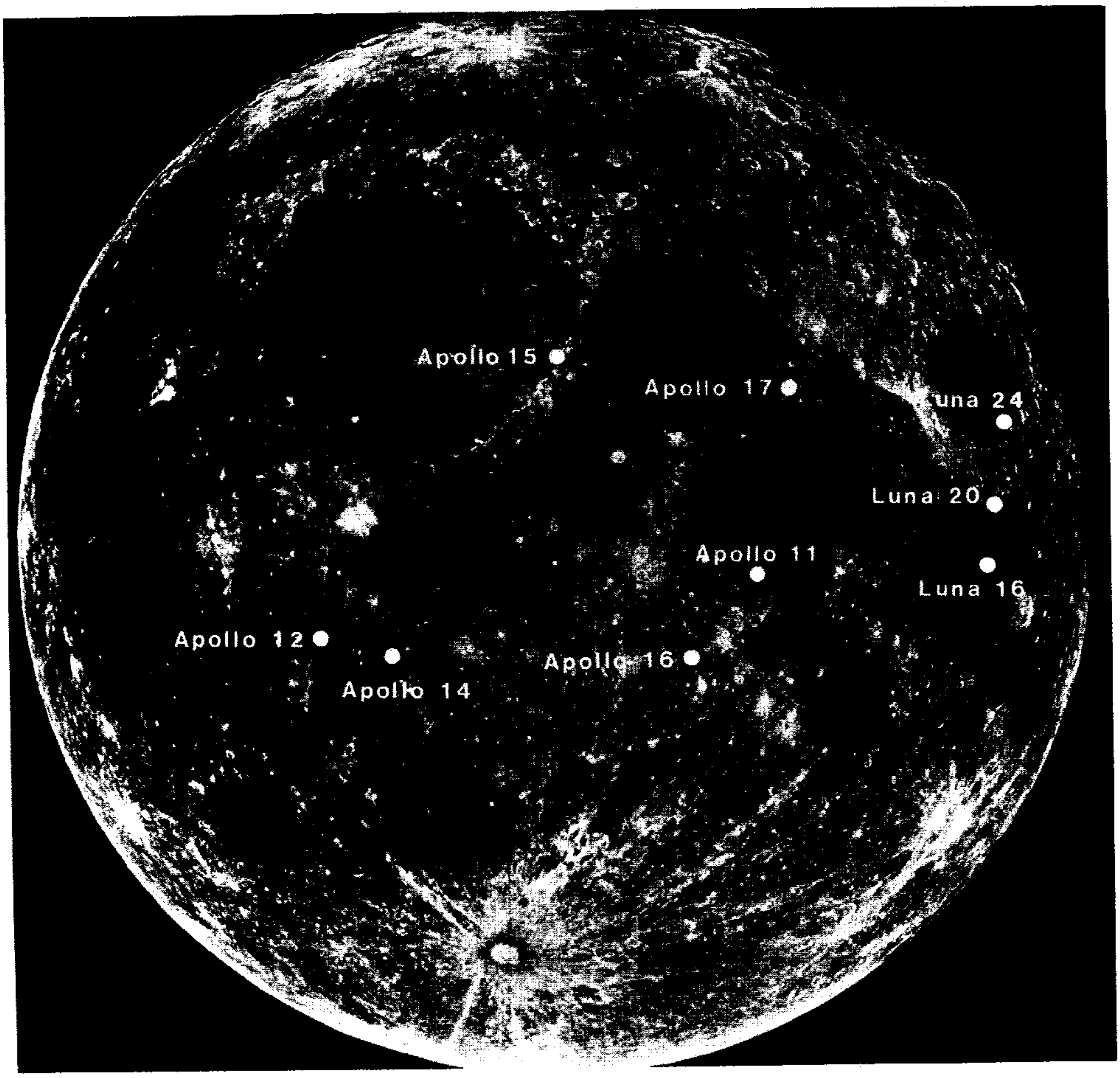

Figure 1: Apollo and Luna sampling sites on the near side of the Moon. S84-31673.

totalled more than 30 km, and nearly 120 kg of rock and soil were collected (Figure 3). This total sample mass was greater than on any previous mission. An Apollo Lunar Surface Experiments Package (ALSEP) was set up near the landing point. Other experiments and numerous photographs were used to characterize and document the site. Descriptions of the pre-mission work and objectives, the mission itself, and results are described in detail in the Apollo 17 Preliminary Science Report (1973; NASA SP-330) and the Geological Exploration of the Taurus-Littrow Valley (1980; USGS Prof. Paper 1080), and others listed in the bibliography at the end of this section. Many of the rock samples have been studied in detail, and some, particularly massif boulders, have been studied in coordinated fashion in formal consortia.

The valley floor samples demonstrate that the valley consists of a sequence of high-Ti mare basalts that were mainly extruded 3.7 to 3.8 Ga ago. The sequence is of the order of 1400 m thick. The sequence consists of several different types of basalt that cannot easily be related to each

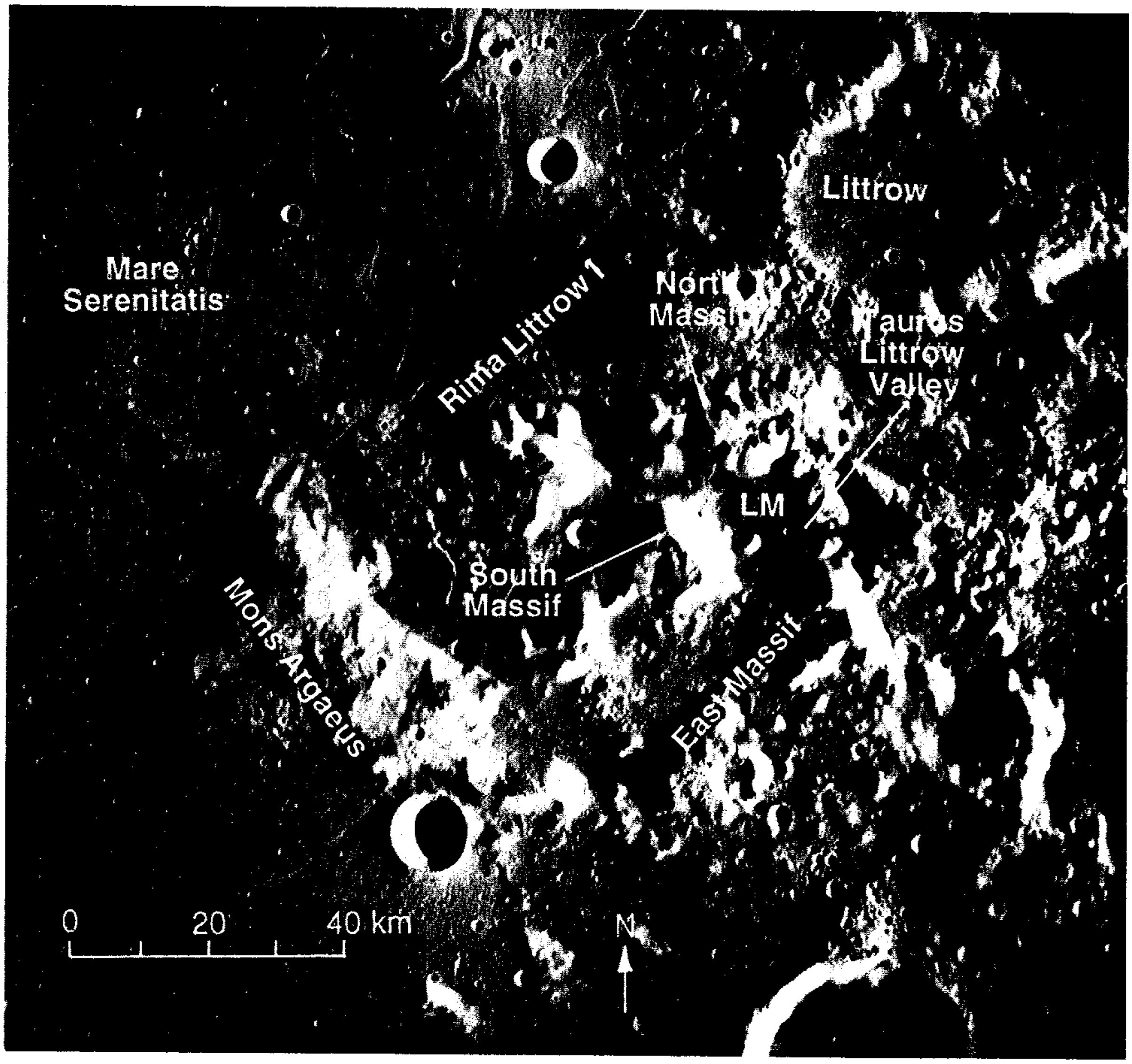

Figure 2: Apollo 17 landing site region showing major geographic features. AS17-M-447.

other (or Apollo 11 high-Ti mare basalts) by simple igneous processes, but instead reflect varied mantle sources, mixing, and assimilation. Orange glass pyroclastics were conspicuous, and is the unit that mantles both the valley fill and part of the nearby highlands. However, they were found to be not younger than other Apollo volcanics, but were only slightly younger than the valley fill. These glasses too are high-Ti basalt in composition. The orange glasses occur in the rocks only as components of some regolith breccias.

The sampling of the massifs was directed at coherent boulders and some rocks, and are dominated by a particular type of crystalline impact melt breccia. This is found on both massifs, and is characterized by an aluminous basalt composition and a poikilitic groundmass. The samples are widely interpreted as part of the impact melt produced by the Serenitatis basin event itself. A second type of impact melt, dark and aphanitic, is represented only by samples from the South Massif stations. It is similar in chemistry to first type, but is more aluminous and

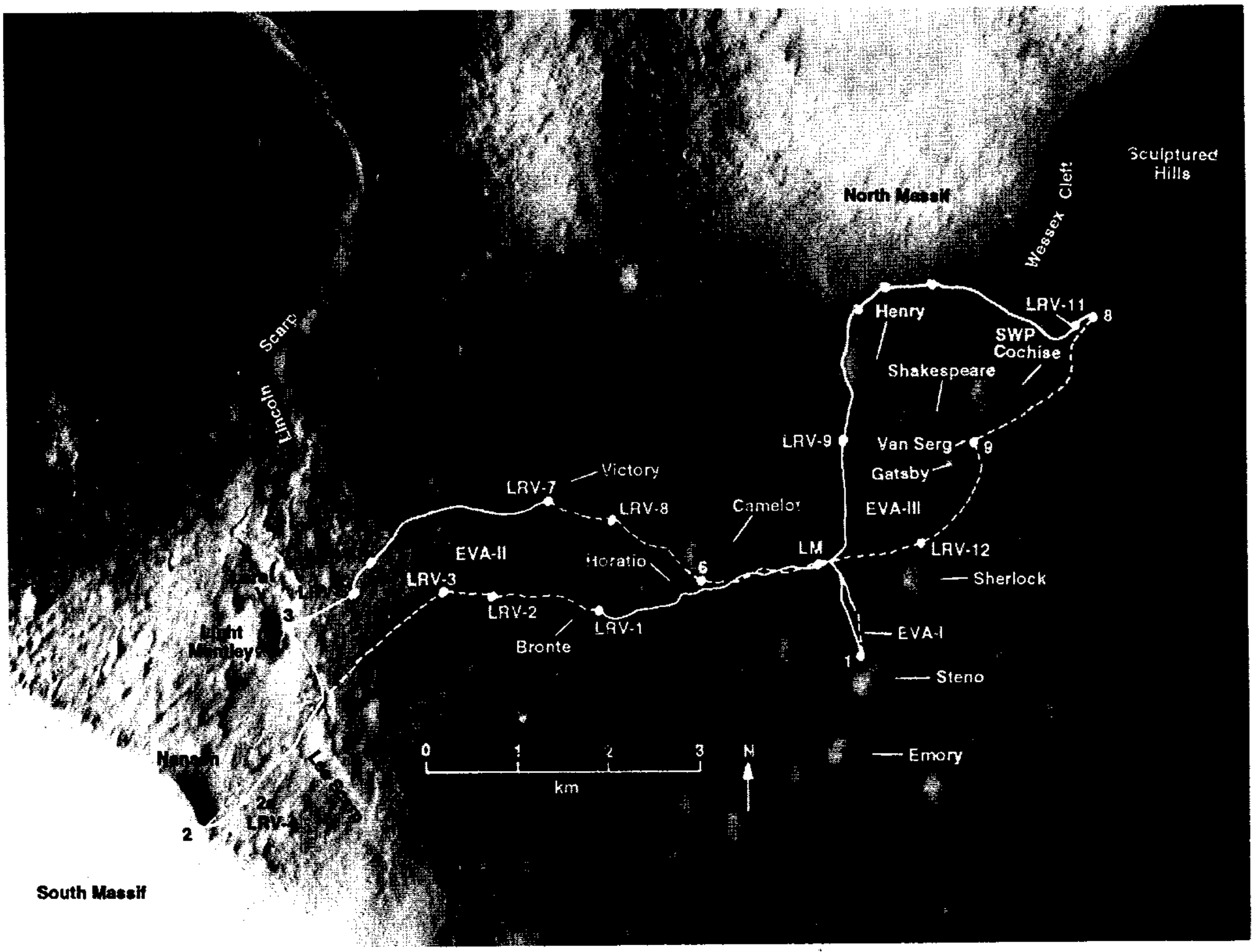

Figure 3: Apollo 17 traverse and sample collection map.

much poorer in TiO_2. It contains a much greater abundance and variety of clast types. Opinion still differs as to whether these aphanites are a variant of the Serenitatis melt or represent something distinct. Both aphanitic and poikilitic melts seem to be most consistent with an age of close to 3.87 (±0.2) Ga. A few rare samples of impact melt have distinct chemistry. Other rock and clasts are pristine igneous rocks, including dunite, troctolite, and norite (some of which formed meter-sized clasts or individual boulders), as well as more evolved types including gabbros and felsic/granitic fragments. Feldspathic granulites are common as clasts in the melt matrices (both aphanitic and poikilitic) and occur as a few small individual rocks. Geochronology shows that many of these granulites and pristine igneous rocks date back as far as 4.2 and even 4.5 Ga. The purer soils of the South Massif contain more alumina and only half of the incompatible element budget of the dominant impact melt rocks, demonstrating that the massifs, representing pre-Serenitatis material, have a component not well represented in the larger collected samples. Conspicuously absent, and not the "missing" component in the soil, is ferroan anorthosite, common at the Apollo 16 site and widely believed to have formed an early lunar crust.

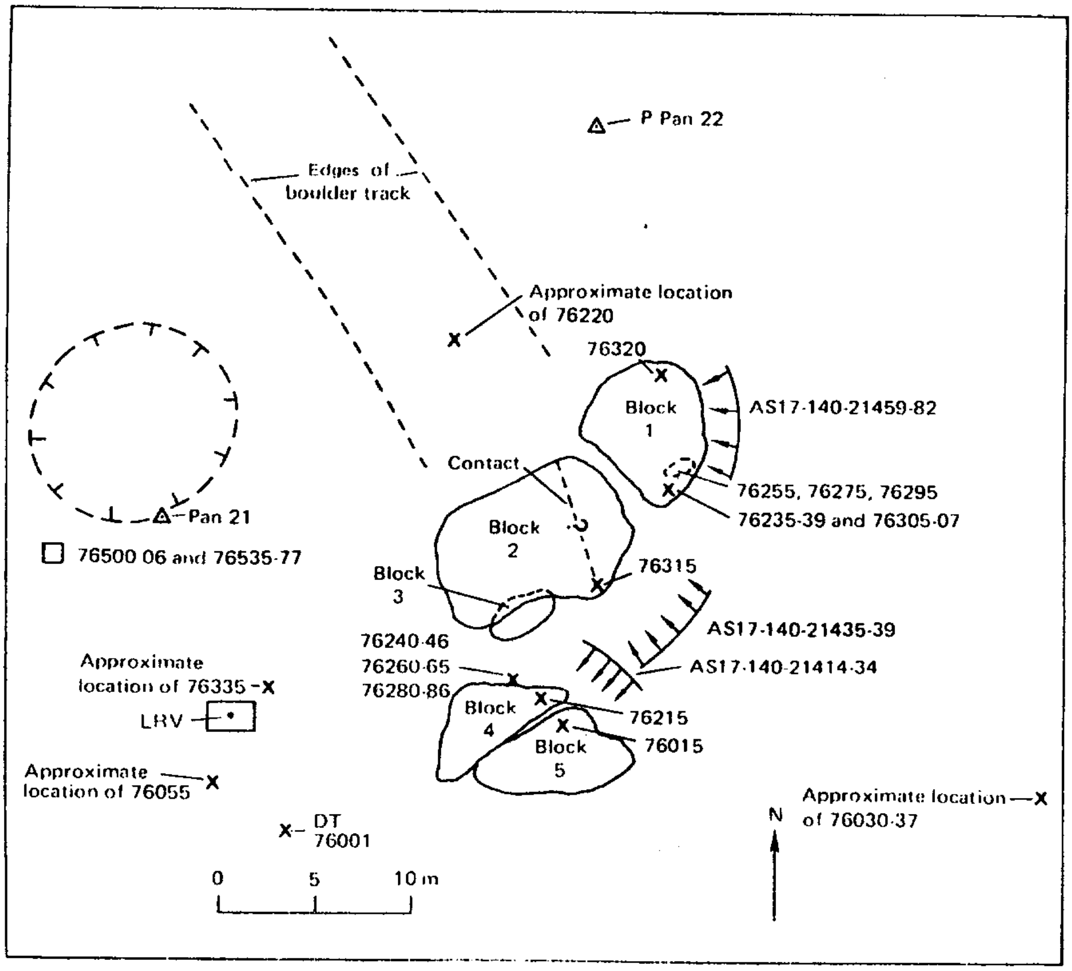

Figure 4: Locations of rocks collected at Station 6. From Wolfe and others (1981).

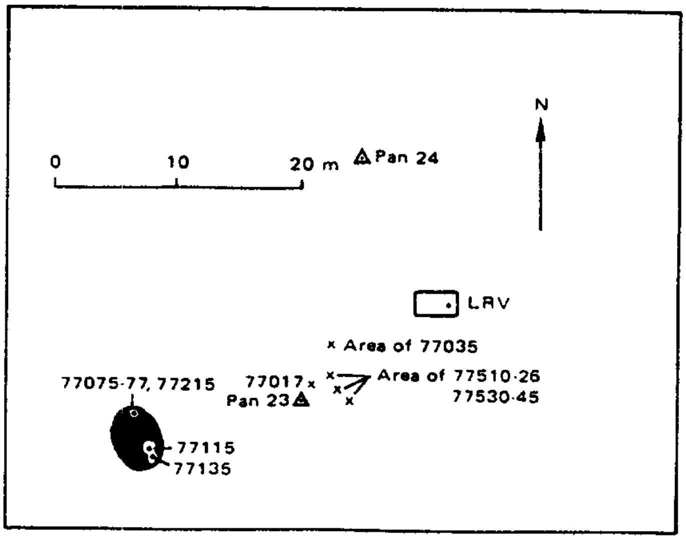

Figure 5: Locations of rocks collected at Station 7. From Wolfe and others (1981).

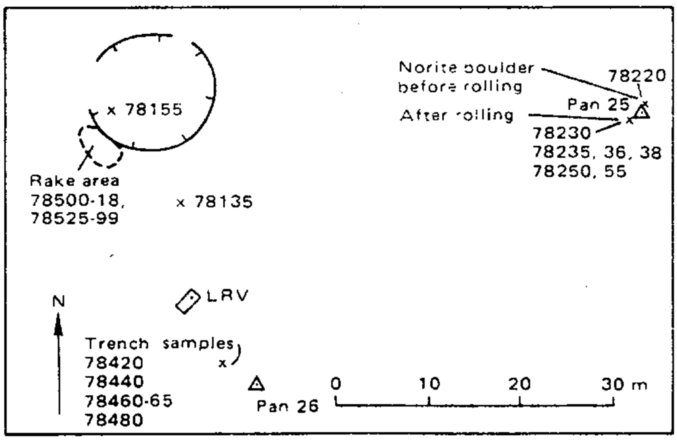

Figure 6: Locations of rocks collected at Station 8. From Wolfe and others (1981).

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NUMBERING OF APOLLO 17 SAMPLES

As in previous missions, five digit sample numbers are assigned each rock (coherent material greater than about 1 cm), the unsieved portion and each sieve fraction of scooped <1 cm material, the drill bit and each drill stem and drive tube section and each sample of special characteristics.

The first digit (7) is the mission designation for Apollo 17 (missions prior to Apollo 16 used the first two digits). As with Apollo 15 and 16 numbers, the Apollo 17 numbers are grouped by sampling site. Each group of one thousand numbers applies to an area as follows:

The first numbers for each area were used for drill stems, drive tubes, and the SESC. Drill stem sections and double drive tubes are numbered from the lowermost section upward.

The last digit is used to code sample type, in conformity with the conventions used for Apollo 15 and Apollo 16. Fines from a given documented bag are ascribed numbers according to:

7WXY0	Unsieved material (usually <1 cm)
7WXY1	<1 mm
7WXY2	1-2 mm
7WXY3	2-4 mm
7WXY4	4-10 mm

Sampling Site	Initial Number
LM, ALSEP, SEP, and samples collected between Station 5 and the LM	70000
Station 1A	71000
Station 2 and between it and the LM	72000
Station 3 and between it and Station 2	73000
Station 4 and between it and Station 3	74000
Station 5 and between it and Station 4	75000
Station 6 and between it and the LM	76000
Station 7 and between it and Station 6	77000
Station 8 and between it and Station 7	78000
Station 9 and between it and Station 8	79000

Rocks from a documented bag are numbered 7WXY5 – 7WXY9, usually in order of decreasing size.

Sample number decades were reserved for the contents of each documented bag. In the cases where the number of samples overflowed a decade, the next available decade was used for the overflow. For example DB 455 contained soil, numbered 71040-71044, and 6 small rocks numbered 71045-71049 and 71075.

Paired soil and rake samples for each sampling area are assigned by centuries starting with 7W500. The soil sample documented bag has the first decade or decades of the century, in conformity with the last digit coding for rocks and fines (as explained above), and the rake sample documented bag uses the following decades. For example, 71500-71509, 71515 were used for the sieve fractions and six rocks from the soil sample in DB 459. Then for the companion rake sample in DB's 457 and 458, 71520 was used for the soil, which was not sieved, and the 38 >1 cm rake fragments were numbered 71535-71539, 71545-71549, etc., to 71595-71597.

In as much as possible all samples returned loose in a sample collection bag or an ALSRC were numbered in a decade. In the cases in which rocks from several stations were put into a single collection bag however, the soil and rock fragments were assigned a decade number that conforms to the site for the largest or most friable rock. The other rocks in the same bag have numbers for their own site, generally in the second or third decade of the thousand numbers for that site.

CAUTIONARY NOTE

Every effort was made for the data to be accurately copied into this catalog. However, it would obviously be prudent for any scientist who wants to use this data to check the original scientific publication (which is referenced) and not rely on copied data for critical argument.

FINAL INTRODUCTORY NOTE

If one is confused by the technical aspects of the study of Moon rocks, one might like to borrow one of the Curator's sets of Educational Lunar Thin Section Sets. There is an instructive booklet to the study of Moon rocks that accompanies these sets of sections (Meyer, 1987).

SAMPLE INVENTORY FOR VOLUME 4

INTRODUCTION: Samples of the North Massif

The North Massif is internally complex, with numerous roughly horizontal structural units that may be depositional or intrusive layers (Schmitt and Cernan, 1973). The tilting and faulting of massif units may relate to their uplift during the Serenitatus impact event or subsequent major basin event (Fig. 1). The rock layers high up on the Massif are interpreted as ejecta sheets of impact melt formed by the Serenitatus event (Spudis and Ryder, 1981). Several authors (Chao et al., 1975; Winzer et al., 1975; Spudis and Ryder, 1981) have found considerable similarity between some samples of the South Massif and the boulder samples of the North Massif.

Samples were collected from several boulders that rolled down the North Massif (see Wolfe and others, 1981).

These include

a) The large boulder at Station 6, which was carefully sampled (chipped) in several places (76015, 76215, 76235, 76255, 76275, 76295, 76315, and others). It has a boulder track down the Massif leading from the blocky layers above (Figs. 2, 3, and 4).

b) Turning Point Rock (LRV10), a small boulder about 0.5 km to the east of Station 6 that was apparently sampled by the scoop taken there (76135, 137).

c) 76055, a small rock that was picked from the regolith about 15 meters to the east of the boulder. It is chemically distinct from the boulder samples and may be slightly older.

d) The boulder at Station 7, which is about 0.6 km to the west (77135, 77115).

However, the most representative samples of the North Massif may be the rake samples or coarse fines collected from the soils (Jolliff et al., 1993). The soil around the boulders does not have the same composition as the boulders, and there are clearly other components in the soil. A large rake sample was taken about 20 meters to the east of Boulder 6 (76500). Two breccia fragments (76035 and 037) were taken from the soil about 25 meters to the west.

A number of fragments were also taken from a trench in the fillet next to the boulder - but these probably are additional pieces of the boulder (76245, 246, 265, 285, and 286).

An index to all of the Apollo 17 rock samples is included at the back of this volume.

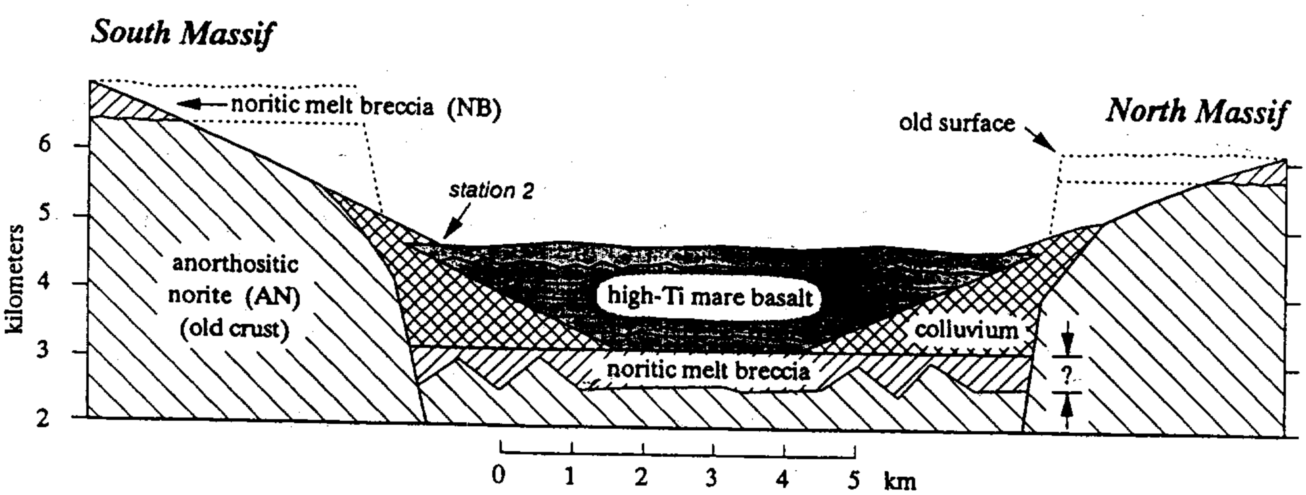


Figure 1: Cross section of the Taurus-Littrow Valley drawn by Korotev (1993).

Figure 2: Composite photo of boulder at Station 6 showing Taurus-Littrow Valley. AS17-140-21497 and 21493. Entrance to Taurus-Littrow Valley is in the distant background.

Figure 3: Photo of astronaut in front of Block 2 of the large broken boulder at Station 6. AS17-146-22294.

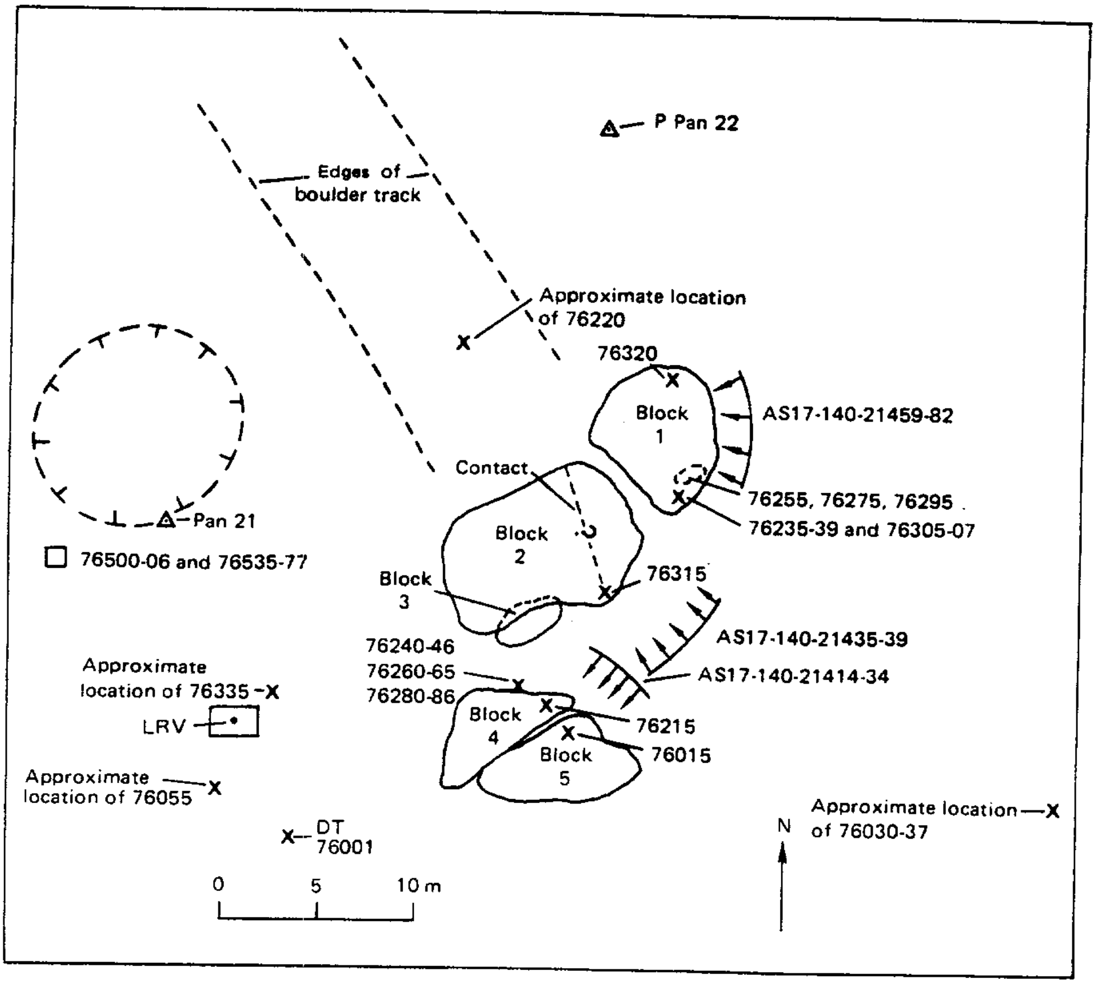


Figure 4: Plan view of the Station 6 Boulder area. From Wolfe and others (1981). Arrows indicate direction of NASA photographs. Note the boulder tracks and sample numbers.

Introduction to Large Boulder at Station 6
Samples 76015, 76215, 76235, 76255, 76275, 76295, and 76315

Also samples 76245, 246, 265, 285, and 286 may have been spalled off the boulder at Station 6. Samples 76230, 236, 237, 238, 239, 305, 306, and 307 are all part of 76235, which was chipped from a distinct clast on Boulder 6.

GEOLOGICAL SETTING

Most of the large samples collected at the Apollo 17 Station 6 are from a large broken boulder (6 x 10 x 18 m) lying at the end of a boulder track that can clearly be seen in the photos taken by the astronauts (see Schmitt and Cernan, 1973, and Wolfe and others, 1981). This boulder track leads from a distinct blocky horizon approximately 1/3 of the way up the North Massif. On the basis of observation of several boulder tracks on North Massif, it appeared to the astronauts that once a boulder was jarred loose from its "source-crop" and began to roll, only a decrease in slope or the break-up of the boulder would stop it. At the end of its track, the big Station 6 Boulder apparently broke into five distinct blocks (Fig. 1) and came to rest at the top of the talus from the North Massif. Blocks 1, 2, and 3 readily fit together; the fit of Boulders 4 and 5 is less obvious. According to Arvidson et al. (1975), the emplacement of the Station 6 Boulder is one of only a few well-dated events on the Moon (22 m.y.).

The Station 6 Boulder is the closest thing to a geological outcrop on the Moon! Photos of the boulder blocks were mapped by G. Heiken et al. (1973) in preparation for the consortium study of the samples led by W. Phinney, C. Simonds, and J. Warner (Figs. 2-6). The Station 6 Boulder was found to be a geologically complex, clast-bearing, impact melt breccia with a matrix that is chemically rather uniform. Four main lithologic units within the boulder cluster have been identified (Heiken et al., 1973, and Phinney, 1981). Unit A is characterized by abundant vesicles (some greater than 5 cm long) flattened along a plane parallel to the contact with the adjacent unit (no samples taken). Unit B is characterized by well-developed foliation or banding (samples 76015 and 76215). Unit C is massive, with no obvious foliation, and contains angular clasts up to 0.8 m long (samples 76235, 255, 275, 295). Unit AB is a discontinuous transition zone up to a few meters wide between units A and B (sample 76315). The samples (described individually) are impact melts and anorthositic clasts. The matrices of the Station 6 Boulder samples contain 50-60% calcic feldspar, ~45% orthopyroxene, and 1-7% ilmenite.

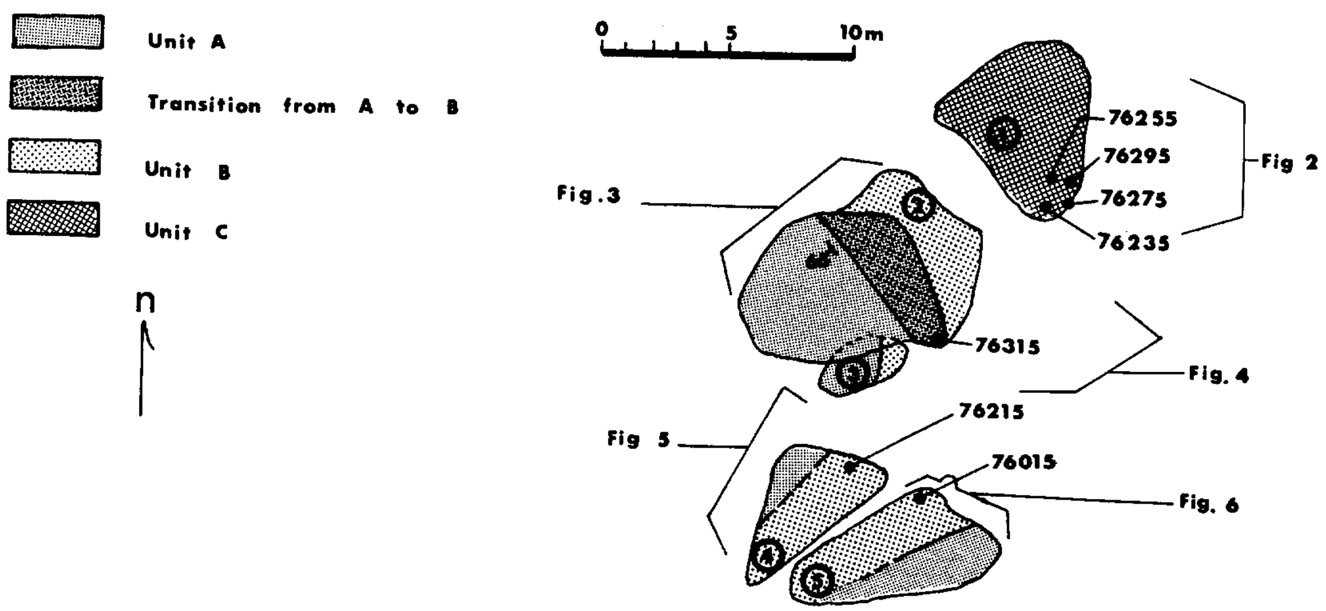


Figure 1: Map of the boulder cluster at Station 6, showing sample locations, location of lithologic units, and index to boulder maps. From Phinney (1981).

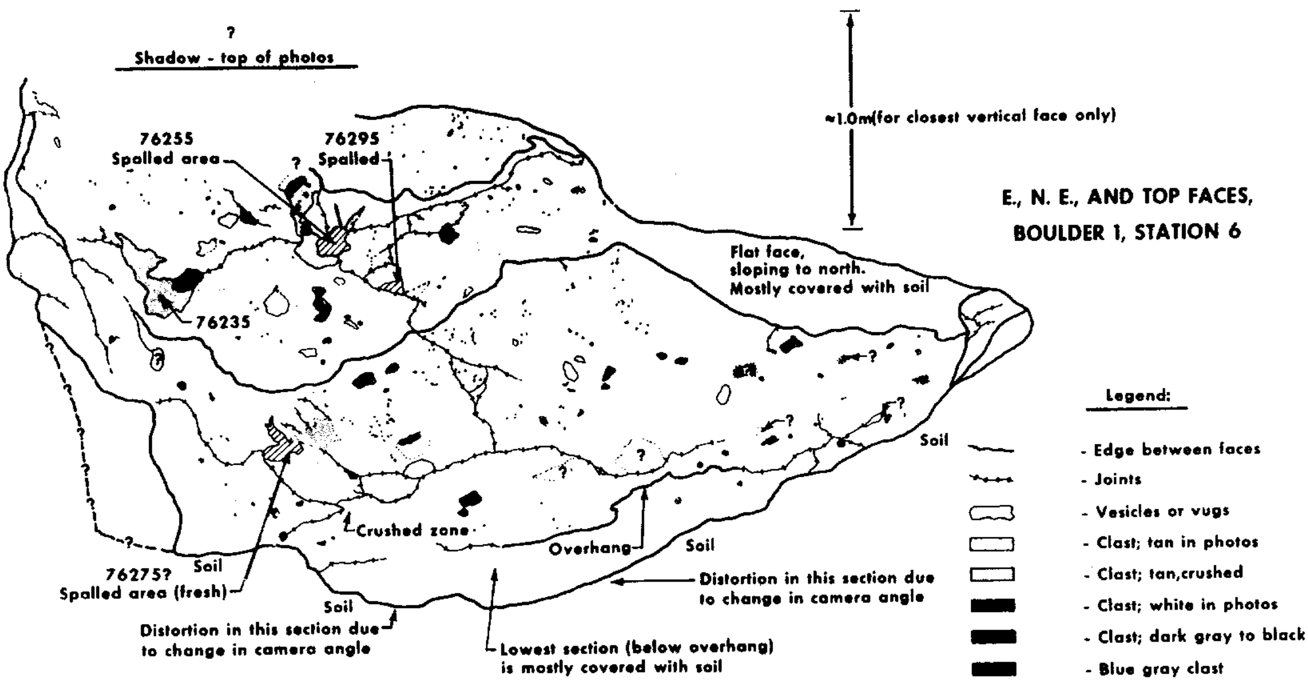


Figure 2: Map of the east, northeast, and top faces of Boulder 1. From Heiken et al. (1973).

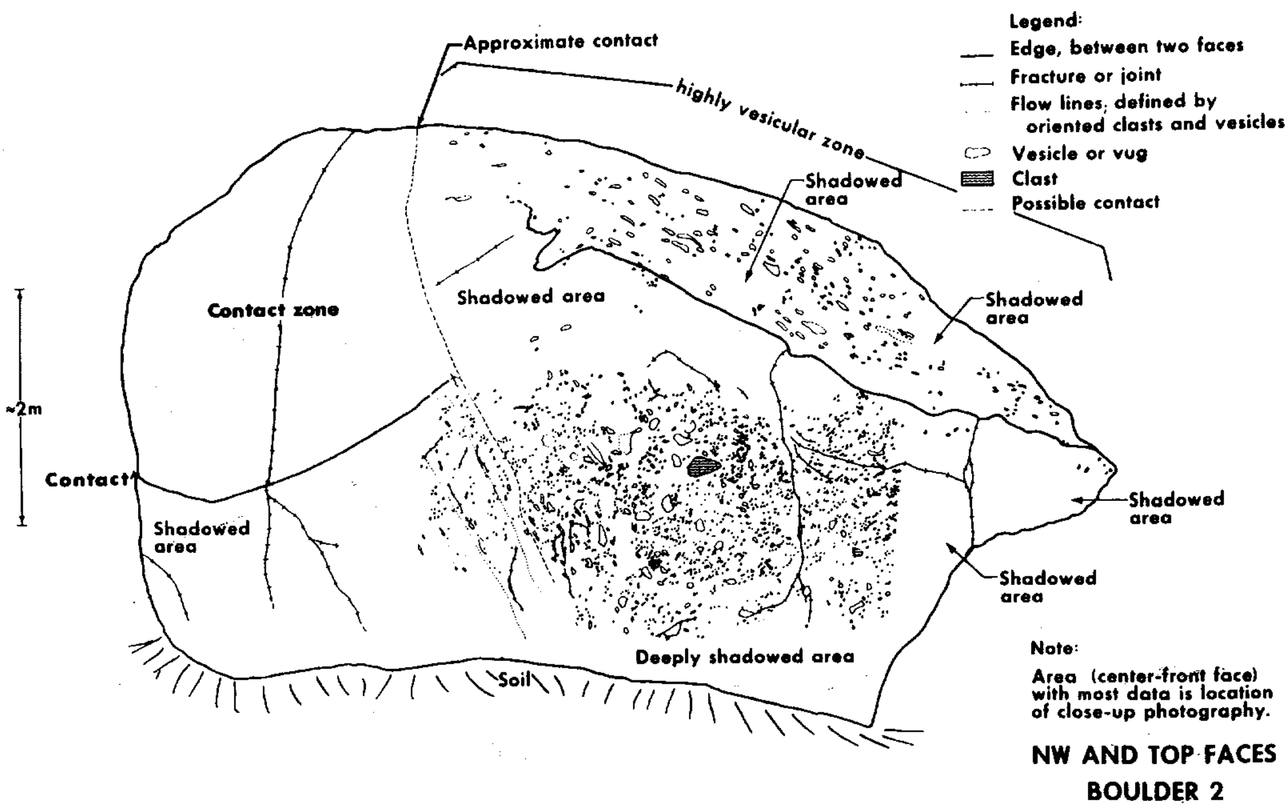


Figure 3: Map of the northwest and top faces of Boulder 2. From Heiken et al. (1973).

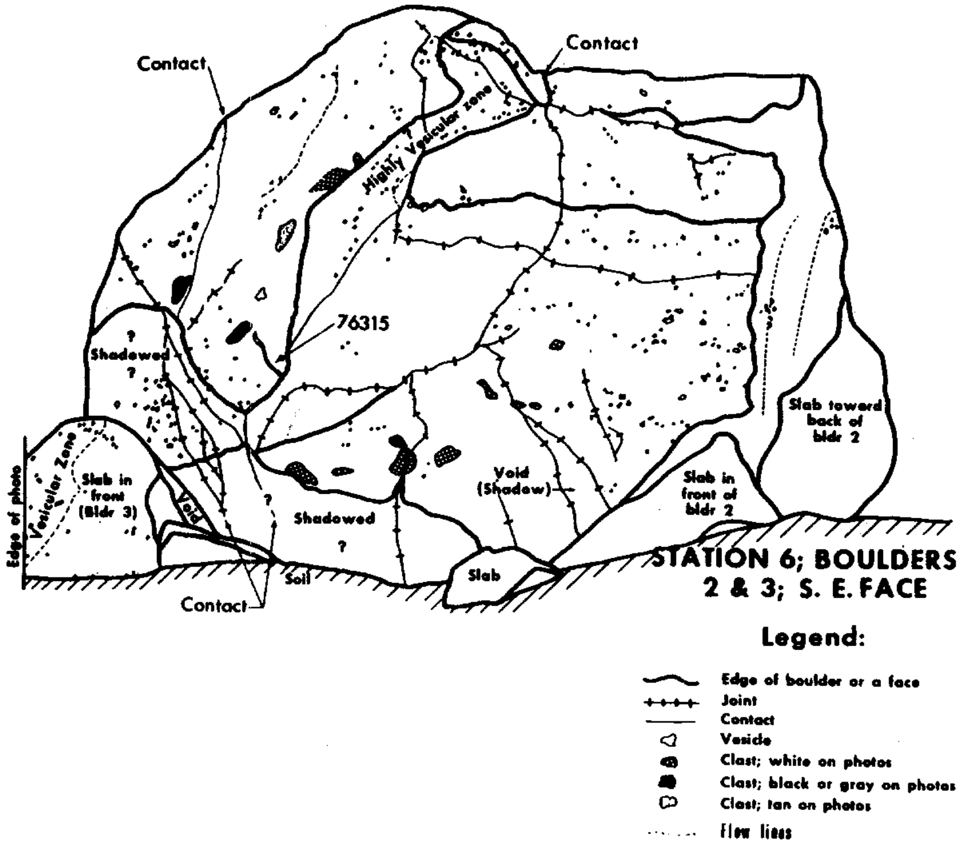


Figure 4: Map of the southeast face of Boulders 2 and 3. From Heiken et al. (1973).

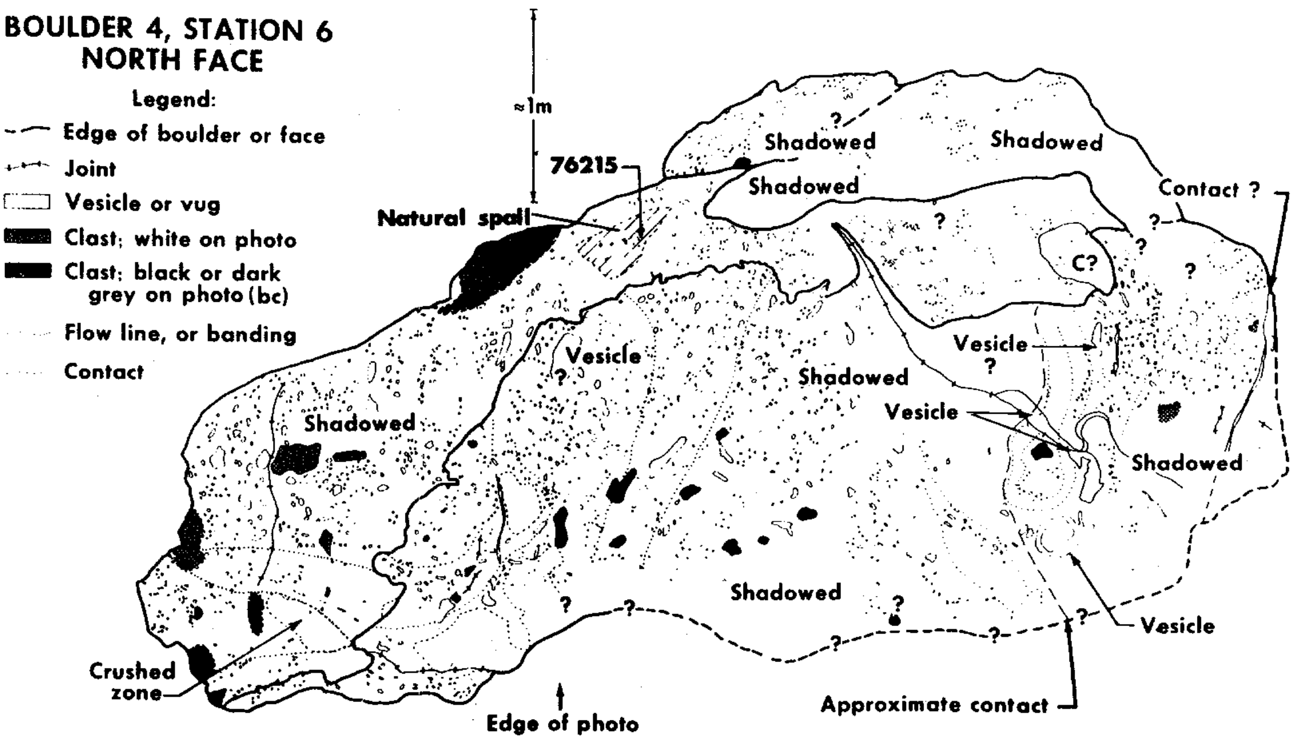


Figure 5: Map of the north face of Boulder 4. From Heiken et al. (1973).

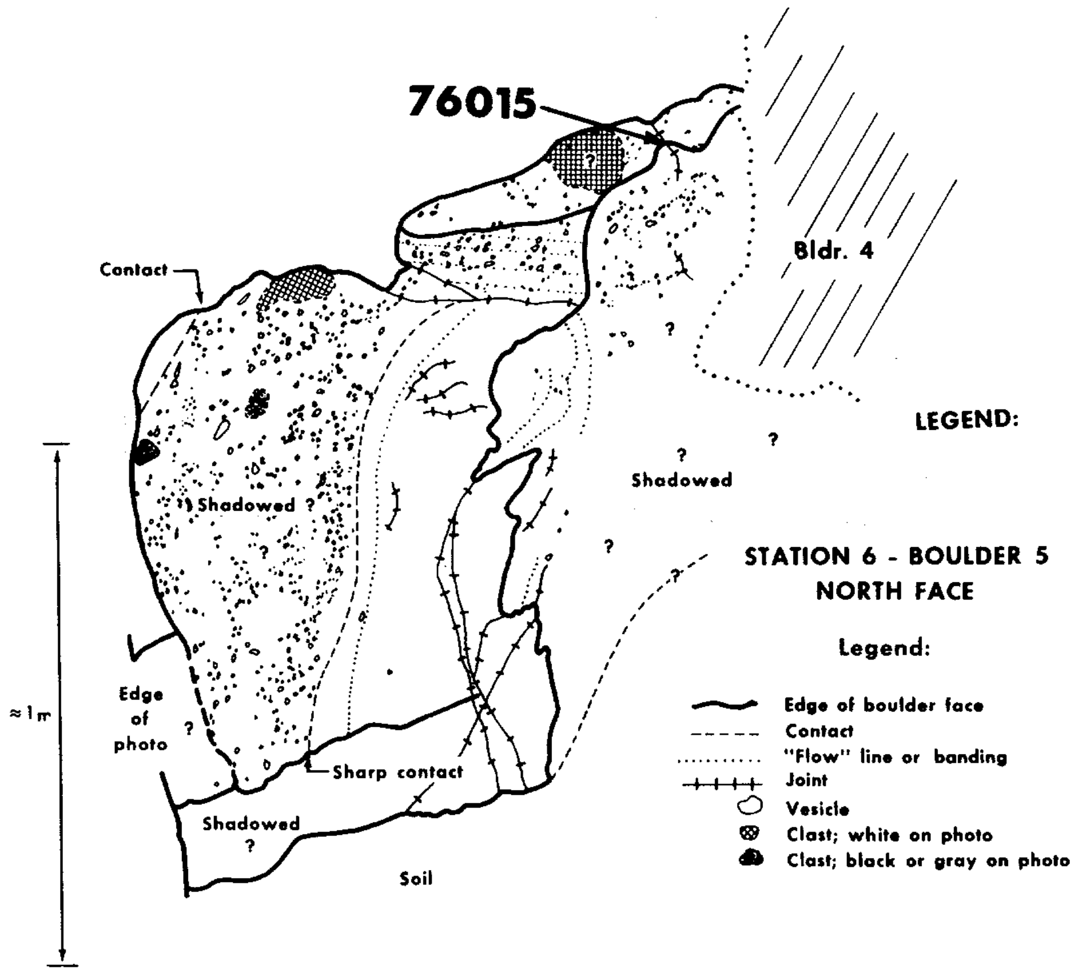


Figure 6: Map of the north face of Boulder 5. From Heiken et al. (1973).

Important clasts contain ~70% feldspar, 30% orthopyroxene, and olivine and trace ilmenite. The matrix of the boulder was apparently homogenized extremely well by the impact process on the scale of this boulder. The major and trace element compositions of the various pieces of matrix form a tight cluster on composition diagrams, including the siderophile elements (Ir-Au-Re) contributed by the meteorite projectile. The clasts display various degrees of brecciation and shock metamorphism. Some clasts (76235, 76255) may be of plutonic origin.

The boulders at Station 6 do not have a composition like that of the soil (Fig. 7). Station 6 is located on the talus of the North Massif. Components of the soil include the boulders, the adjacent mare surface, and the softer portions of the North Massif. It will take a careful study of the coarse fines from the soil to discern what the rest of the North Massif is made of (Jolliff et al., 1993). Samples like 76535 and 76335 may be more representative of the main portion of the North Massif than the samples of the boulder.

PATINA

A distinct brown patina is well developed on all the weathered rock surfaces of the otherwise tan or blue-grey breccia, including the fractured surfaces of the blocks of the Station 6 Boulder (Schmitt and Cernan, 1973). The exterior surfaces of boulder samples are covered with micrometeorite craters and contain solar flare tracks. An unusual feature of two of the samples, 76015 and 76215, is that they each had a patina covered "lip" that was partially protected from micrometeorite bombardment, which led to the development of an especially dark (thick?) patina.

CONSORTIUM STUDIES

The samples of the boulder blocks at Station 6 were the subject of consortium studies led by W. Phinney (1981). Photos of the boulder surfaces (mapped by Heiken et al., 1973) allowed each sample to be

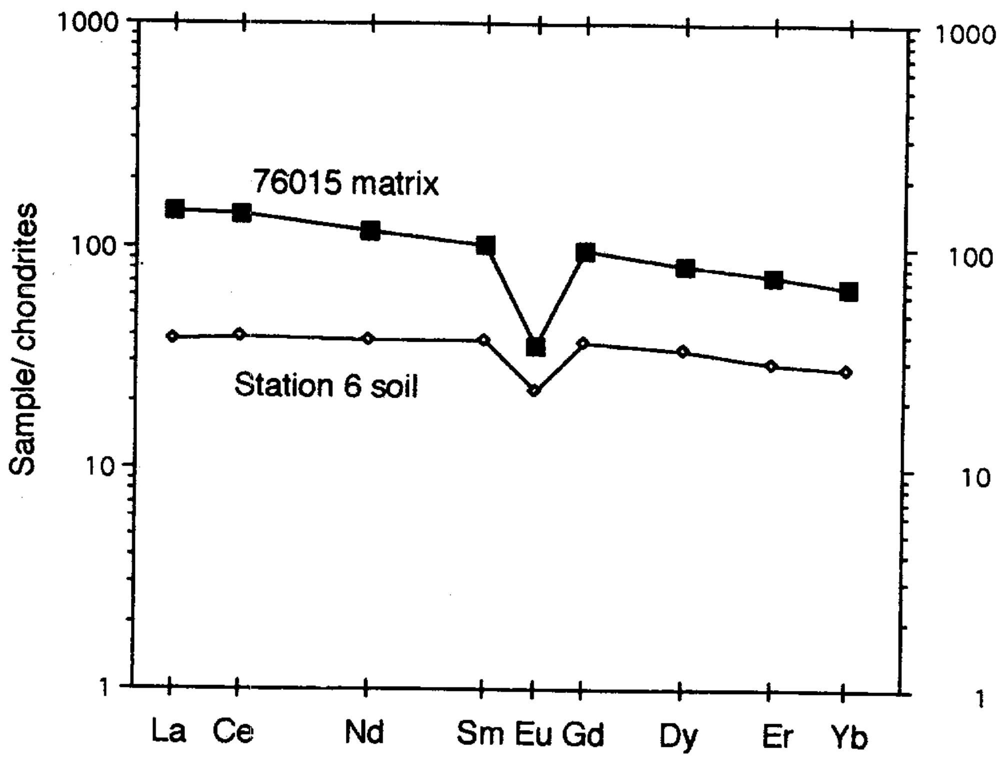


Figure 7: Normalized rare earth element diagram comparing 76015 (typical of boulder) with Station 6 soil.

related to a specific lithology of the boulder. These consortium studies were not completed because many of the samples (i.e., 76275) were slow to be processed and not delivered until after consortium members had left. However, the consortium concluded that the poikilitic texture of these rocks was formed in a melt sheet after the impact (Simonds, 1975; Simonds et al., 1976; and Onorato et al., 1976). This consortium went on to study impact melt sheets in terrestrial impact craters (see JGR 83, 2729-2816).

A summary of the ages of the clasts and matrix samples from the Station 6 Boulder is given in Table 1 from Cadogan and Turner (1976).

There is general agreement that these data (mean age 3.96 ± 0.04 b.y.) give the age of the Serenitatus impact event (see arguments in Spudis and Ryder, 1981).

A major finding of the consortium was that all the matrix samples were of the same chemical and mineralogical composition (Phinney, 1981). Especially remarkable was the tight grouping in siderophile elements (Higuchi and Morgan, 1975, and Hertogen et al., 1977).

The collection of samples from Boulder 6 provides the most comprehensive set of related samples that has been available for lunar magnetic studies. Gose et al. (1978) carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder. The direction of magnetization after alternating field demagnetization of breccia samples was found to be roughly uniform for clast-free matrix samples (76015, 76215) while generally scattered for the clast-rich samples (76275). Gose et al. proposed that the natural remanent magnetization of impact melt breccias is the vector sum of two magnetizations: a pre-impact magnetization and a partial thermoremanence acquired during breccia lithification. The large scatter of magnetization direction of the clast-rich samples implies the predominance of pre-impact magnetization.

Table 1: Summary of Ar 39/40 plateau ages from the Station 6 Boulder samples.
Data from Cadogan and Turner (1976).

Sample no.	Irradiation	Plateau age (G.y.)	% ^{39}Ar recoil (matrix samples only)
Matrix samples			
76215,30	SH36	3.94 ± 0.04	0.8
76015,38	SH36	3.93 ± 0.04	1.1
76315,36	SH31	3.98 ± 0.04	1.4
76295,1 (tan)	SH36	3.95 ± 0.04	3.9
76295,3 (blue)	SH36	3.96 ± 0.04	2.4
76275,39	SH40	4.02 ± 0.04	2.9
Clasts			
76235,3	SH36	3.93 ± 0.06	—
76235,3	SH40	3.95 ± 0.06	—
76315,67 (C3)	SH31	3.97 ± 0.04	—
76315,61 (C2)	SH31	3.98 ± 0.04	—
		(4.10 ± 0.05)	
76255,46	SH40	4.02 ± 0.04	—
Mineral concentrates			
76015,38 (plag)	SH36	3.96 ± 0.06	—
76015,36 (plag)	SH36	3.92 ± 0.04	—
76015,38 (px)	SH36	(3.79 ± 0.07)	—
76015,36 (px)	SH36	(3.92 ± 0.09)	—
Mean age		3.96 ± 0.04	

76015

Vesicular Micropoikilitic Impact Melt Breccia
2819 g, 20 x 16 x 14 cm

INTRODUCTION

Sample 76015 was chipped off of the top corner of Block 5 of the big boulder at Station 6 (Fig. 1, Wolfe and others, 1981). It is a sample of lithologic unit B of Boulder 6 and is similar in color and texture to 76215 from Block 4 (also from unit B). This lithology was originally referred to as the "green-grey" breccia lithology (Fig. 2). 76015 has a well-documented orientation based on laboratory photography and has a well-known exposure history because of its certain relationship to several other samples of the Station 6 Boulder (Heiken et al., 1973).

One surface of 76015 was part of a shielded cavity that was oriented parallel to the sunline, which had an azimuth of approximately 106 deg and elevation of approximately 36 deg to the horizontal. This unique cavity has allowed several interesting studies of the solar flare, cosmic ray, and micrometeorite bombardment of the lunar surface (Blanford et al., 1974; Morrison and Zinner, 1975; Crozaz et al., 1974). The "lip" of this cavity has a thick, undisturbed patina (Fig. 3).

Spudis and Ryder (1981) summarize the arguments that this boulder is from the melt sheet or ejecta blanket from the Serenitatus impact event. Simonds et al. (1976) and Onorato et al. (1976) provide a comprehensive thermal model for the lithification of impact melt breccias based on their detailed study of the textures of samples from Boulder 6 and in comparison with melt sheets from large terrestrial craters.

PETROGRAPHY

Sample 76015 is a very vesicular, crystalline-matrix breccia with <0.1 mm to 5 cm long irregular vesicles that compose about 20% of the rock by volume. The flattened

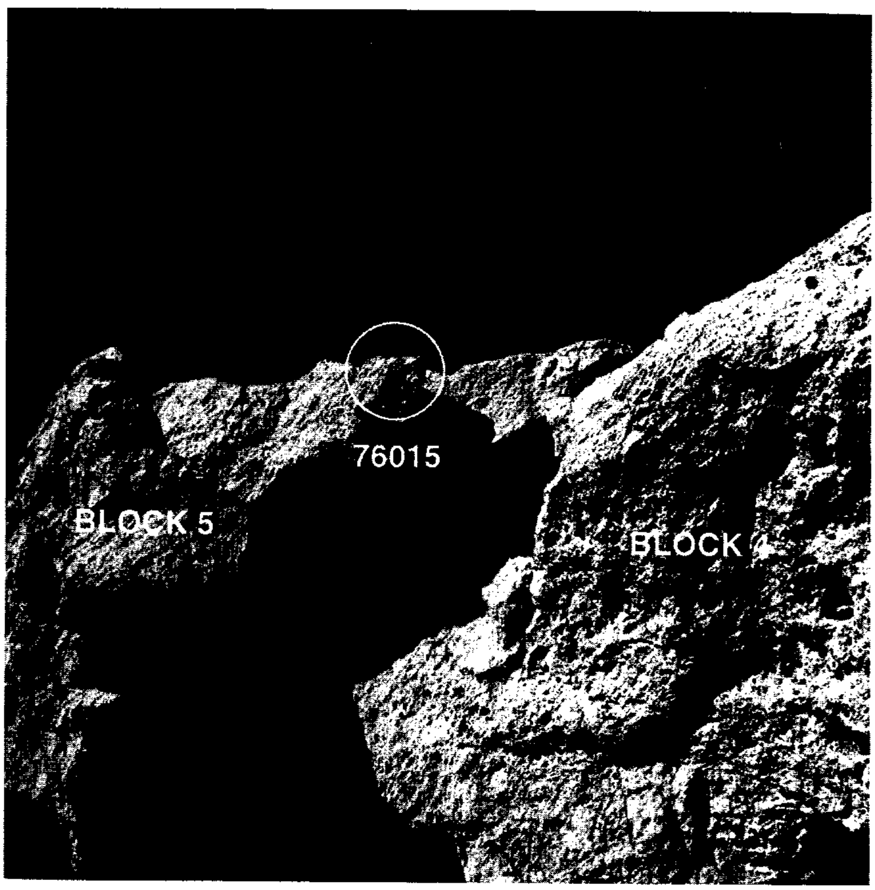


Figure 1: Location of 76015 on Block 5 before sampling. Note the well-documented orientation. AS17-140-21411.

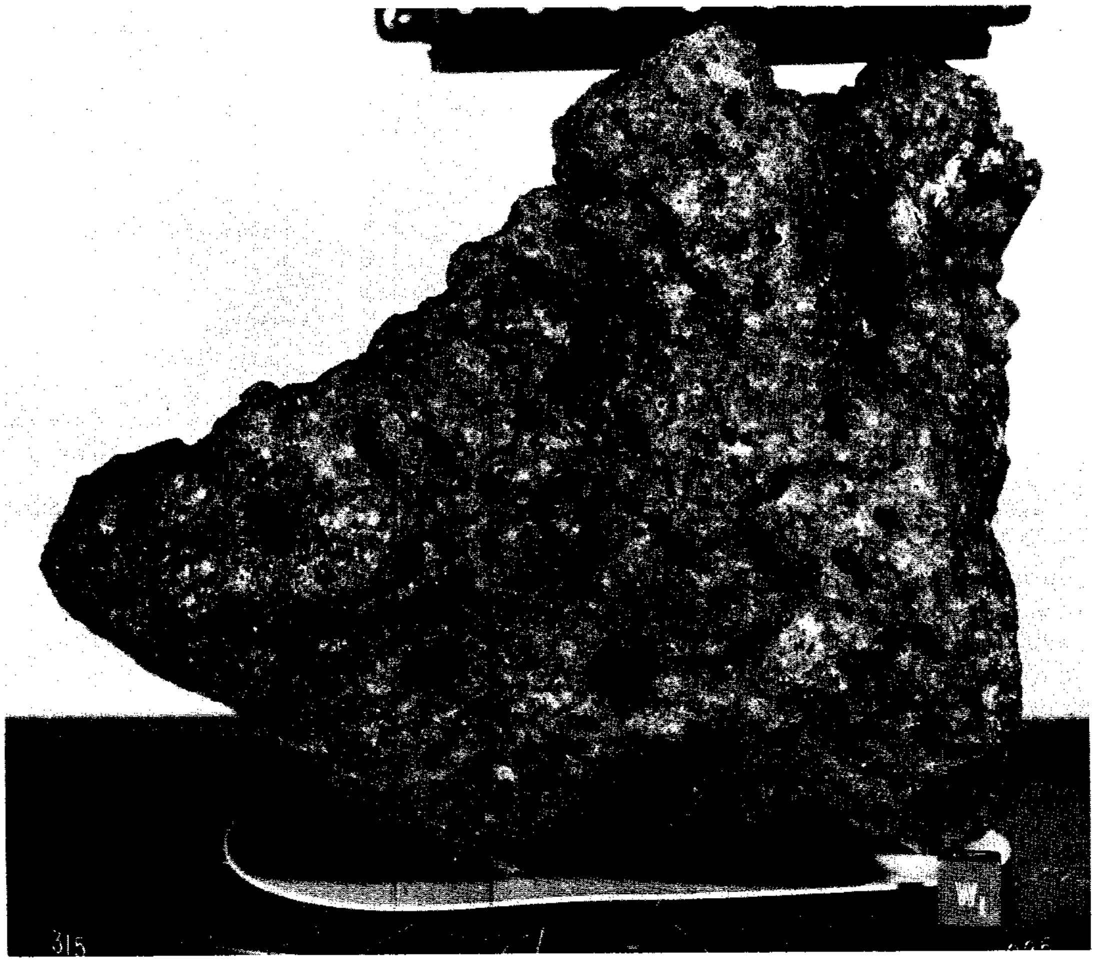


Figure 2: The exterior surface of 76015 has been heavily eroded by micrometeorite bombardment and is covered with glass-lined micrometeorite craters (zap pits) with white spall zones. The foliation of the abundant large vesicles is evident in this photo. Scale is 1 cm. S73-15015.

vesicles define a preferred orientation best seen on the west (W1) side of the sample (Fig. 2). The modal mineralogy of 76015 is about 50% plagioclase, 40% low-calcium pyroxene, with minor amounts of augite, olivine, ilmenite, armalcolite, and metallic iron. The poikilitic matrix of 76015 (Fig. 4) consists of a nearly continuous mass of elongated and occasionally aligned 0.2-0.3 by 0.7-1.5 mm low-calcium pyroxene oikocrysts ($Wo_{4\text{-}9}En_{61\text{-}76}Fs_{19\text{-}25}$). Tabular feldspar 10-50 μm long occurs both within and between the pyroxene grains and ranges from An_{82} to An_{96}, with a distinct peak at An_{89} (Fig. 5). Small amounts of augite ($Wo_{35\text{-}40}En_{42\text{-}46}Fs_{12\text{-}15}$) are found as <20 μm grains both within and between the low-calcium pyroxene oikocrysts. Both poikilitic ilmenite and armalcolite grains up to 200 μm long, with spinel and rutile lamellae, are concentrated between the pyroxene oikocrysts.

Mineral and lithic clasts compose 5-15% of the rock. Mineral clasts are recognized because they are typically over 50 μm across, much larger than the matrix grains. Simonds et al. (1974 and 1975) studied numerous small lithic clasts in 22 thin sections of 76015 and found that they were predominantly granoblastic or poikilitic in texture, generally with 70-80% feldspar. Some of the small clasts were described as annealed "dunite" and "troctolite" fragments.

Simonds (1975) describes the poikilitic matrix of 76015 as a continuous network of interlocking pigeonite oikocrysts with about half of the pyroxene in a tight cluster in the compositional diagram $Wo_{5\text{-}6}En_{70\text{-}73}Fs_{22\text{-}26}$. Simonds notes that the narrow range of pyroxene and feldspar composition agrees with the uniform compositional data of Rhodes et al. (1974) and Hubbard et al. (1974) for widely separated portions of the sample. They conclude that the matrix of this sample is very homogeneous in composition.

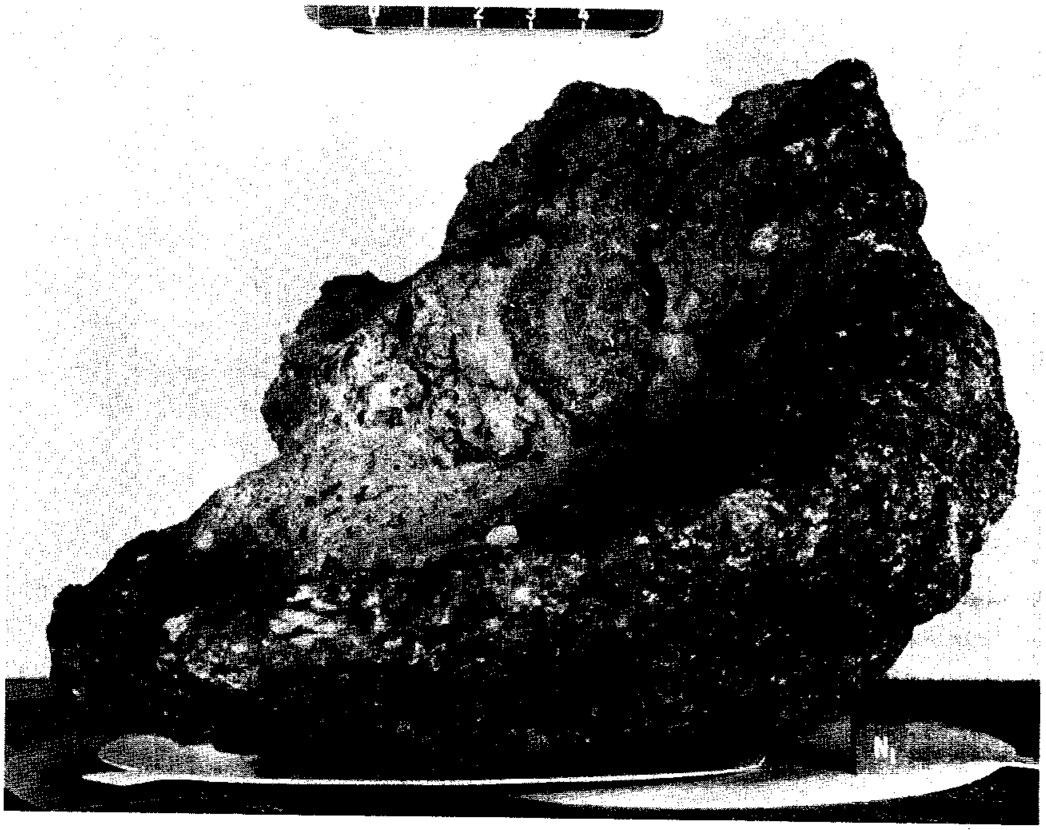


Figure 3: This photo of 76015 illustrates the patina covered "lip" that was partially shielded from micrometeorites (see text). The large vesicular basalt "vug" clast is evident in the center of the photo. Scale is 1 cm. S73-18764.

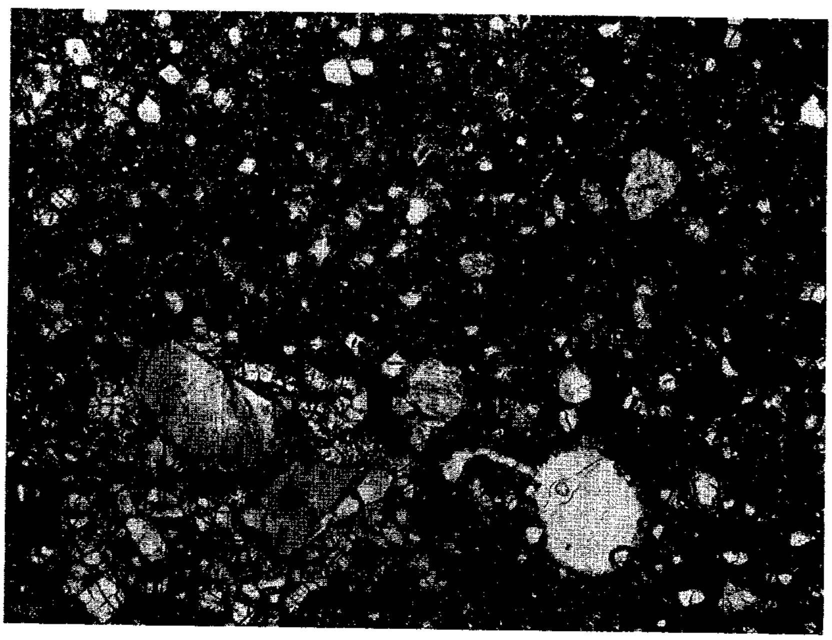


Figure 4: Photomicrograph of 76015 matrix. Note the partially digested relict clast and the large vesicle. The texture of the matrix of 76015 is poikilitic with large pyroxene grains surrounding small plagioclase laths and mineral inclusions. This texture is typical of the matrix of all the Station 6 boulders as well as many Apollo 16 melt rocks. Field of view is 4 x 5 mm.

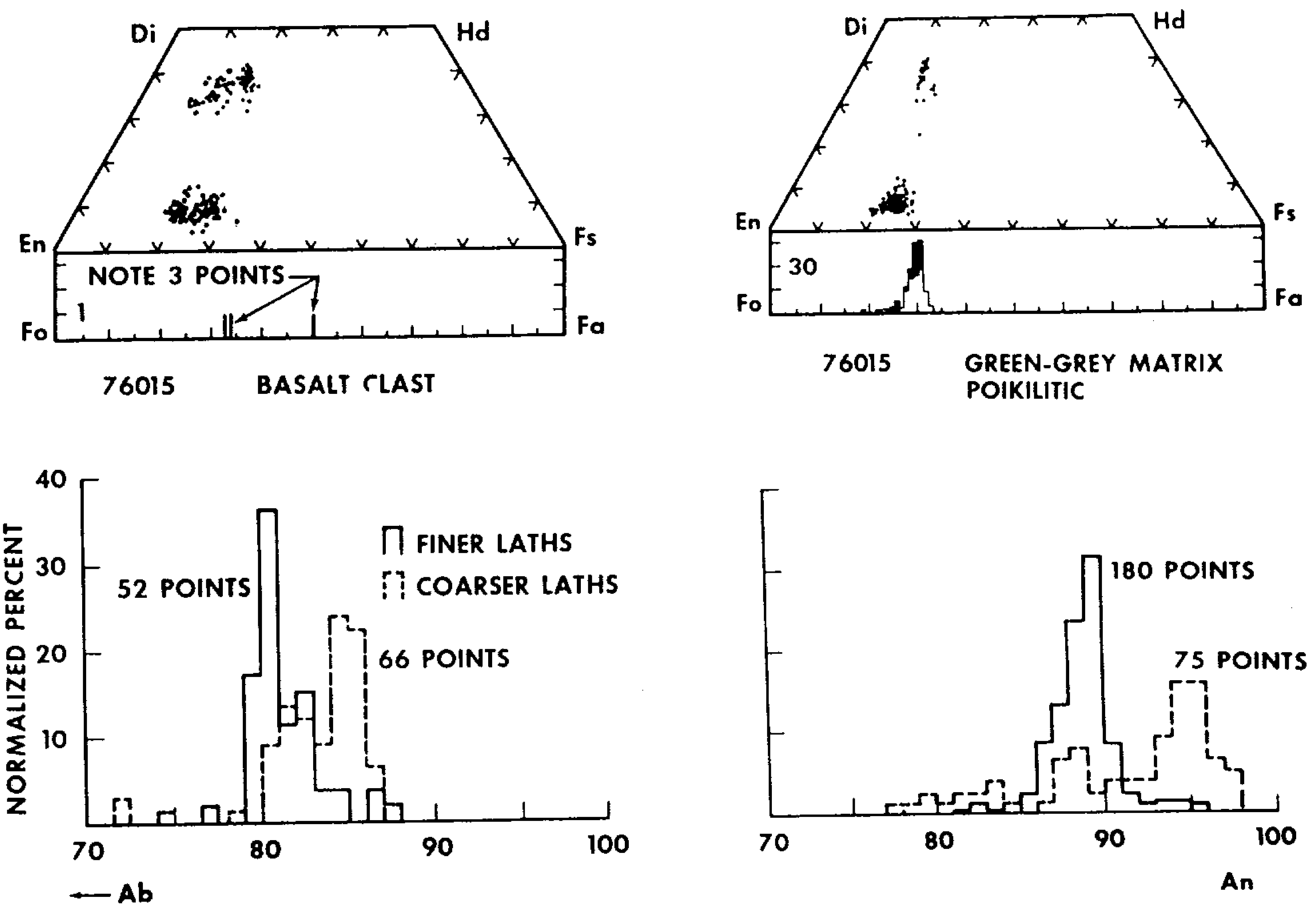


Figure 5: Pyroxene, olivine, and plagioclase compositions of the matrix and the vesicular basalt clast in lunar breccia 76015 (from Simonds, 1975). Note that the larger plagioclase inclusions in the green-grey matrix are more calcic (An_{95}) than the plagioclase laths in the matrix (An_{89}).

Misra et al. (1976) have studied the complex metallic nickel-iron particles included in 76015 (Fig. 6).

WHOLE-ROCK CHEMISTRY

The matrix of 76015 is very homogeneous in composition (Table 1) and the composition is also very similar to that of the other samples of this boulder (Fig. 7).

Higuchi and Morgan (1975) find that the trace siderophile element compositions of all the samples of the Station 6 Boulder form a tight grouping (meteorite group 2) on compositional diagrams (Fig. 8). 76015 and 76215 have a lower abundance of these meteoritic elements than the matrix for 76275 and 76295 (Table 2).

SIGNIFICANT CLASTS

Simonds (1975) and Phinney (1981) describe a large (2 cm) porous basalt clast ("vug" filling?) in 76015 with intersertal texture (Fig. 9). The plagioclase in this clast is found to be somewhat less calcic than that of the breccia matrix (Fig. 5). However, there appear to be no chemical or isotopic data on this large basalt clast (see also Fig. 3).

RADIOGENIC ISOTOPES

Cadogan and Turner (1976) determined the crystallization age of 76015 by the ^{39}Ar-^{40}Ar plateau technique. The matrix yielded an intermediate temperature plateau which covered 70% of the release of ^{39}Ar and corresponds to an age of 3.93 ± 0.04 b.y. A similar but less well-defined age of 3.96 ± 0.06 b.y. was obtained for a plagioclase separate (Fig. 10).

Nyquist et al. (1974) have reported Rb-Sr data for several splits of matrix from 76015 (Fig. 11 and Table 3) and note that the Rb-Sr systematics are probably partially reset by the Serenitatus impact event (see Phinney, 1981). U-Th-Pb data by Leon Silver were also reported in Phinney (1981).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Crozaz et al. (1974) have studied the long-term exposure history of a surface of 76015 that was exposed to the sky through a small solid angle (as evidenced by a marked gradient of dark to light patina) (see figure in their paper). As a consequence of the small solid angle factor, the effects of erosion over a long period of time are removed, allowing for a study of the solar flare spectrum without the complication of continuous erosion. Indeed, the measured solar flare track density for 76015 was found to fall off much faster with depth than for other lunar samples (which have experienced erosion) and is comparable with data on the energy of solar flares derived by studies of recent solar flares using the Surveyor glass (Crozaz et al.). The solar flare track exposure age (18 ± 3 m.y.) is found to be concordant with the galactic proton age (17.5 ± 0.5 m.y.) as determined by the Kr-Kr method, although somewhat younger than the 22 m.y. exposure age determined for 76315 (Arvidson et al., 1975). Presumably a portion of the surface of 76015 eroded away in the past (Crozaz et al.).

Bogard et al. (1974) (see unpublished data in Phinney, 1981) have determined the noble gas abundances in 76015.

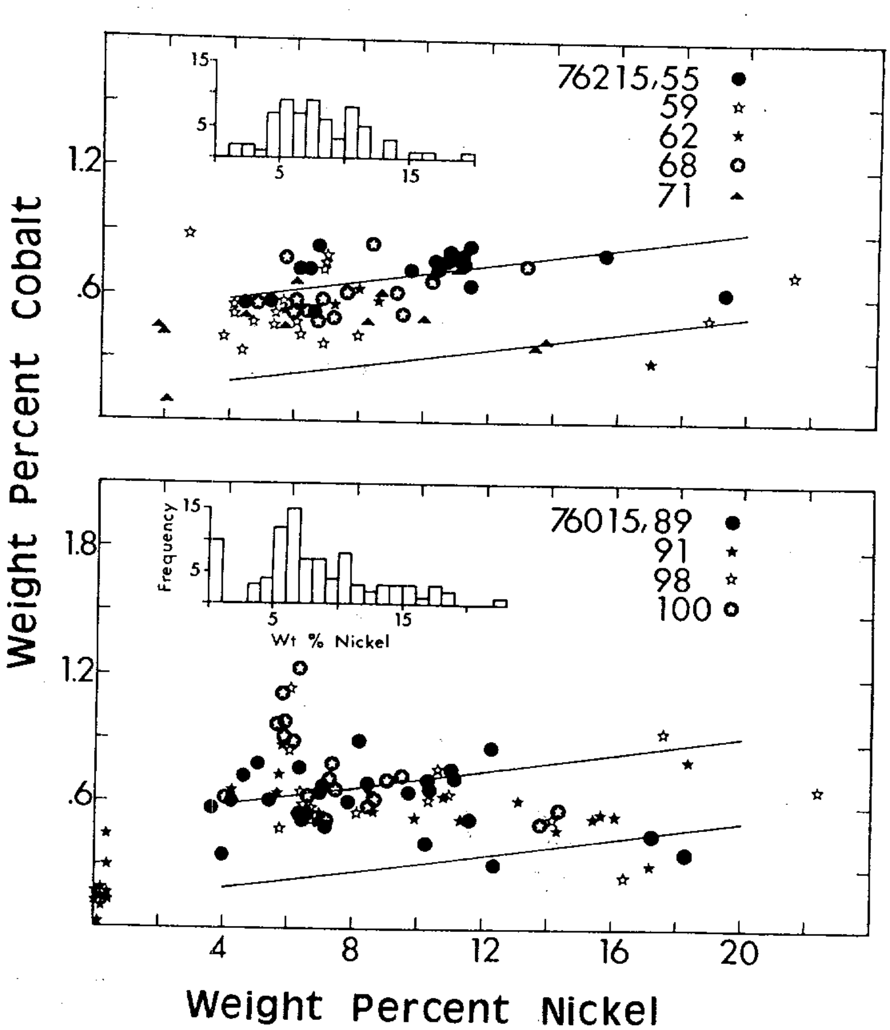


Figure 6: Nickel vs. cobalt contents of metal grains in 76015 and 76215. From Misra et al. (1976).

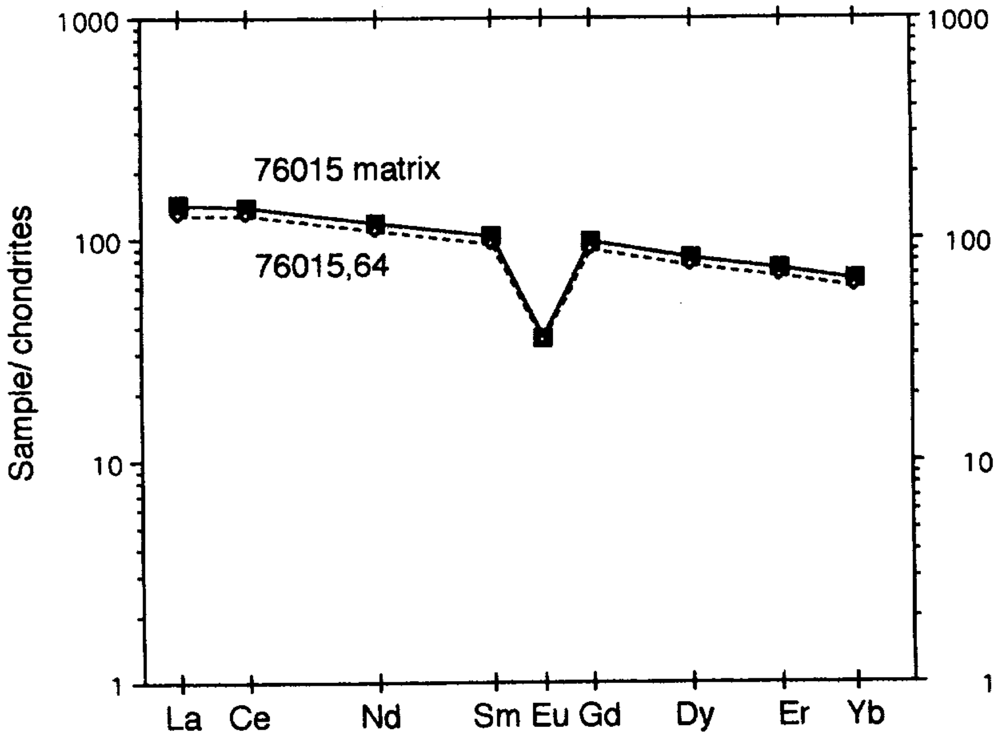


Figure 7: Normalized rare earth diagram for 76015. All subsamples have the same pattern and are similar to the matrix of 76215 and 76315. This sample provides a good reference for the other samples of the North Massif. Data from Hubbard et al. (1974).

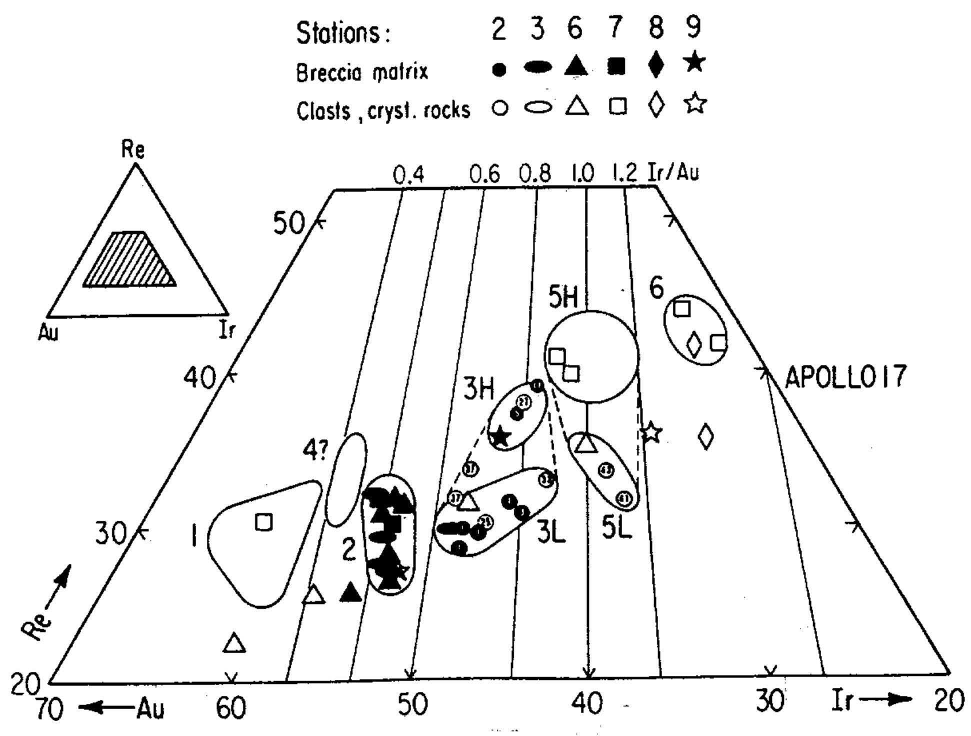


Figure 8: Ir-Au-Re compositions of Station 6 Boulder matrix all fall within Cluster 2 (see Higuchi and Morgan, 1975).

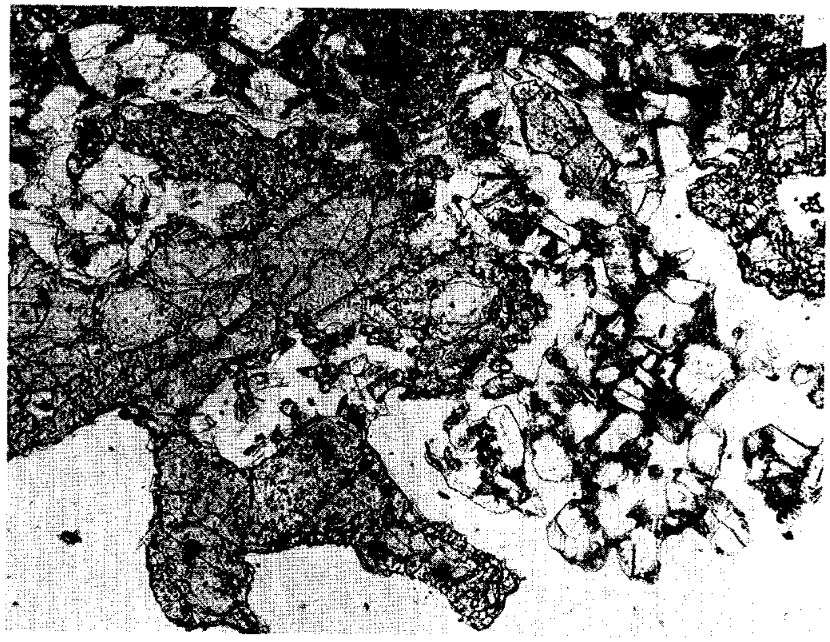


Figure 9: Large pyroxene grains and plagioclase laths in vesicular basalt clast (see Phinney, 1981). Scale is 4 x 5 mm.

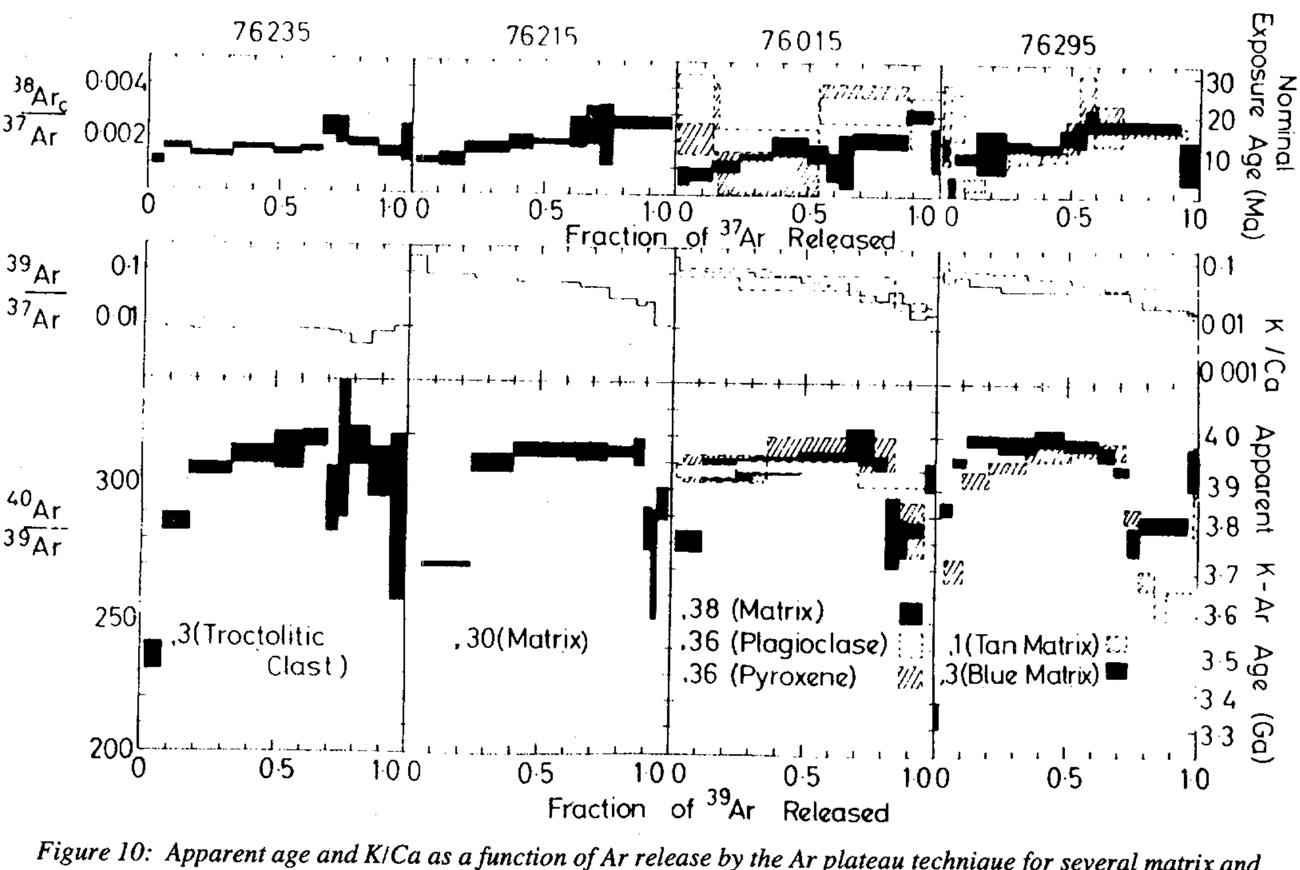


Figure 10: Apparent age and K/Ca as a function of Ar release by the Ar plateau technique for several matrix and mineral fractions of Station 6 Boulder samples. From Cadogan and Turner (1976).

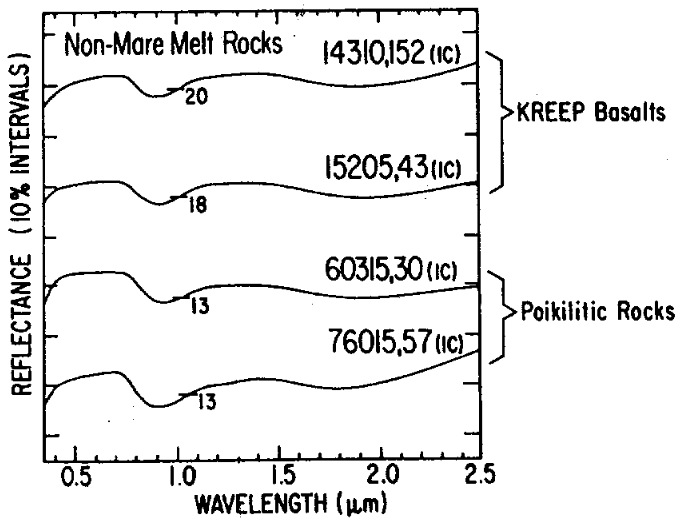


Figure 11: Comparison of reflectance spectra of poikilitic rocks (including 76015) and KREEP basalts. From Charette and Adams (1977).

MAGNETIC STUDIES

Pearce et al. (1974) and Gose et al. (1978) have carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder. The direction of magnetization of clast-free samples from unit B (including 76015) cluster fairly well after alternating field demagnetization. Gose et al. propose that the natural remanent magnetization of impact melt breccias is the vector sum of two magnetizations, a pre-impact magnetization and a partial thermoremanence acquired during breccia lithification.

SURFACE STUDIES

The thickness of the patina that developed on the T1 surface of 76015 (Fig. 3) is unusual and is a function of the exposure geometry of a partially to completely shielded cavity on top of the boulder. The T1 surface subtended a small solid angle and intercepted few large particles capable of eroding the surface, as is the case on the fully exposed exterior surface where there is a less well-developed patina due to constant steady-state erosion. There is a marked gradation in patina from the thick deposit of the partially shielded lip of the rock to a lack of patina in the completely shielded region. The thick deposit is made of accumulated glass splashes, pancakes, and presumably condensed vapor that may have come from the opposite face of the cavity.

The surface patina on 76015 has been carefully described by Blanford et al. (1975). The partially shielded part of the surface of 76015 has accumulated accretionary particles over a long period of time (22 m.y.?), while the exposed surface of 76015 reached a steady state of micrometeorite erosion and accumulated glass splashes. Accretionary particles are small objects adhering to the host surfaces. They include glass splashes, stingers, and pancakes as well as angular dust particles. Glassy accretionary particles are formed by fusion of target material by hypervelocity micrometeorites. Patina is the result of the accumulation of this fused material on nearby surfaces. High resolution examination of the stratigraphically oldest glass particles on the exterior surface of 76015 suggests that their surfaces have been altered by solar wind sputtering. Older particles have a granular appearance in contrast to the perfectly smooth appearance of the superposed younger particles.

Charette and Adams (1977) have determined the reflectance spectra of the surface of 76015 and report that the spectra of poikilitic rocks are similar to KREEP with a slight upturn at the high wavelength (Fig. 11). It would be interesting to determine the difference in spectra for patina-covered surfaces as compared to fresh surfaces (76015 is the ideal sample for such study).

EXPERIMENTAL

Experimental studies by Delano (1977) showed that 76015 has olivine as its liquidus phase at 0 kbars. Olivine + spinel coexist on the liquidus in the pressure interval from 5 to 12 kbar. Olivine + spinel + orthopyroxene are simultaneously on the liquidus at 12 kbar. Orthopyroxene + spinel are the liquidus phases at pressures greater than 12 kbar (Fig. 12). Experimental phase relations of these experiments suggest that the 76015 composition does not represent magma derived by partial melting of either cosmic or differentiated source regions at any pressure on the Moon.

VUGS

This sample has numerous vugs and cavities with well-known orientation (Fig. 13). Morrison and Zinner (1975) used two of these cavities to study the possible directional variations in the flux of micrometeorites and solar flare particles. Studies by Blanford et al. (1975) (Fig. 14) and Morrison and Zinner (1975) found no anisotropy in the flux of micrometeorites between the north direction and the ecliptic, whereas Hutcheon (using different samples) determined that the ecliptic flux was seven times as high as the flux from the south (see discussion in Zinner and Morrison, 1976).

Morrison and Zinner determined that there are 900 0.1 μm craters produced per cm^2 per year per 2 π steradian. Based on their observation of numerous fresh 0.1 μm craters, they concluded that there is not more than an estimated maximum solar-wind erosion rate of 0.07 Å/yr.

Morrison and Clanton (1979) have documented differences in the micrometeorite populations and surface characteristics between the surface of 76015 that was exposed in the plane of the ecliptic and the surface that was exposed perpendicular to the ecliptic.

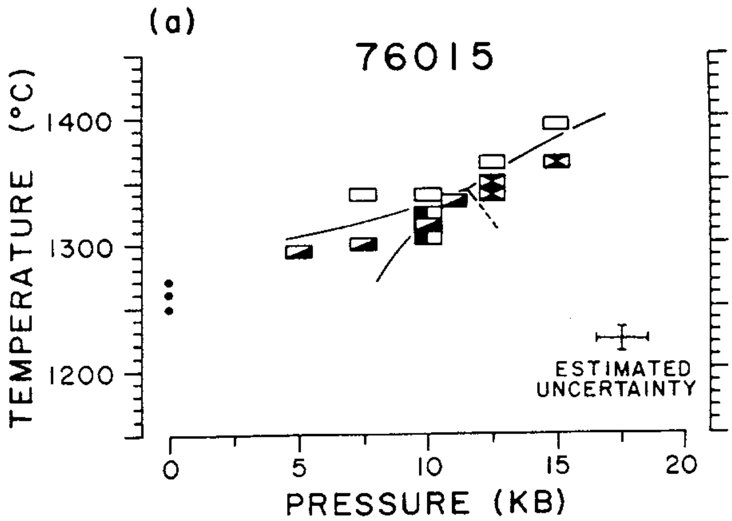
Carter et al. (1975) have studied the euhedral crystals of pyroxene, plagioclase, ilmenite, metallic iron, and troilite that line the vugs of 76015.

Phinney (1981) reports that large apatite crystals occur in the vugs of 76015 as honey-yellow, transparent, single crystals up to 1 mm in greatest dimension. They are found to be doubly terminated and loosely adhering to the cavity walls. Large beta-cristobalite crystals and wiry and dendritic metallic Cu are also reported in these cavities.

PROCESSING

A slab and a column were cut from the center of this rock (see maps in Phinney, 1981). A second slab and column were cut at right angles to the first slab in 1988. A large piece (330 g) has been used for public display.

The largest piece remaining (,18) weighs 1307 g and is stored at Brooks Air Force Base. The second largest piece (,19) weighs 630 g. There are 30 thin sections.



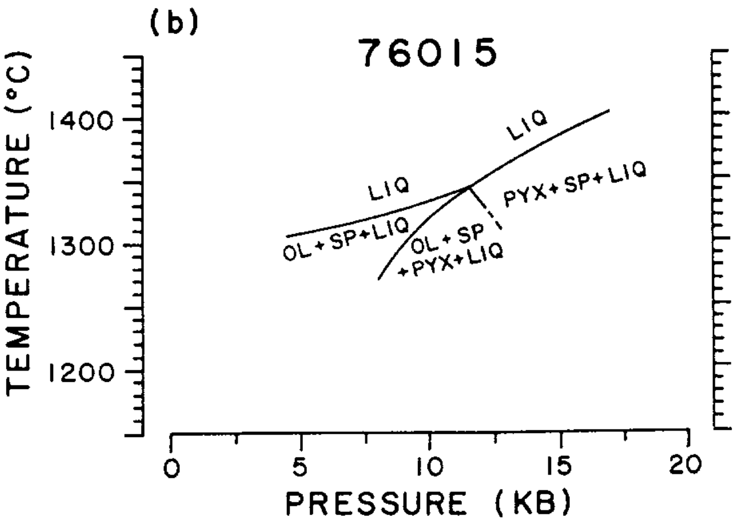


Figure 12: Melting relations of 76015 as function of temperature and pressure. From Delano (1977).

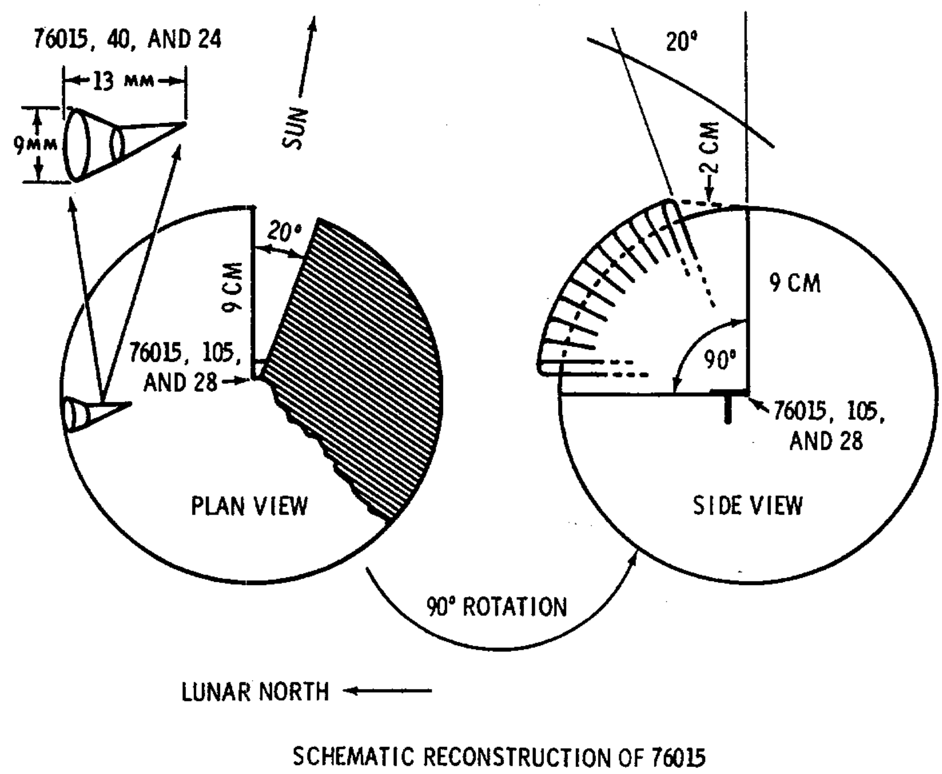


Figure 13: Orientation and exposure geometry of 76015,105 ,24 and ,40. From Morrison and Zinner (1975).

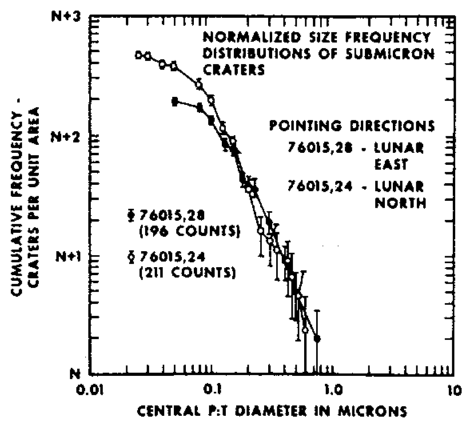


Figure 14: Size-frequency distributions of zap pits on oriented surfaces of 76015. From Blanford et al. (1975).

Table 1: Whole-rock chemistry of 76015.
a) Rhodes et al. (1974a); Hubbard et al. (1974); b) Palme et al. (1978)
See also Wiesmann and Hubbard (1975) and Phinney (1981).

Split Technique	,22M (a) XRF, IDMS	,37M (a) XRF, IDMS	,41M (a) XRF, IDMS	,64M (a) XRF, IDMS	,12 (b) XRF, INAA
SiO_2 (wt%)	46.16	46.38	46.38	46.59	46.52
TiO_2	1.52	1.55	1.53	1.48	1.54
Al_2O_3	17.17	17.78	17.77	18.00	17.86
Cr_2O_3	–	–	–	–	0.19
FeO	9.81	9.65	9.07	9.10	8.08
MnO	0.13	0.13	0.12	0.12	0.11
MgO	13.03	12.40	12.67	12.43	12.57
CaO	10.77	11.13	11.11	11.10	10.99
Na_2O	0.70	0.72	0.69	0.75	0.68
K_2O	0.26	0.26	0.26	0.29	0.24
P_2O_5	0.27	0.29	0.29	0.28	0.28
S	0.09	0.06	0.08	0.08	0.39
Nb (ppm)					32
Zr	490	515	507	484	480
Hf	12.5	12.7	–	–	11.81
Ta					1.62
U	1.46	1.59	1.96	1.48	1.2
Th	5.44	5.64	5.56	5.41	4.18
Y					112
Sr	172	178	177	174	180
Rb	6.41	6.67	6.57	7.46	–
Li	18.3	19.8	21.6	18.5	17.7
Ba	348	362	358	354	340
Cs					0.20
Ni					1140
Co					90.2
Sc					16.7
La	–	34.3	33.4	29.9	33.8
Ce	83.3	85.9	84.9	78.4	89.2
Nd	52.8	54.4	54.0	49.3	54
Sm	14.9	15.3	15.2	14.0	14.11
Eu	1.94	2.02	1.99	1.97	1.99
Gd	18.7	19.0	18.9	17.6	18.1
Tb					3.04
Dy	19.5	20.0	19.9	18.3	19.9
Er	11.5	11.8	11.7	10.9	–

Table 1: (Concluded).

Split Technique	,22M (a) XRF, IDMS	,37M (a) XRF, IDMS	,41M (a) XRF, IDMS	,64M (a) XRF, IDMS	,12 (b) XRF, INAA
Yb	10.6	11.0	10.8	10.0	11.43
Lu	–	–	1.30	1.50	1.55
Ga					–
F					45.8
Cl					6.9
Ge (ppb)					–
Ir					43
Au					18

Table 2: Trace element data for 76015. Concentrations in ppb.
From Higuchi and Morgan (1975).

	Sample 76015,77 matrix
Ir	3.41
Os	
Re	0.315
Au	1.89
Pd	
Ni (ppm)	135
Sb	1.02
Ge	164
Se	76
Te	2.7
Ag	1.02
Br	46.8
In	
Bi	0.22
Zn (ppm)	2.8
Cd	3.2
Tl	0.67
Rb (ppm)	5.77
Cs	266
U	1490

Table 3: Rb-Sr composition of 76015.
Data from Nyquist et al. (1974).

Sample	76015,22M	,37M	,41M	,64M
wt (mg)	52.3	53.5	63.6	51.5
Rb (ppm)	6.41	6.67	6.57	7.46
Sr (ppm)	171.8	177.5	176.6	173.8
$^{87}Rb/^{86}Sr$	0.1079 ± 9	0.1088 ± 9	0.1076 ± 9	0.1242 ± 10
$^{87}Sr/^{86}Sr$	0.70589 ± 5	0.70605 ± 5	0.70589 ± 11	0.70693 ± 6
T_B	4.39 ± 0.07	4.45 ± 0.07	4.40 ± 0.11	4.40 ± 0.07
T_L	4.45 ± 0.07	4.52 ± 0.07	4.45 ± 0.11	4.44 ± 0.07

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

76035

Nonvesicular Impact Melt Breccia
376.2 g, 12 x 5.5 x 5 cm

INTRODUCTION

Sample 76035 was collected from the soil about 20 meters downslope from the large boulder in the Station 6 area. It is a nonvesicular, clast-bearing, blue-grey impact melt breccia.

Chao et al. (1975) believe that 76035 is very similar to 77115 and to 72435. Ryder (1993) describes the matrix of 76035 as fine-grained with olivine microphenocrysts.

PETROGRAPHY

The photo of one side of this sample (Fig. 1) shows that the main mass of it is the blue-grey impact melt breccia typical of the highlands; the other side has an assemblage of light and dark clasts folded together like in an omelet (Fig. 2). Angular inclusions of light impact melt breccia are included in the blue-grey matrix of 76035. There is an apparent basaltic clast included in the blue-grey impact melt (see Fig. 1). Some thin sections show the dark lithology is a soil breccia—but it is very minor portion of the overall sample.

This sample has not been studied.

There are only three thin sections of 77035.

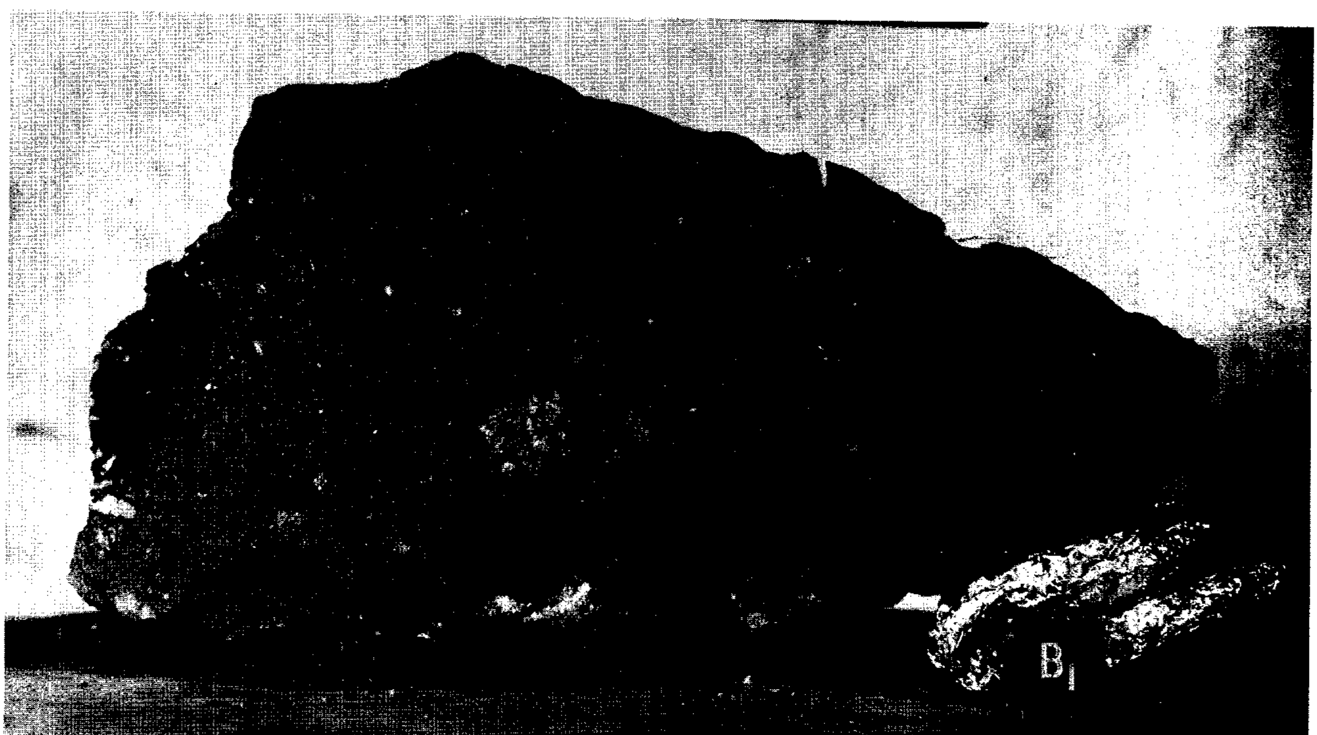


Figure 1: Freshly broken surface of 76035, showing basalt clast. There are few vesicles compared with the Station 6 Boulder. Scale is 1 cm. S73-19355.

Figure 2: Angular inclusions of light impact melt breccia included and attached to matrix of 76035. Scale is 1 cm. S73-15457.

76036
Impact Melt Breccia
3.95 g, 2.5 x 2 x 0.6 cm

INTRODUCTION

Sample 76036 was collected from the soil about 20 meters downslope from the Boulder 6 area. It is a dark grey impact melt breccia.

PETROGRAPHY

Sample 76036 has not been studied, but it is apparently similar to and probably a piece of 76035. One side has small impact craters; the other side has a few white inclusions (Fig. 1).

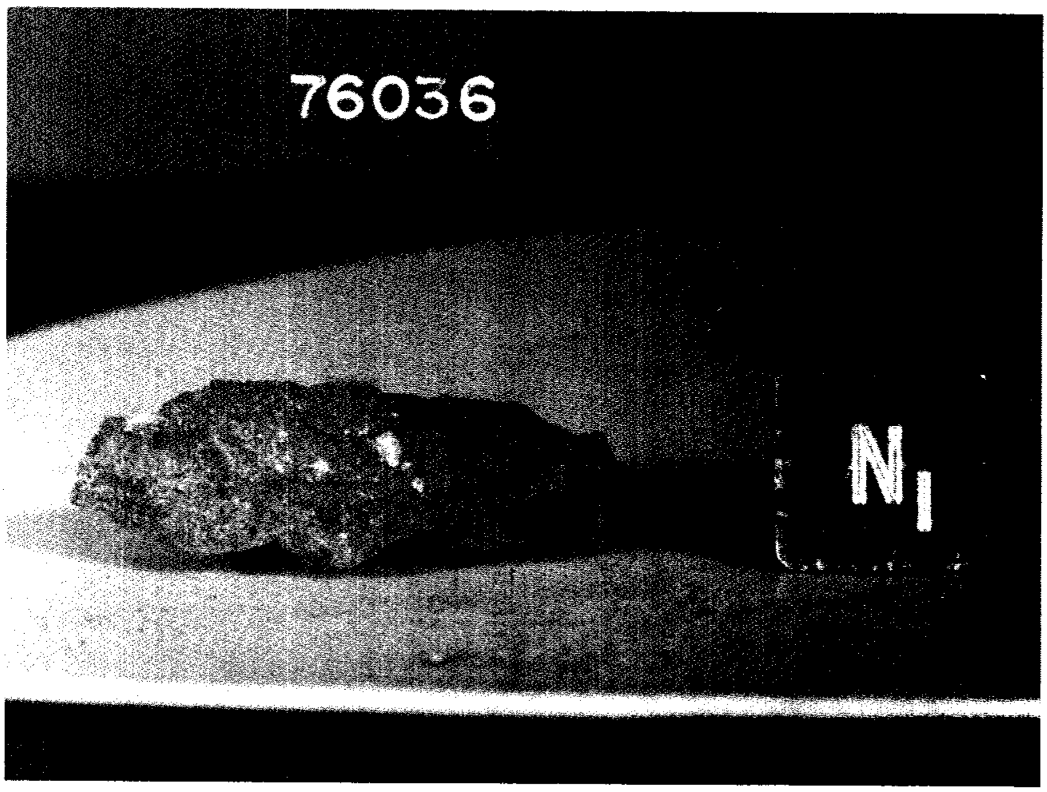


Figure 1: Dark grey impact melt breccia 76036. Cube is 1 cm. S73-17959.

76037
High-Ti Mare Basalt
2.52 g, 1.7 x 1.2 x 0.8 cm

INTRODUCTION

Sample 76037 was collected from the soil about 20 meters downslope from the Boulder 6 area as part of a soil sample. It is a coarse-grained ilmenite basalt (Fig. 1).

PETROGRAPHY

Neal et al. (1990) classify 76037 as a Type 1B mare basalt, typical of other A17 basalts (Fig. 2). They report a mode of 0.5% olivine, 46% pyroxene, 33% plagioclase, and 17% ilmenite. Grain size is 0.1 to 1 mm.

MINERAL CHEMISTRY

Neal et al. (1990) have studied the mineral chemistry. Olivine is $Fo_{50\text{-}65}$, plagioclase is $An_{78\text{-}88}$, and pyroxene is $Wo_{8\text{-}40}En_{25\text{-}63}$.

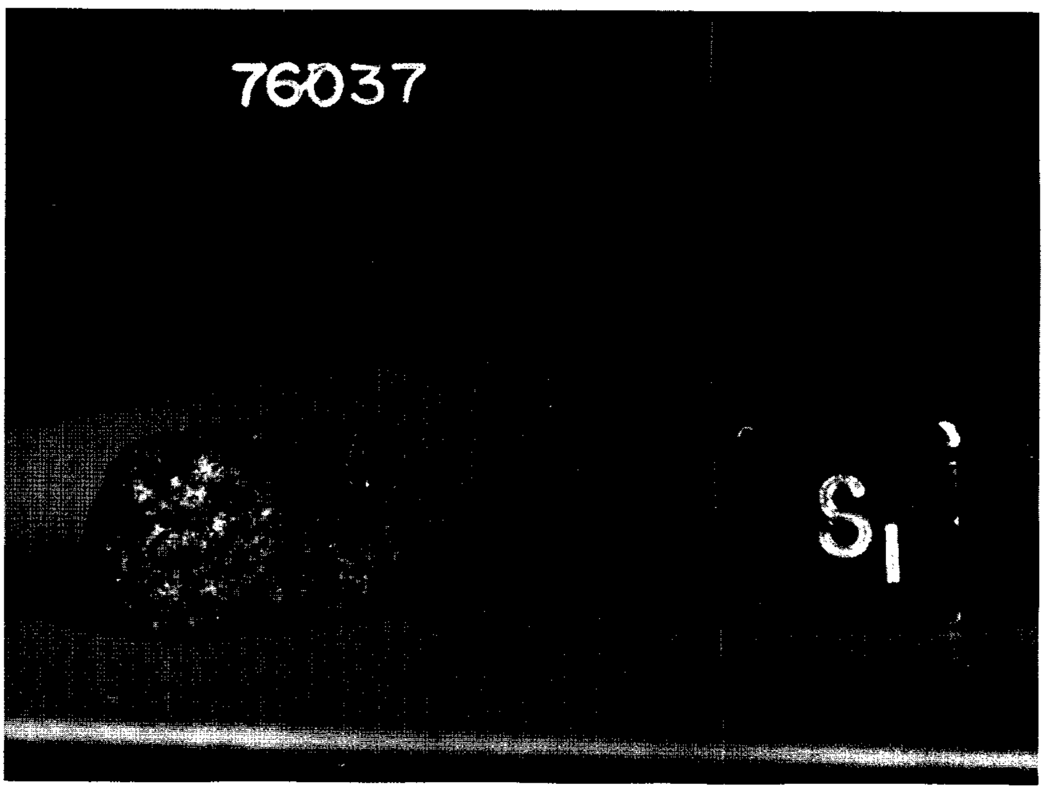


Figure 1: Ilmenite basalt 76037. Cube is 1 cm. S73-17958.

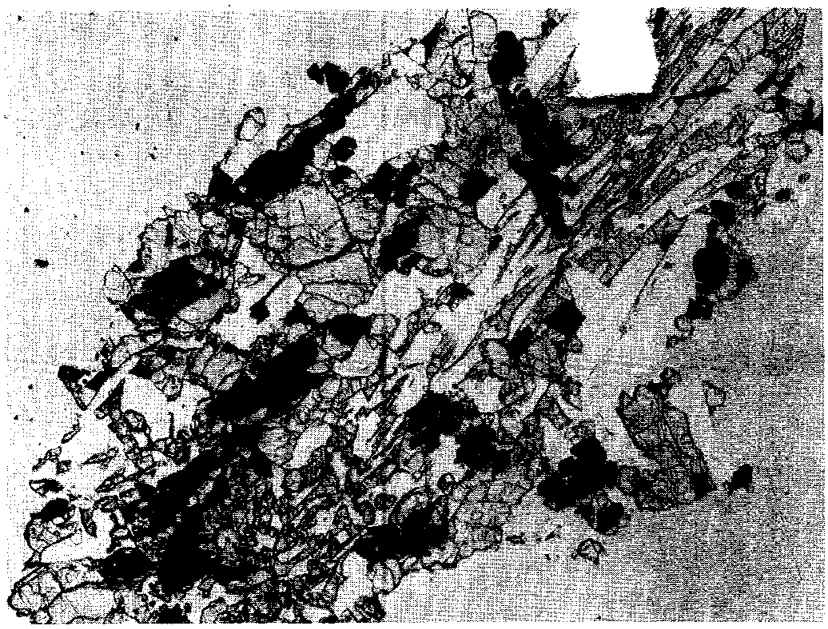


Figure 2: Photomicrograph of ilmenite basalt 76037. Field of view is 4 x 5 mm.

76055
Impact Melt Breccia
6412 g, 23 x 13 x 13 cm

INTRODUCTION

Sample 76055 was picked up from the regolith at some distance (10-15 meters) from the Station 6 Boulder. The hand specimen appeared to be relatively homogeneous and clast free, but the thin sections show many minute clasts. This rock contains a prominent foliation that is defined by many small lenticular vesicles up to 0.2 x 3 mm in size. The surface of the sample is covered with zap pits, including one glass splash of about 1 cm.

This sample appears to be slightly older than the Station 6 Boulder and other Serenitatus impact melts. The bulk composition is also apparently distinct from the boulder samples (with lower Al and REE; higher Mg and Mg/Fe ratio).

This large sample has not received adequate attention. It may be a separate sample of the Serenitatus melt sheet from high on the North Massif.

PETROGRAPHY

Sample 76055 is a massive impact melt breccia with aphanitic matrix (Fig. 1). Literature descriptions of 76055 by Chao (1973), Warner et al. (1973), and Albee et al. (1973) are all apparently from the same set of thin sections, all of which included the same atypical clast in the breccia matrix (see below).

Other sections taken of the main mass of the sample show that it is an impact melt like that of the Station 6 Boulder and broadly similar to the poikilitic breccias from the South Massif (Fig. 2). Sawn surfaces show that the interior of 76055 is an assemblage of aphanitic breccia clasts, included in larger aphanitic pods, all included in a vesicular aphanitic matrix that displays a swirled, banded foliation.

The matrix of 76055 consists of about 10% subangular plagioclase and olivine clasts (50 to 500 μm) set in a finer-grained (10 μm) poikilitic matrix of subhedral orthopyroxene intergrown with anhedral plagioclase. The pyroxene has a constant composition of about

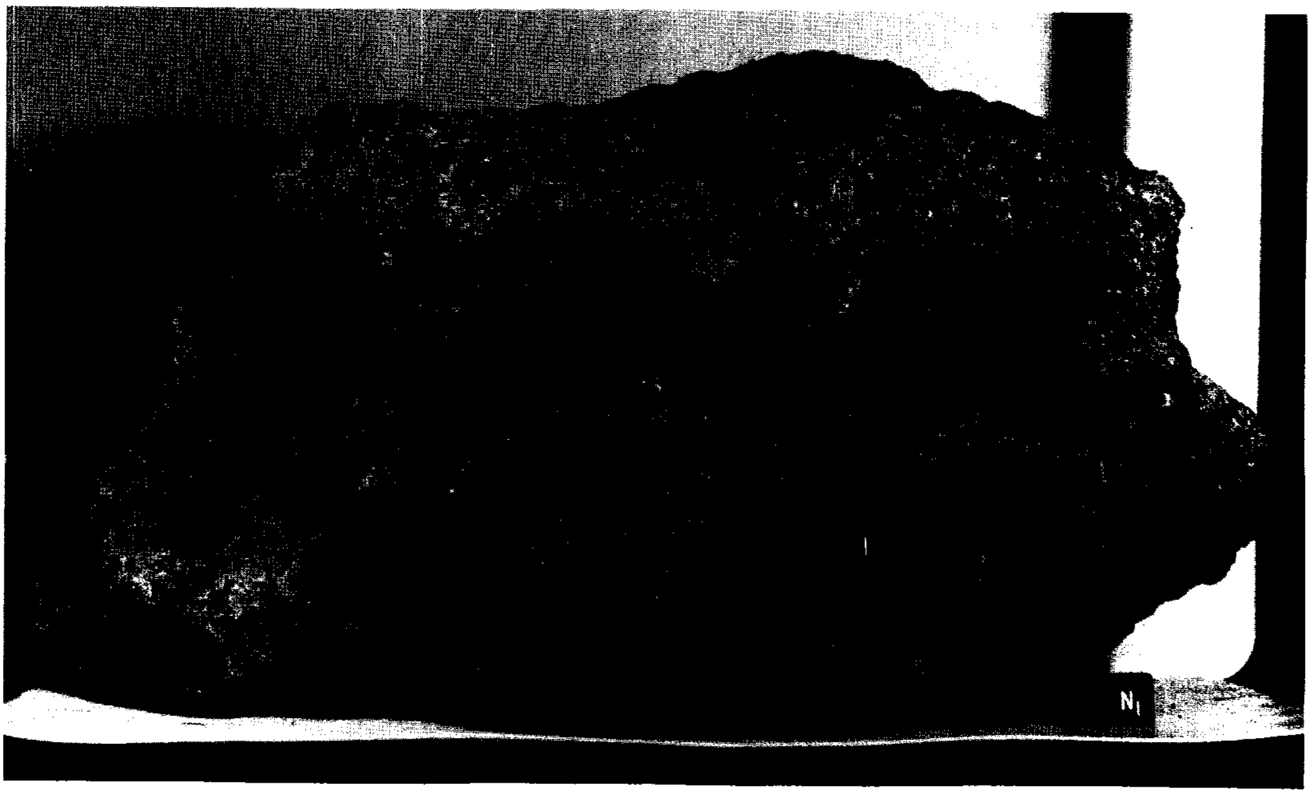


Figure 1: Impact melt breccia 76055. Scale is 1 cm. S73-15714.

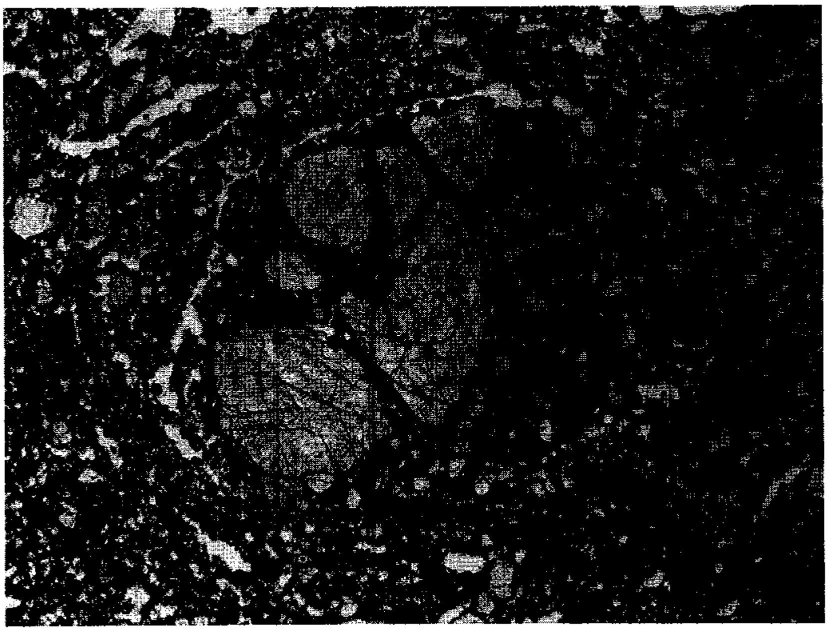


Figure 2: Interior texture of impact melt breccia 76055, showing foliation of elongate vesicles wrapping around a partially dissolved mafic clast. Field of view is 4 x 5 mm.

$Wo_4En_{77}Fs_{19}$, plagioclase An_{86-90}, and olivine Fo_{77}. The mode is about 41% plagioclase, 24% orthopyroxene, 18% olivine—with minor augite, armalcolite, and iron metal (Albee et al., 1973). If this mode is correct, then this sample has higher olivine content than the other Station 6 breccias, which may explain its high Mg content.

Chao et al. (1975) believe that 76055 may be similar to 77135.

MINERAL CHEMISTRY

Albee et al. (1973) give the detailed compositions of many of the minerals in 76055, including plagioclase, pyroxene, olivine, armalcolite, iron metal, apatite, and whitlockite (Fig. 3). The compositions of the minerals appear to be similar to those of the big boulder at Station 6.

WHOLE-ROCK CHEMISTRY

Sample 76055 has a distinctly higher Mg content and higher Mg/Fe ratio than the samples of the boulder at Station 6. This was first noticed by the preliminary examination team (LSPET 1973) (Fig. 4). Palme et al. (1978) have studied 76055 for its siderophile signature (Table 1). The REE are significantly less than for the samples of the Station 6 Boulder, giving further evidence that this is a separate impact melt rock (Fig. 5).

SIGNIFICANT CLASTS

Albee et al. (1973) give a detailed description of an olivine-bearing, "pod" or "metaclastic" clast in a thin section of 76055,7. Chao (1973) has apparently also studied the same clast in thin section 76055,10, but terms it an "olivine micronorite hornfels." Warner et al. (1973) describe the same clast in section 76055,13 as an "angular poikilitic relic."

RADIOGENIC ISOTOPES

Huneke et al. (1973) determine the age of 76055 to be 3.97 ± 0.04 b.y. by the broad intermediate plateau in the ^{40}Ar -^{39}Ar release (Fig. 6). Turner et al. (1974) determine a plateau age of 3.98 ± 0.05 b.y. (Fig. 7). Both groups notice an unusual decrease in the apparent age at the highest temperature release. Kirsten et al. (1973) and Kirsten and Horn (1974) report a slightly older Ar plateau age of 4.05 ± 0.07 b.y. (Fig. 8), but this is within the precision of the others.

Nyquist et al. (1974) have reported Rb-Sr data for the matrix of 76055 (Table 2) and note that the Rb-Sr systematics are probably partially reset by the Serenitatus impact event.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Huneke et al. (1973) calculate an Ar exposure age of 140 m.y. from their data, Turner et al. (1974) report 125 m.y., and Kirsten et al. (1973) report 120 ± 15 m.y. This is much older than the exposure age of the big boulder (i.e., 22 m.y.).

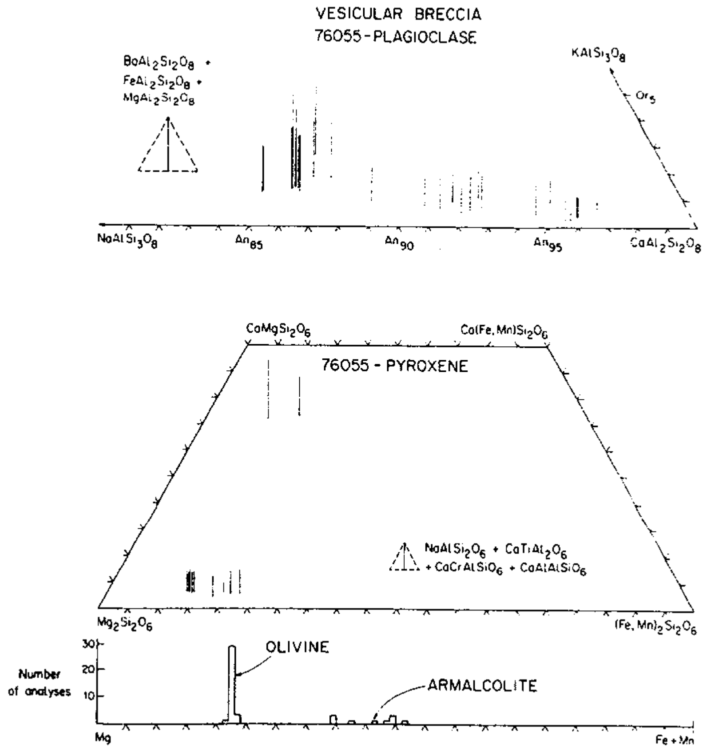


Figure 3: Mineral compositions of matrix to 76055. From Albee et al. (1973).

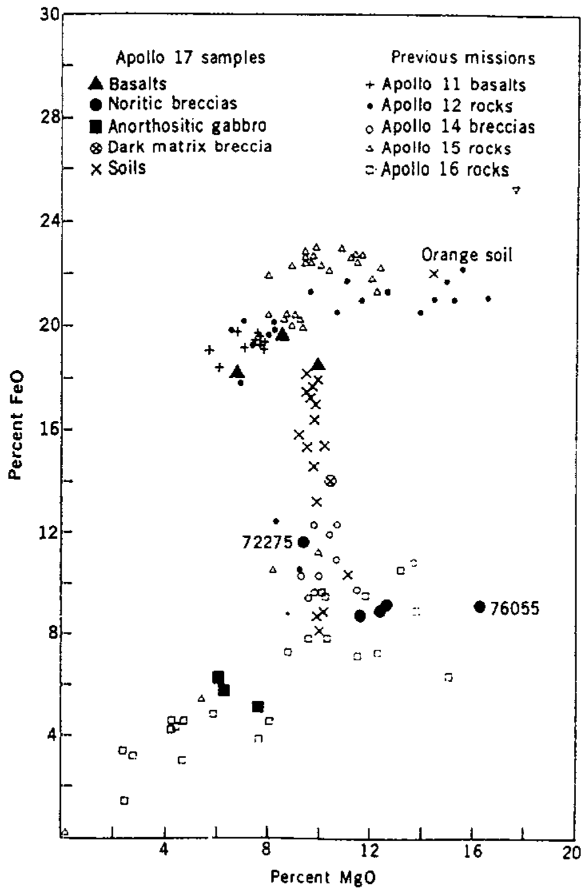


Figure 4: FeO vs. MgO composition of 76055. From LSPET (1973).

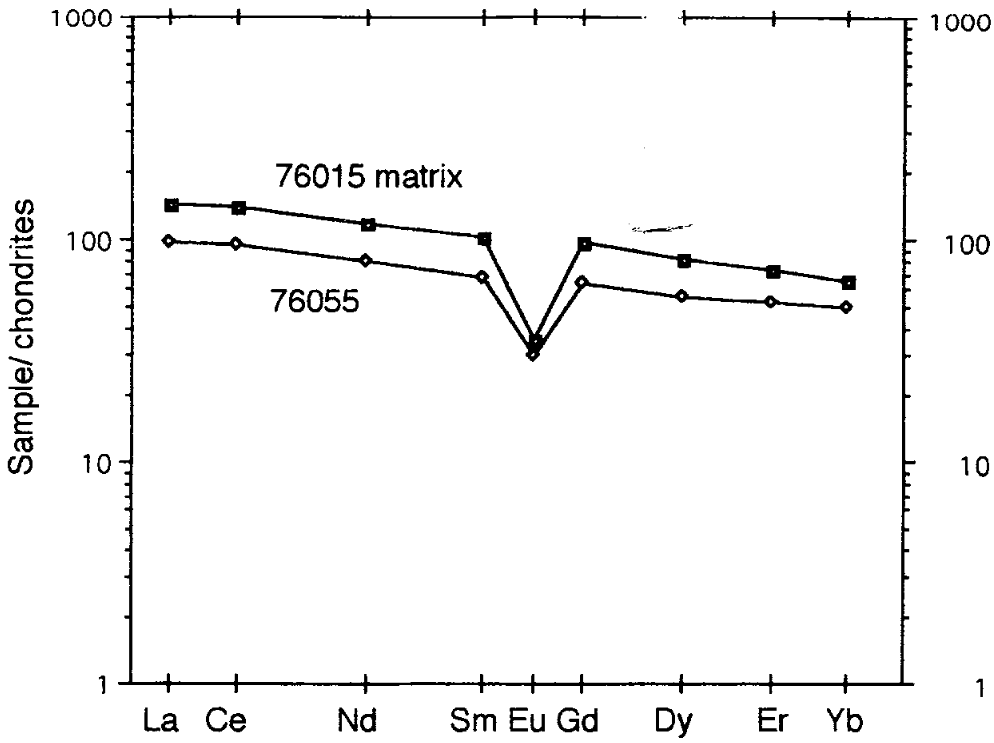


Figure 5: Normalized rare earth diagram of 76055 compared to matrix of Station 6 Boulder (76015). Data from Hubbard et al. (1974).

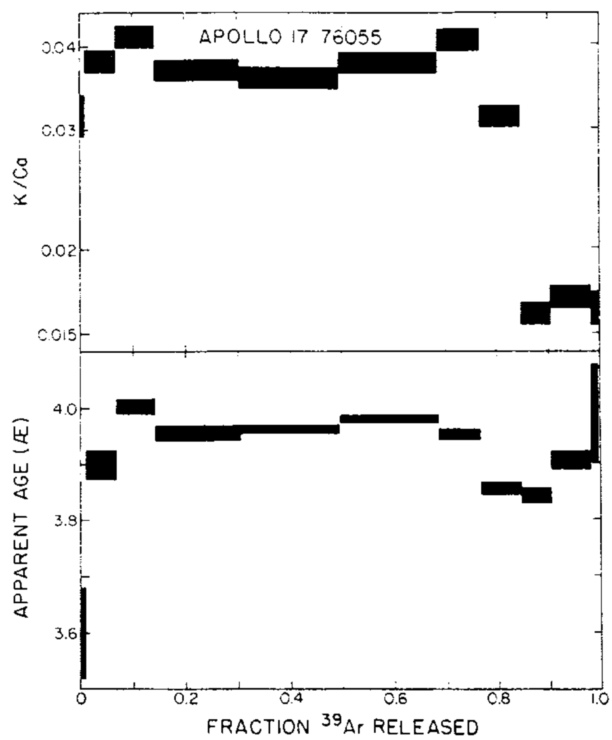


Figure 6: Argon plateau age for 76055 by Huneke et al. (1973).

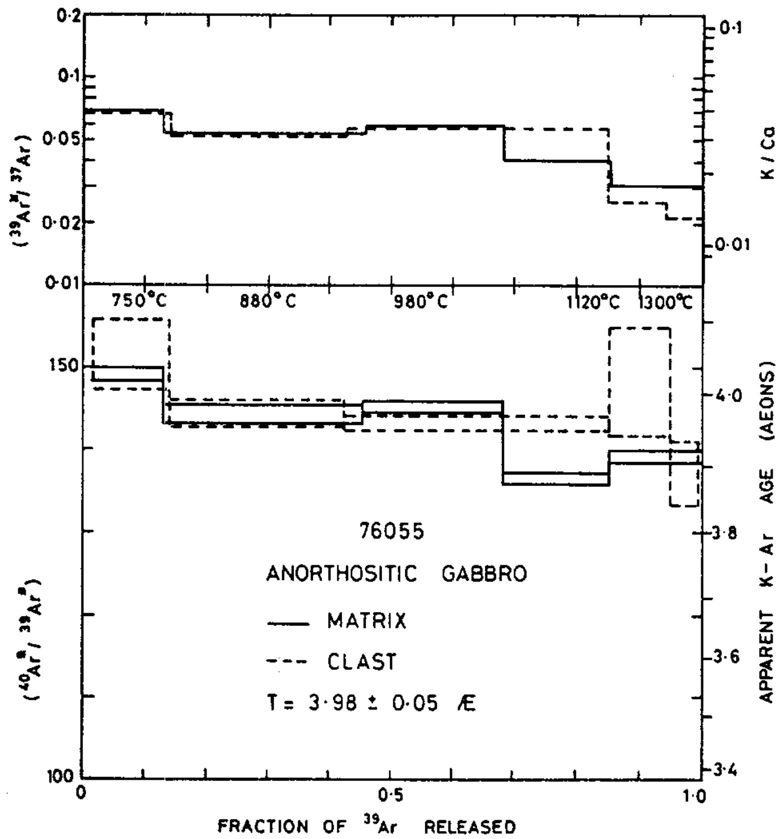


Figure 7: Argon plateau age of 76055 by Turner et al. (1974).

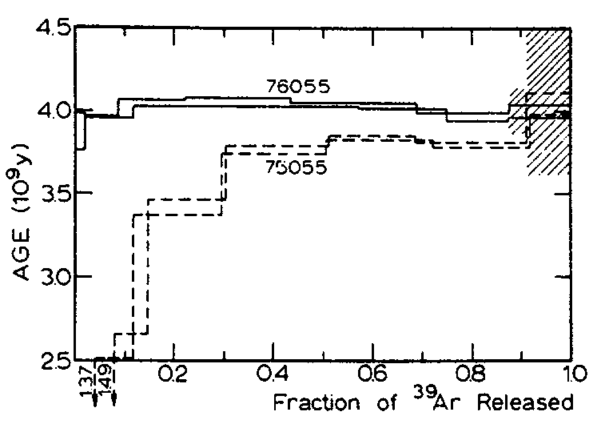


Figure 8: Argon plateau age of 76055 by Kirsten et al. (1973).

SURFACE STUDIES

Storzer et al. (1973) determined a mean galactic track density of 6.7 x 10^6 tracks/cm^2 for feldspar in 76055.

EXPERIMENTAL

Experimental studies by Delano (1977) showed that 76055 has olivine as its liquidus phase in the pressure range of 0 to 23 kbars. Olivine + orthopyroxene are simultaneously on the liquidus at 23 kbar. Orthopyroxene is the liquidus phase at pressures greater than 23 kbar (Fig. 9). Experimental phase relations of these experiments suggest that the 76055 composition does not represent magma derived by partial melting of either cosmic or differentiated source regions at any pressure on the Moon.

PROCESSING

The sample was sawn into three approximately equal chunks, but it was not slabbed.

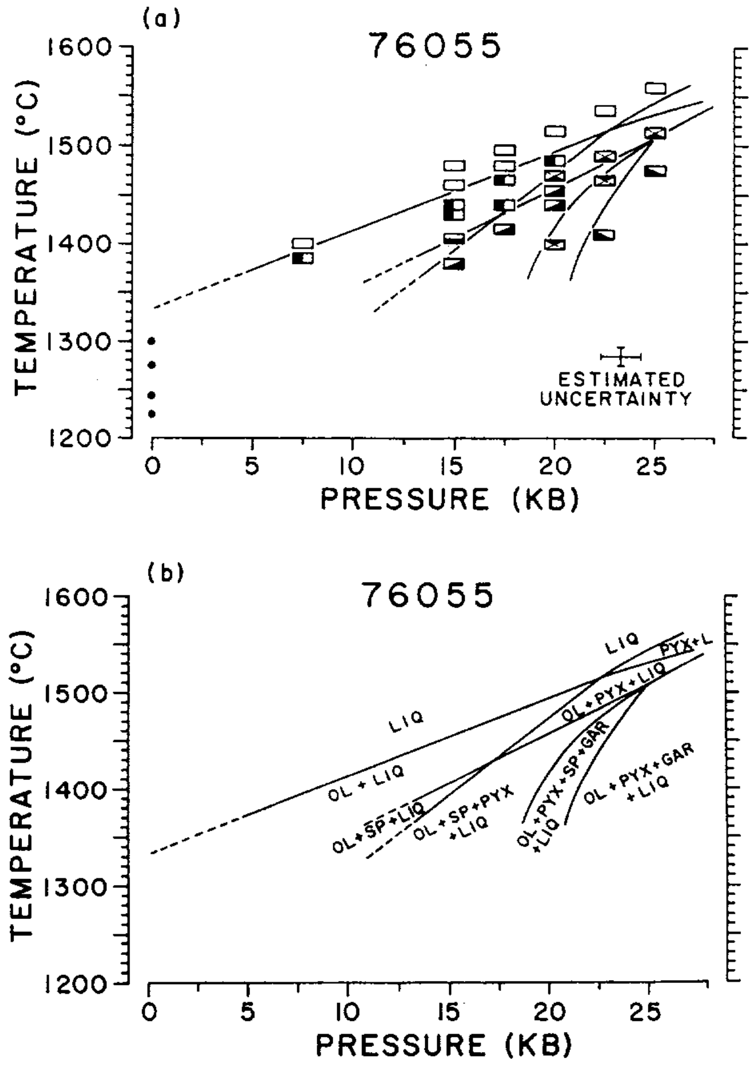


Figure 9: The melting relations of 76055 as a function of temperature and pressure. From Delano (1977).

Table 1: Whole-rock chemistry of 76055.
a) LSPET (1973); Hubbard et al. (1974); b) Nava (1974); Philpotts et al. (1974a); c) Palme et al. (1978)

Split Technique	,5 (a) XRF, IDMS	,3 (b) IDMS	,40 (c) XRF, INAA
SiO_2 (wt%)	44.65	45.7	45.60
TiO_2	1.24	1.38	1.28
Al_2O_3	16.47	15.84	15.91
Cr_2O_3	0.19	0.19	0.20
FeO	9.11	9.27	9.21
MnO	0.11	0.122	0.12
MgO	16.33	17.89	16.50
CaO	9.93	9.13	9.69
Na_2O	0.48	0.55	0.57
K_2O	0.20	0.223	0.18
P_2O_5	0.19	0.220	0.20
S	0.07		0.07
Nb (ppm)			24
Zr		399	345
Hf			8.78
Ta			1.24
U			0.88
Th			3.52
W			0.44
Y			84
Sr	156.6	154	158
Rb	5.17	5.0	5.62
Li		13.5	11.7
Ba	253	291	285
Cs			0.093
Zn			0.81
Pb			
Cu			2.98
Ni			490
Co			43.1
Sc			14.0
La	22.6		25.09
Ce	56.3	65.5	65.0
Nd	35.8	42.1	40
Sm	10.1	12.0	10.62
Eu	1.71	1.81	1.73
Gd	12.7	–	12.9

Table 1: (Concluded).

Split Technique	,5 (a) XRF, IDMS	,3 (b) IDMS	,40 (c) XRF, INAA
Tb			2.36
Dy	13.5	16.0	15.3
Er	8.18	9.66	9.31
Yb	7.64	8.84	8.72
Lu	–	1.37	1.21
Ga			3.55
F			38.9
Cl			1.7
Ge (ppb)			700
Ir			13
Au			7.2
Re			1.6

Table 2: Rb-Sr composition of 76055.
Data from Nyquist et al. (1974).

Sample	76055,5
wt (mg)	47.7
Rb (ppm)	5.17
Sr (ppm)	156.6
$^{87}Rb/^{86}Sr$	0.0955 ± 8
$^{87}Sr/^{86}Sr$	0.70511 ± 9
T_B	4.39 ± 0.11
T_L	4.44 ± 0.10

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

76135

Vesicular Poikilitic Impact Melt Breccia
133.5 g, 7 x 6 x 4 cm

INTRODUCTION

Sample 76135 was scooped from the soil next to turning point rock (LRV10)—the astronauts were attempting to get a piece of turning point rock by sampling the fillet next to it. Turning point rock is a boulder that rolled down from (or was blasted off of) North Massif. Chao et al. (1975) believe that 76135 may be similar to 76055, but it is lighter in color and more vesicular.

PETROGRAPHY

Sample 76135 is a vesicular, clast-bearing, poikilitic impact melt breccia (Fig. 1). It has two populations of vesicles, large (1 cm) and small (>1 mm). Both show "frosted" crystalline interiors. These crystal-lined interiors deserve SEM study. The poikilitic matrix includes many small mineral clasts (Fig. 2).

There are no other studies of 76135 reported to date.

There are only three thin sections of 76135.

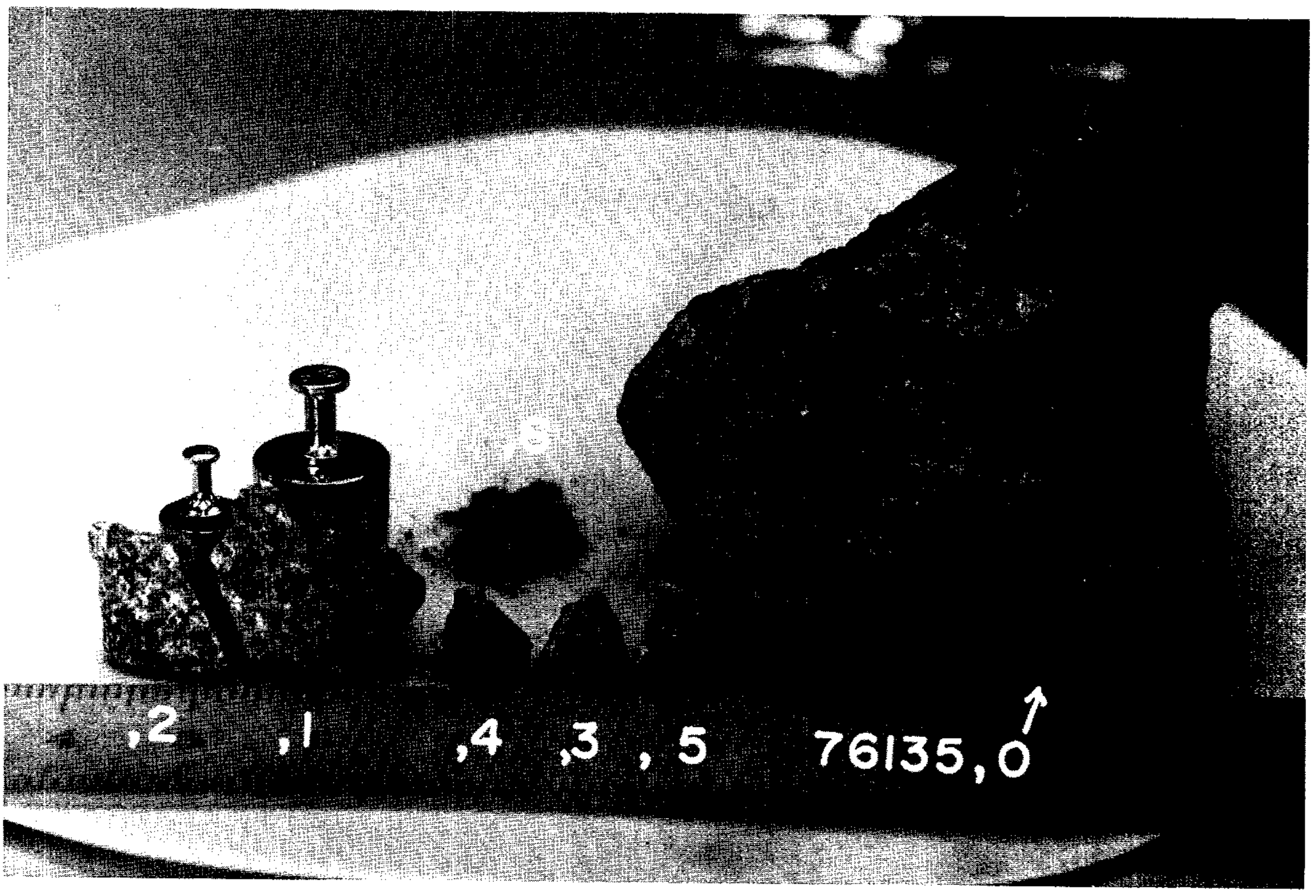


Figure 1: Vesicular poikilitic impact melt breccia 76135. Scale is 1 cm. S74-25040.

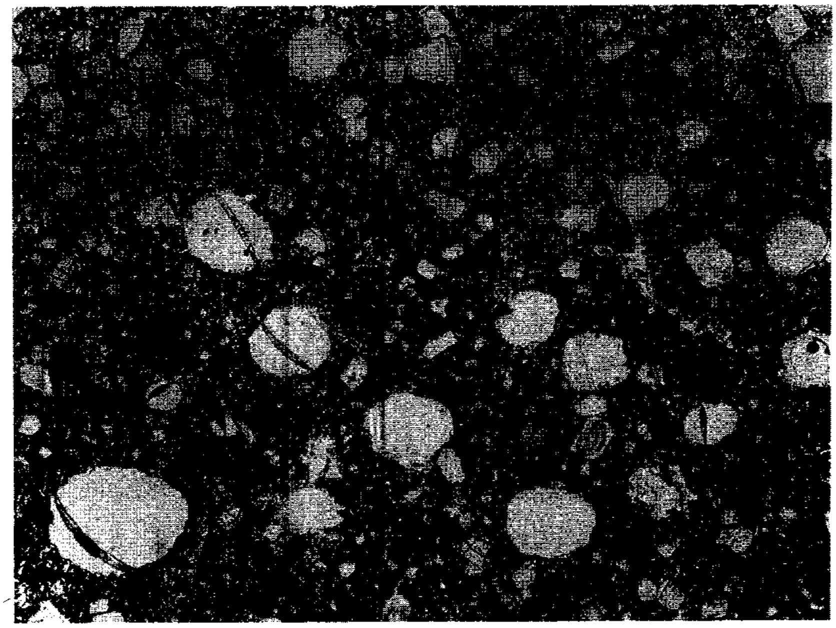


Figure 2: Photomicrograph of the poikilitic texture of 76135. Scale is 4 x 5 mm.

76136
High-Ti Mare Basalt
86.6 g, 6 x 4 x 3 cm

INTRODUCTION

The top of this rock is covered with many large (~0.5 mm) micro-meteorite pits lined with grey glass (Fig. 1). Several large crystal-lined cavities occur in this basalt. This rock is a typical Apollo 17 basalt fragment.

PETROGRAPHY

Sample 76136 consists of large, randomly-oriented ilmenite plates in a fine-grained holocrystalline matrix with ~6% equant olivine rimmed by blocky pyroxene. The pyroxene-plagioclase matrix varies from crudely variolitic (or sheath-like) to intersertal in texture (Fig. 2).

Brown et al. (1975) report the mineral mode of 76136 to be 15% plagioclase, 46% clinopyroxene, 6% olivine, 31% opaques, and 1.5% silica.

WHOLE-ROCK CHEMISTRY

Rhodes et al. (1976a) define three self-consistent basalt types at Apollo 17 on the basis of fine-grained, rapidly chilled samples. The chemical variation within each group is attributed to moderate amounts (5-20%) of crystal fractionation dominated by removal of olivine, armalcolite/ilmenite, and chrome spinel. Table 1 gives the composition, and Fig. 3 compares the REE content of 76136 with the soil and the boulder.

RADIOGENIC ISOTOPES

Nyquist et al. (1976) report whole-rock Rb-Sr data (Table 2).

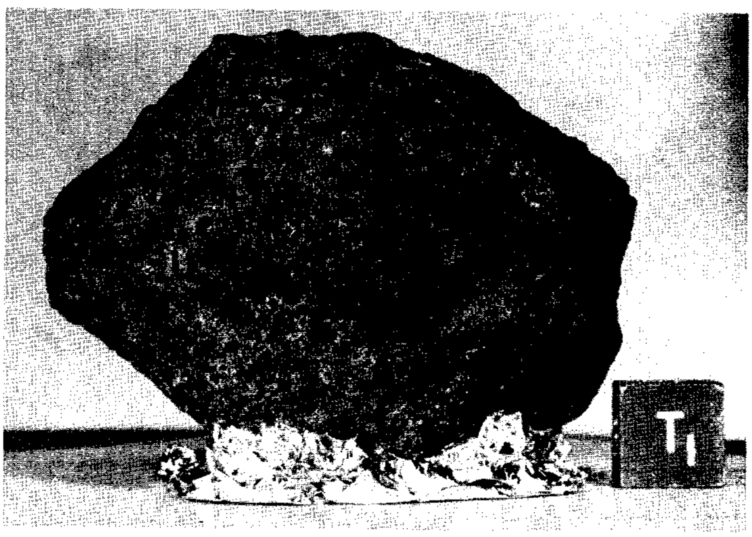


Figure 1: Micrometeorite craters on surface of 76136, ilmenite basalt. S73-23931.

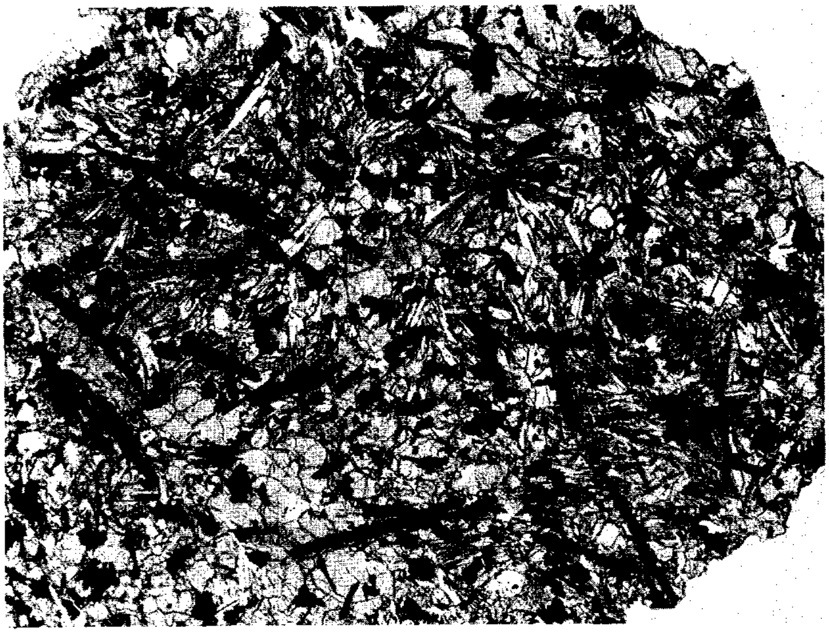


Figure 2: Photomicrograph of texture of 76136 basalt. Field of view is 4 x 5 mm.

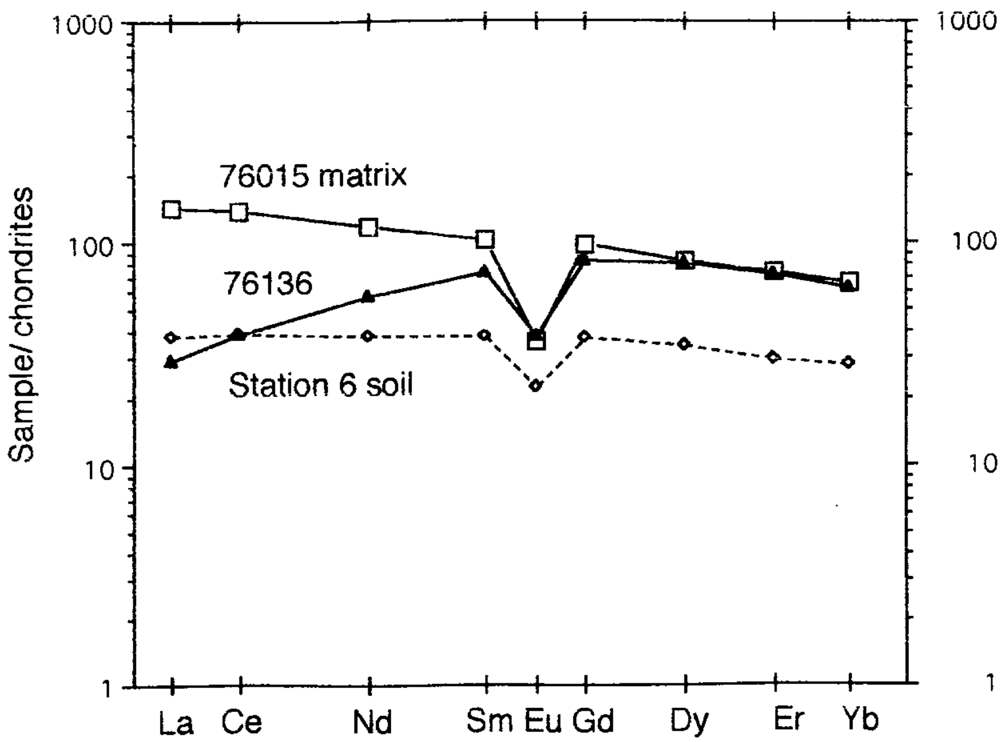


Figure 3: Normalized rare earth element composition of 76136 compared with soil and boulder at Station 6.

Table 1: Whole-rock chemistry of 76136.
From Rhodes et al. (1976a).

Split Technique	,8 XRF, ID, *INAA*	Split Technique	,8 XRF, ID, *INAA*
SiO_2 (wt%)	38.60	Li	8.9
TiO_2	12.64	Ba	83.7
Al_2O_3	8.65	Ni	
Cr_2O_3	0.44	Co	*18.7*
FeO	19.12	Sc	*82*
MnO	0.28	La	6.91
MgO	8.61	Ce	23.8
CaO	10.53	Nd	26.2
Na_2O	0.38	Sm	10.9
K_2O	0.06	Eu	2.14
P_2O_5	0.06	Gd	16.4
S	0.18	Tb	
Nb (ppm)		Dy	19.3
Zr		Er	11.4
Hf	*9.4*	Yb	10.2
Sr	190	Lu	*1.42*
Rb	0.67		

Table 2: Rb-Sr composition of 76136.
Data from Nyquist et al. (1976).

Sample	76136,8
wt (mg)	60
Rb (ppm)	0.665
Sr (ppm)	190
$^{87}Rb/^{86}Sr$	0.0101 ± 2
$^{87}Sr/^{86}Sr$	0.69974 ± 4
T_B	4.42 ± 0.36
T_L	4.89 ± 0.36

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

76137

Poikilitic Impact Melt Breccia
2.46 g, 1 x 1.5 x 1.8 cm

INTRODUCTION

Sample 76137 is apparently the same lithology as 76135. It was scooped from the soil next to turning point rock (LRV10)—the astronauts were attempting to get a piece of turning point rock by sampling the fillet next to it. Turning point rock is a boulder that rolled down from (or was blasted off of) North Massif.

Sample 76137 is a light-colored impact melt breccia (Fig. 1). It has not been studied.

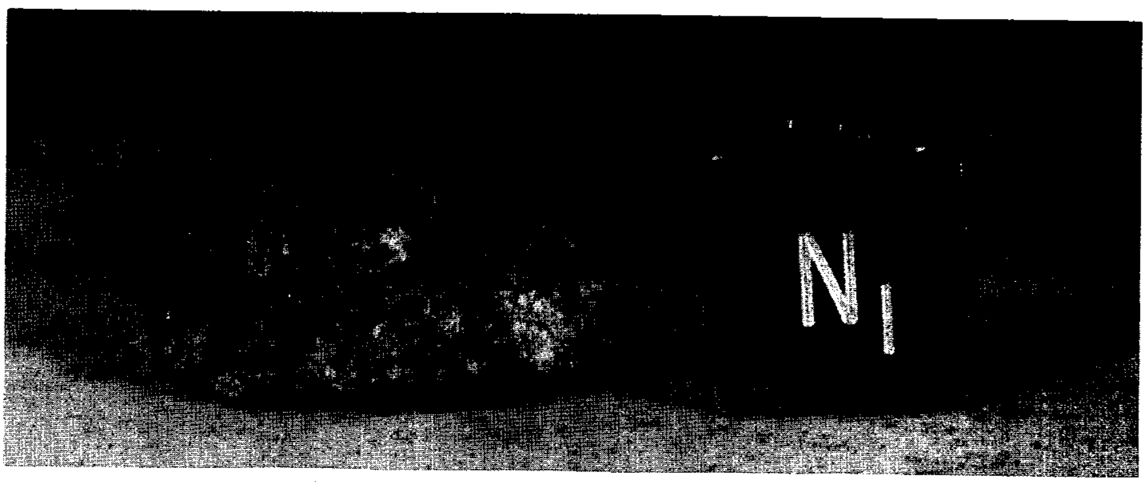


Figure 1: Poikilitic impact melt breccia 76137. Cube is 1 cm. S73-21762.

76215
Vesicular Micropoikilitic Impact Melt Breccia
644 g, 10.5 x 8 x 6 cm

INTRODUCTION

Breccia sample 76215 was collected from the lunar surface next to the large Station 6 Boulder, but it was most certainly spalled from the top surface of Block 4 of Boulder 6 (Wolfe and others, 1981), where there is a fresh mark that fits the sample directly above the location of the sample on the soil (Fig. 1). Sample 76215 is from the same lithologic unit B as sample 76015 (Heiken et al., 1974) and has the same overall color (green-grey) and vesicular texture.

As in the case of 76015, 76215 has an apparently shielded interior surface of a large cavity (this may be why these samples broke off of the boulder). One surface of this sample was the interior surface of a large cavity (vesicle?). The "lip" of this cavity has a thick, undisturbed patina (Fig. 2). The thickness of the patina in this cavity is gradational from the "lip" to the shielded interior (at the bottom of the photo).

Spudis and Ryder (1981) summarize the arguments that Boulder 6 is from the melt sheet or ejecta blanket from the Serenitatus impact event. Simonds et al. (1976) and Onorato et al. (1976) provide a comprehensive thermal model for the lithification of impact melt breccias based on their detailed study of the textures of samples from Boulder 6.

PETROGRAPHY

Sample 76215 is a vesicular, crystalline matrix breccia with a crude macroscopic foliation defined by the alignment of vesicles and cavities, including the roughly flat side of a large cavity that defines one side of the sample (Fig. 2). The sample has two distinctive matrix textures that differ only slightly in modal mineralogy—both are 50% plagioclase, 30% pigeonite, 4-11% augite, 7-14% olivine, and 2% ilmenite (Simonds, 1975). Most of

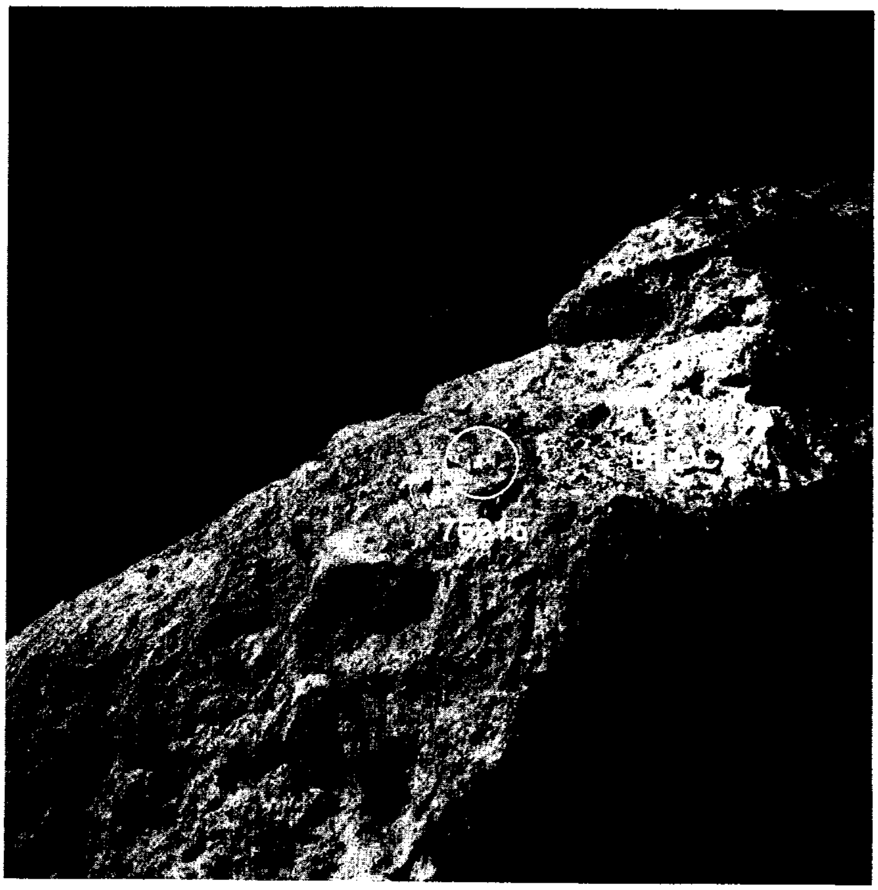


Figure 1: Photograph of the top of Block 4 where 76215 was originally located. Sample was picked from the soil directly beneath this point and was clearly broken from this spalled area on the top of the block. AS17-140-21421.

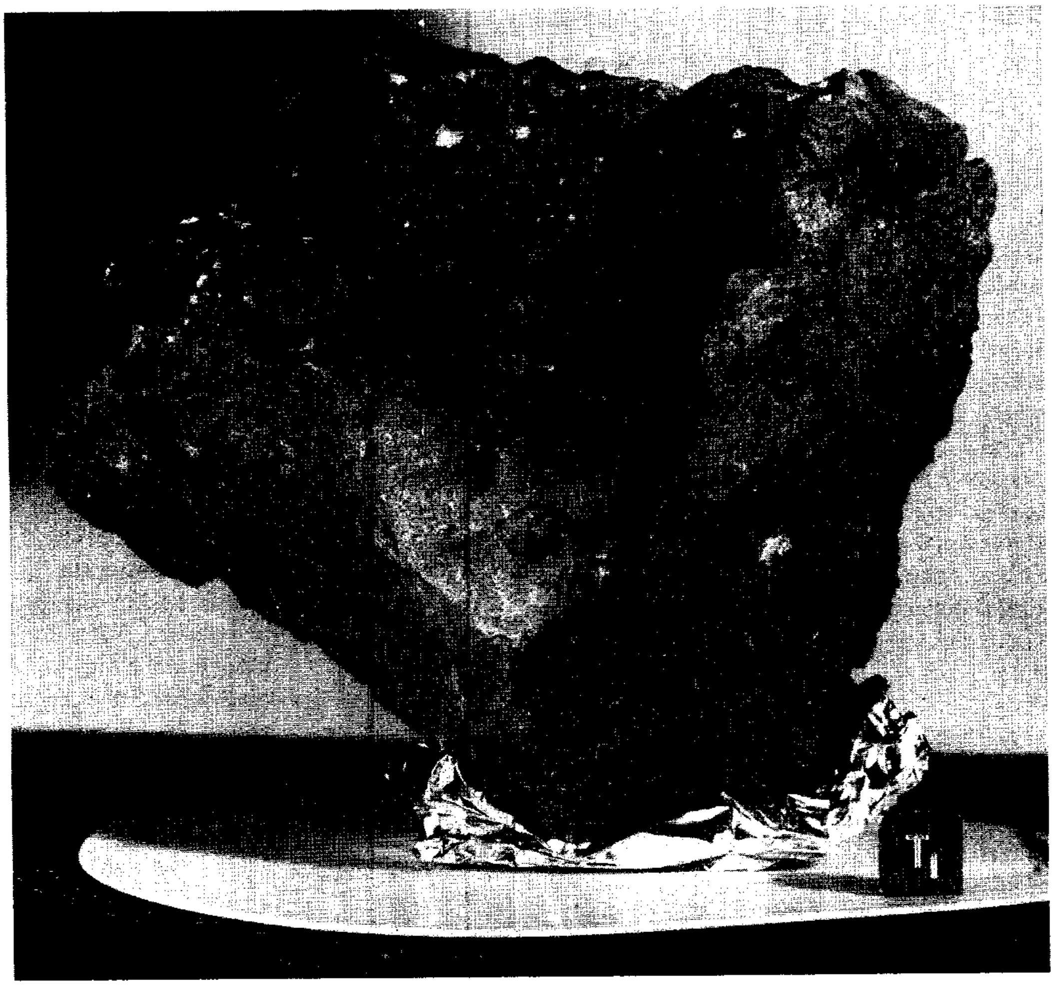


Figure 2: Sample 76215, showing the patina-covered surface of the interior vug. Sample 76215 is a poikilitic impact melt breccia with vesicles. S72-56373.

the sample has a clast-laden, poikilitic texture that is similar to the other Apollo 16 and 17 impact melt rocks. However, this sample also has regions with ophitic textures similar to basaltic sample 14310 (Fig. 3). The contact between the regions with this change in texture is reported to be distinct, but the ophitic areas are very irregular in outline and lack evidence of reaction. Simonds argues that one is not a clast in the other.

Simonds (1975) describes the poikilitic areas as a "continuous network of pigeonite and subordinate augite oikocrysts (0.5 to 2 mm) enclosing a myriad of evenly distributed, tiny (10-30 μm) tabular feldspar grains." Olivine occurs both as irregular chadocrysts within pyroxene and as granular grains between oikocrysts. Fig. 4 compares the compositions of pyroxene, olivine, and plagioclase in the ophitic matrix with those of the poikilitic matrix (Simonds, 1975). The region with ophitic texture is an intergrowth of subhedral pyroxene (0.2 to 0.8 mm) and euhedral plagioclase (0.2 to 0.35 mm). Plagioclase clasts in the ophitic regions have overgrowths up to 30 μm wide. Olivine is the only mafic clast in the ophitic regions. The coarser cavities appear to be vesicles that were trapped when the rock crystallized. The smaller cavities are vug that may have been made by gas that was exsolved as the rock crystallized.

The poikilitic region contains cm-size clasts of anorthosite displaying polygonal feldspar grains up to 2 mm across—some with a granulitic texture with 120 deg triple junctions (Fig. 5).

Misra et al. (1976) have studied the complex metallic nickel-iron particles included in 76215 and other samples of the Station 6 Boulder.

Figure 3: Photomicrograph of the texture of the matrix of 76215. Note the large vesicle and the regions of ophitic texture within the overall poikilitic matrix. Field of view is 4 x 5 mm.

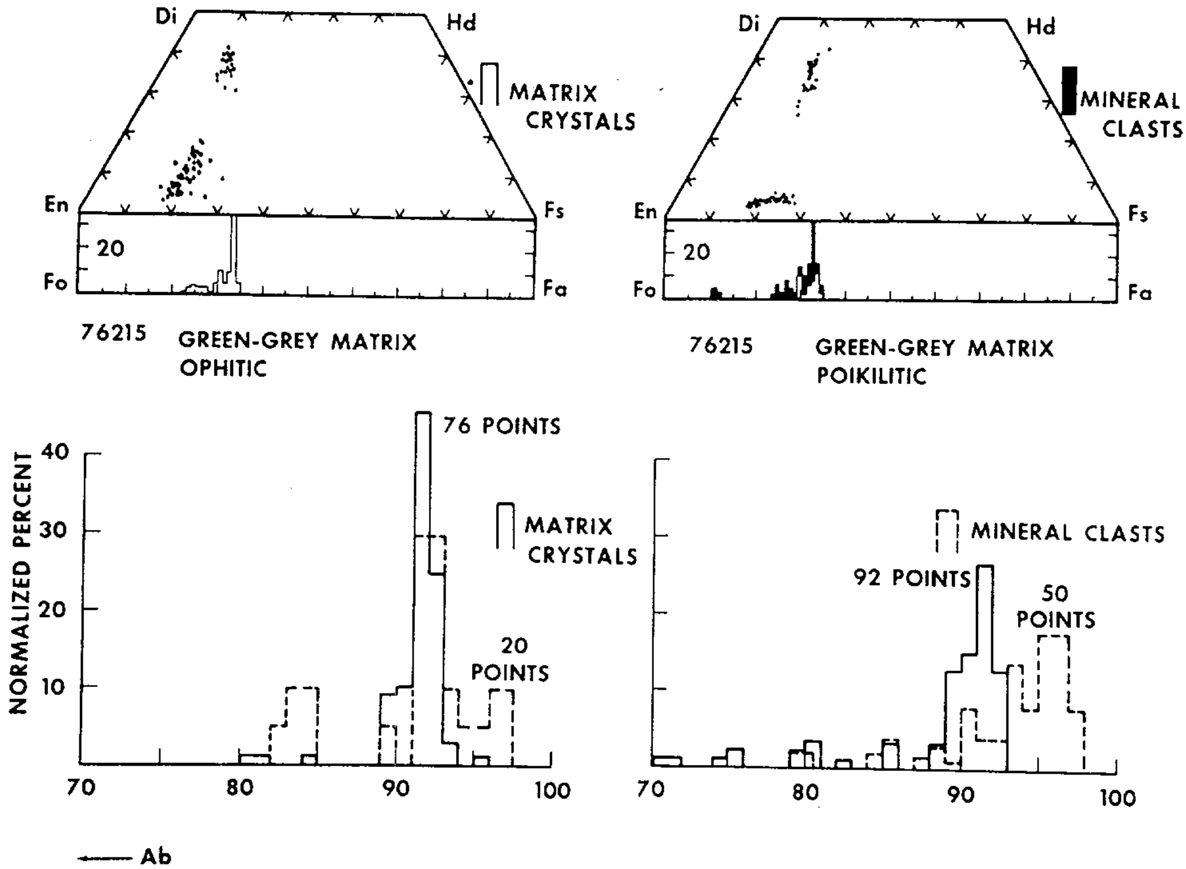


Figure 4: Pyroxene, olivine, and plagioclase compositions in two regions of matrix of 76215 (from Simonds, 1975). Plagioclase clasts are more calcic than plagioclase laths in the matrix.

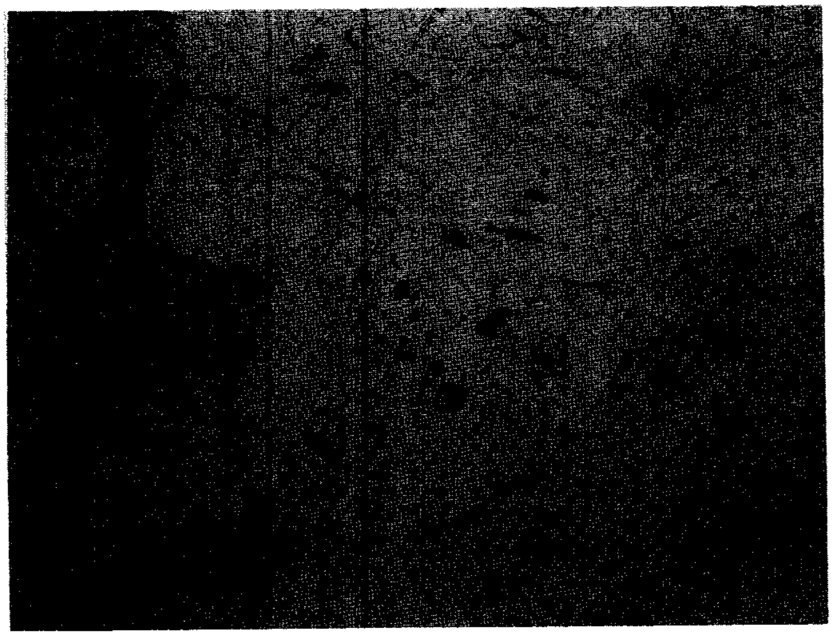


Figure 5: Photomicrograph of large (0.5 cm) clast of anorthosite in 76215,70. Field of view is 4 x 5 mm.

WHOLE-ROCK CHEMISTRY

The matrix of 76215 is very homogeneous in composition (Table 1), and the composition is also very similar to that of the other samples of this boulder (Fig. 6). Higuchi and Morgan (1975) find that the trace siderophile element compositions of all the samples of the Station 6 Boulder form a tight grouping (meteorite group 2) on compositional diagrams (Fig. 7). 76015 and 76215 have a lower abundance of these meteoritic elements than the matrix for 76275 and 76295 (Table 2).

RADIOGENIC ISOTOPES

Cadogan and Turner (1976) determined the crystallization age of 76215 by the ^{39}Ar-^{40}Ar plateau technique (Fig. 8). The matrix yielded an intermediate temperature plateau which covered 65% of the release of ^{39}Ar and corresponded to an age of 3.94 ± 0.04 b.y.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Some of the Apollo 17 samples (including 76215) provided a unique opportunity to study the energy spectrum (and potential angular anisotropy) of the incident proton flux from the August 1972 solar flare (Rancitelli et al., 1974; Keith et al., 1974). Table 3 compares the induced activity of 76215 with other samples of the boulder.

Bogard et al. (1974) (see unpublished data in Phinney, 1981) have determined the noble gas abundances in 76215.

MAGNETIC STUDIES

Gose et al. (1978) have carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder. The direction of magnetization of clast-free samples from unit B (including 76215) cluster fairly well after alternating field demagnetization. Gose et al. propose that the natural remanent magnetization of impact melt breccias is the vector sum of two magnetizations, a pre-impact magnetization, and a partial thermoremanence acquired during breccia lithification. Brecher (1976) is convinced that alignment of magnetism follows the direction of foliation and is caused by "textural remanent magnetization."

SURFACE STUDIES

A large part of one surface of 76215 was apparently the interior surface of a large vug or cavity in the boulder (Fig. 2). Part of this shielded surface has a patina indicating that a portion of the vug or cavity was open to the sky, but there is a nice gradation of patina along the vug surface with apparent depth into the original vug opening, as though there had been shielding from the sky. The thick

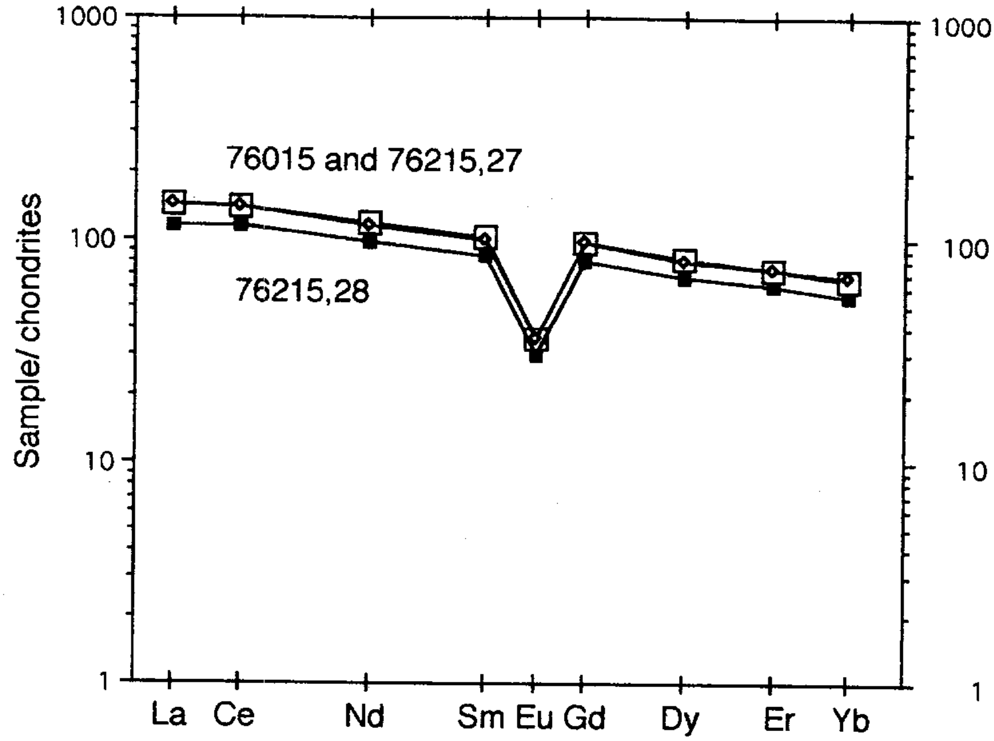


Figure 6: Normalized rare earth diagram. The matrix of 76215 has the same composition as that of 76015. Data from Simonds (1975).

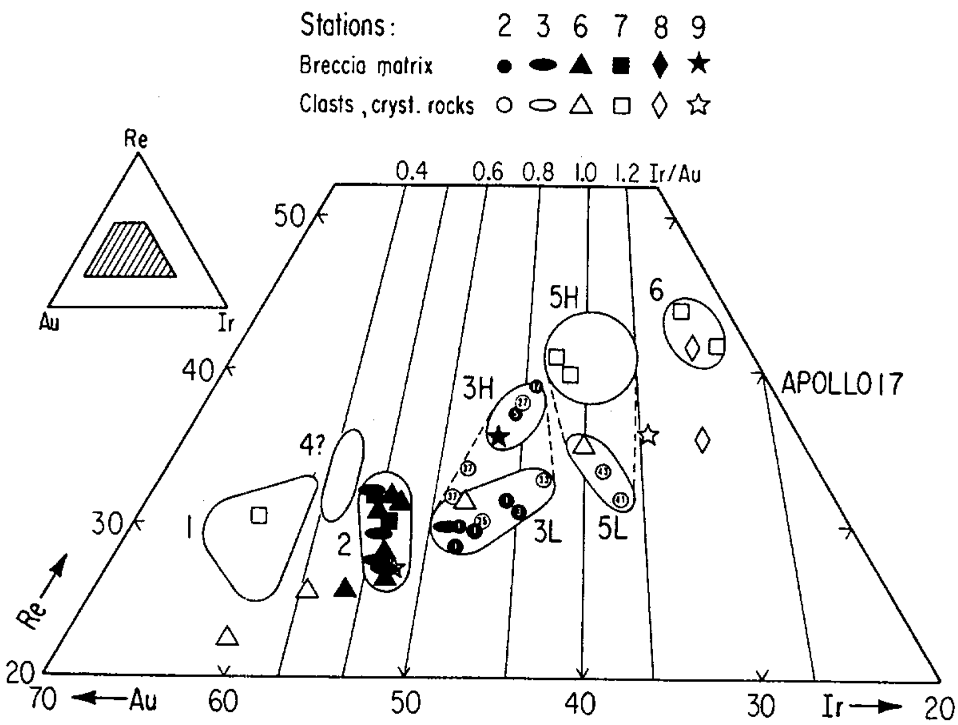


Figure 7: Diagram comparing the Ir-Au-Re compositions of 76215 with those of other lunar samples. From Higuchi and Morgan (1975).

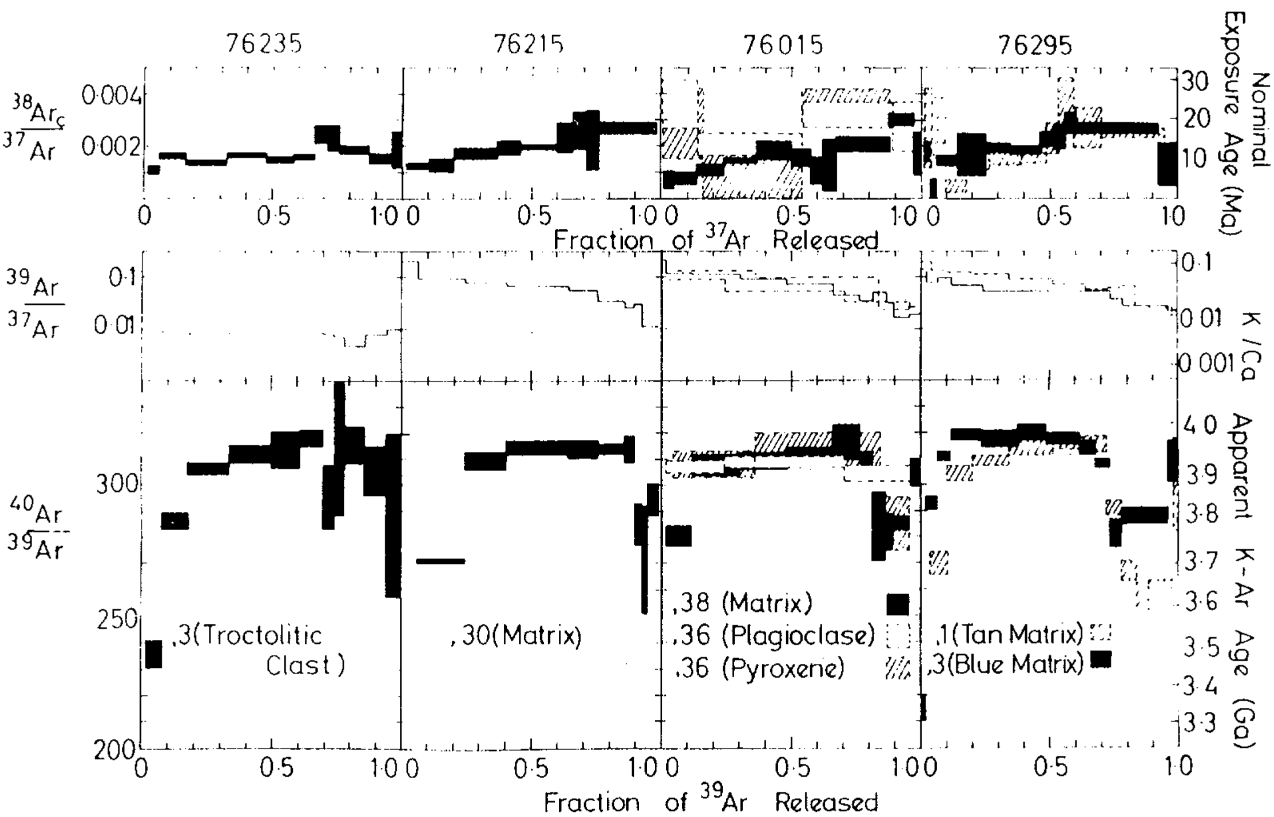


Figure 8: Argon release diagram for 76215. From Cadogan and Turner (1976).

deposit is made of accumulated glass splashes, pancakes, and presumably condensed vapor that may have come from the opposite face of the cavity.

Morrison and Zinner (1977) have studied the solar flare tracks and micrometeorite craters on a single crystal of anorthite from 76215. They determined a solar flare track age of 1.6 x 10^4 years in agreement with the Mg and Fe exposure ages of 2.1 and 2.4 x 10^4 years as determined by ion microprobe analysis (Zinner et al., 1977) of implanted solar wind. The solar flare tracks extend to a depth of about 80 microns where the background of cosmic ray tracks becomes noticeable (Fig. 9).

Morrison and Zinner (1977) have also reported the distribution of small micrometeorite craters on the surface of 76215 (Fig. 10). Measurements by Hutcheon (1975) on the production rate of micron-sized craters on the lunar surface disagree with the finding of Morrison and Zinner (1975) by a factor of approximately 50. According to Zinner and Morrison (1976), this disagreement cannot be due to experimental technique or assumptions, but might be due to sampling difficulties.

Samples of 76215 and other vesicular breccias at this site are suitable for studies of the interior surfaces of cavities. Goldberg et al. (1975) have studied the surface coating of F on the exteriors and interiors of vugs in 76215. Carter et al. (1975) have studied the euhedral crystals of pyroxene, plagioclase, ilmenite, metallic iron, and troilite that line the vugs of 76215.

PROCESSING

A slab and a column were cut from this rock (see lithology maps and diagrams in Phinney, 1981).

The largest remaining piece of 76215 weighs 308 g. There are 19 thin sections.

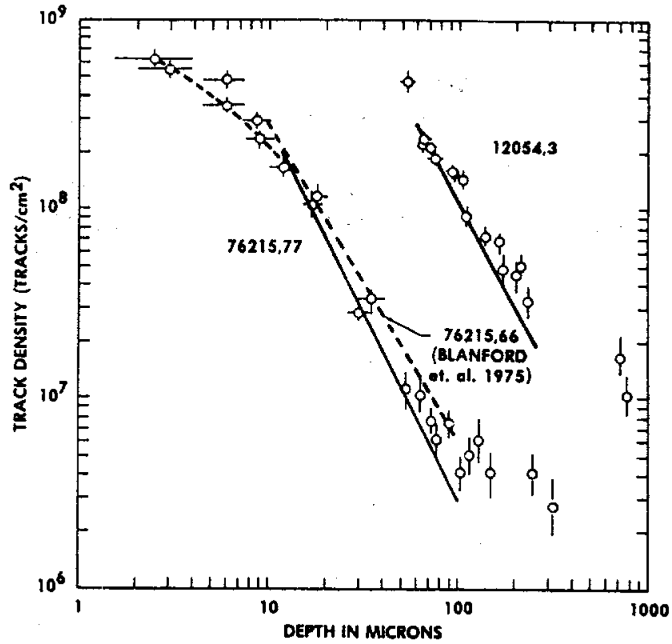


Figure 9: Track density vs. depth profiles for 76215. From Morrison and Zinner (1977).

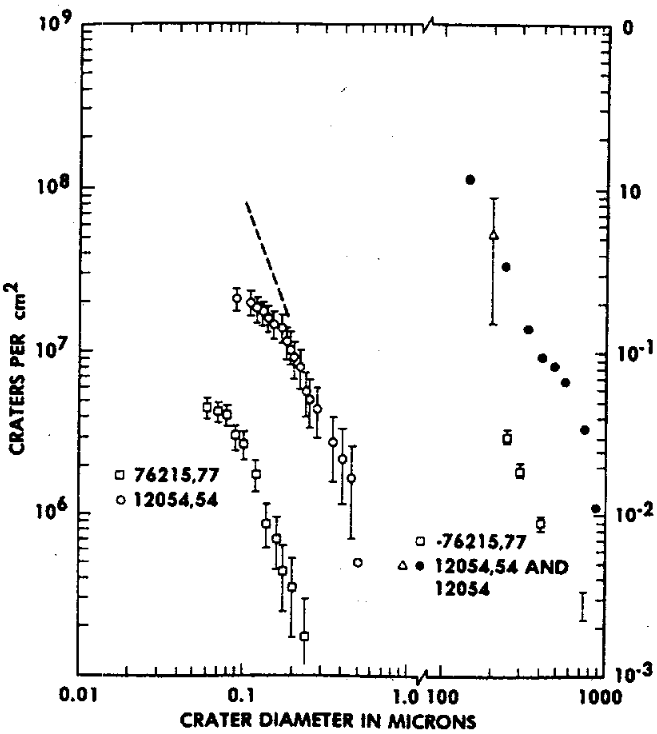


Figure 10: Crater densities for 76215. From Morrison and Zinner (1977).

Table 1: Whole-rock chemistry of 76215.
Simonds (1975); Wiesmann and Hubbard (1975); Phinney (1981)

Split Technique	,27M XRF, IDMS	,28M XRF, IDMS
SiO_2 (wt%)	46.02	46.13
TiO_2	1.52	1.24
Al_2O_3	17.83	18.73
Cr_2O_3	–	–
FeO	8.70	8.08
MnO	na	0.06
MgO	12.21	12.43
CaO	11.10	11.50
Na_2O	na	0.70
K_2O	0.27	0.25
P_2O_5	0.28	0.24
S	0.05	0.06
Nb (ppm)		
Zr	495	459
Hf	–	–
U	1.5	1.26
Th	5.20	4.61
Sr	–	–
Rb	6.89	6.10
Li	19.6	22.6
Ba	352	294
La	33.4	27.3
Ce	83.6	68.9
Nd	52.2	43.7
Sm	14.9	12.3
Eu	1.99	1.70
Gd	19.3	15.9
Tb		
Dy	19.7	16.5
Er	11.8	9.9
Yb	10.9	9.0
Lu	–	–

Table 2: Trace element data for 76215. Concentrations in ppb.
From Higuchi and Morgan (1975).

	Sample 76215,48 matrix		Sample 76215,48 matrix
Ir	0.829	Ag	0.87
Os		Br	50.5
Re	0.07	In	
Au	0.526	Bi	0.34
Pd		Zn (ppm)	2.5
Ni (ppm)	54	Cd	1.08
Sb	0.44	Tl	0.63
Ge	31.5	Rb (ppm)	2.51
Se	60	Cs	188
Te	3.6	U	1120

Table 3: Solar flare induced activity from large solar flare, August 1972.
a) Keith et al., (1974); b) Rancitelli et al., (1974); c) O'Kelley et al., (1974)

	Sample 76215 (a)	Sample 76255 (b)	Sample 76275 (b)	Sample 76295 (b)	Sample 76295 (c)
dpm/Kg					
^{26}Al	56 ± 3	79 ± 4	110 ± 3	71 ± 4	67 ± 5
^{22}Na	60 ± 4	71 ± 4	100 ± 3	64 ± 3	54 ± 4
^{54}Mn	22 ± 17	38 ± 9	103 ± 20	69 ± 26	38 ± 15
^{56}Co	45 ± 6	37 ± 4	86 ± 9	35 ± 5	41 ± 7
^{46}Sc	5 ± 3	3.9 ± 1.2	7 ± 2	6.4 ± 2.6	5 ± 2
^{48}V					
Natural activity					
Th (ppm)	4.6	2.33	5.69	5.76	
U (ppm)	1.27	.58	1.40	1.55	
K (ppm)		2900	2250	2300	

76235
Feldspathic Granulitic Impactite
26.56 g, 5 x 3 x 2 cm

INTRODUCTION

Several fragments, all with the same unique lithology, were chipped from the same clast on Block 1 of the Station 6 Boulder (Fig. 1). They may have broken further in the sample bag. These include samples numbered 76230, 76235, 236, 237, 238, 239, 305, 306, and 307 (Heiken et al., 1973; Phinney, 1981). Most of these fragments have a thin brown patina with many micrometeorite craters. However, 76235 and 76305 lack patina or pitted surfaces.

This light-colored sample of dense, feldspathic, granulitic impactite (Fig. 2) appears to be uniform in texture and homogeneous in composition on a scale of 1 cm. On the moon, Schmitt called the texture "aplitic."

PETROGRAPHY

Sample 76235 is from a large (0.8 m) feldspathic clast in the Station 6 Boulder. All of the pieces have the same texture and lithology. The mineralogical mode of 76235 is 70% plagioclase (An_{94-95}), 20% pigeonite ($Wo_4En_{74}Fs_{22}$), and 10% olivine (Fo_{73}) (Simonds, 1975). The equant feldspar have seriate grain-size distribution ranging from 20 to 600 μm, but, according to Simonds (1975), lack the polygonal texture of a well-annealed rock (Fig. 3). Rounded mafic inclusions up to 30 μm across occur in the larger feldspars. The compositions of minerals are very homogeneous (Fig. 4). Necklaces of inclusions, indicating overgrowth, are missing in this rock. Opaques include minute iron, troilite, and chromite. Ilmenite only occurs as lamellae in chromite.

Warner et al. (1977) describe the texture of 76235 as poikoblastic and suggest that rounded plagioclase regions about 1 mm across are

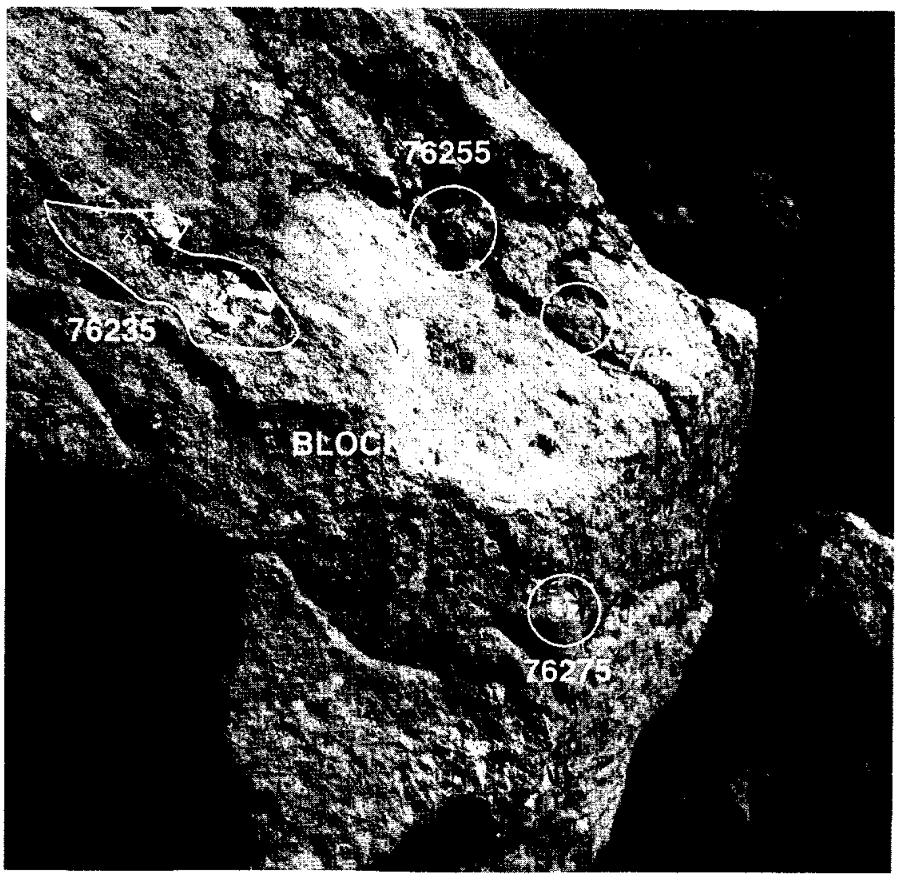


Figure 1: Surface of Block 1 of the big boulder at Station 6, showing numerous large clasts (see section on boulder, page 5). Sample 76235 and related pieces were chipped from large clast in boulder (see Wolfe and others, 1981). AS17-140-21443.

Figure 2: Light-colored, feldspathic, granulitic impactite 76235. Cube is 1 cm. S73-16733.

megacrysts of anorthosite. These regions of apparent anorthosite are the only evidence that the rock may be polymict in origin since the mineral composition has been homogenized (however, see siderophiles below). Warner et al. and others group this rock with feldspathic, granulitic impactites.

WHOLE-ROCK CHEMISTRY

The chemical analysis of 76230 (Table 1) reported by LSPET (1973) and Hubbard et al. (1974) is of the same rock material as 76235 (Fig. 5). Higuchi and Morgan (1975) report a very high meteoritic (5%) component in this clast (Table 2).

RADIOGENIC ISOTOPES

Cadogan and Turner (1976) determined the crystallization age of two samples of the 76235 clast by the ^{39}Ar-^{40}Ar plateau technique (Figs. 6 and 7). This feldspathic clast yielded plateau ages of 3.93 ± 0.06 b.y. and 3.95 ± 0.06 b.y. over 80% of the gas release curve. This is the same age as the breccia matrix surrounding this clast in the boulder.

Rb-Sr isotopic data (Table 3) by Nyquist et al. (1975) show that 76230 (same as 76235) is not equilibrated with the matrix of the Station 6 Boulder (Fig. 8).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Bogard et al. (1974) (see unpublished data in Phinney, 1981) have determined the noble gas abundances in 76235.

MAGNETIC STUDIES

The magnetization of sample 76307 (same as 76235) has been studied by Gose et al. (1978).

There are only three thin sections of 76235.

Figure 3: Photomicrograph of thin section 76235,19. Relict clastic texture has been annealed. Poikilitic pyroxene includes plagioclase and olivine inclusions. Field of view is 4 x 5 mm.

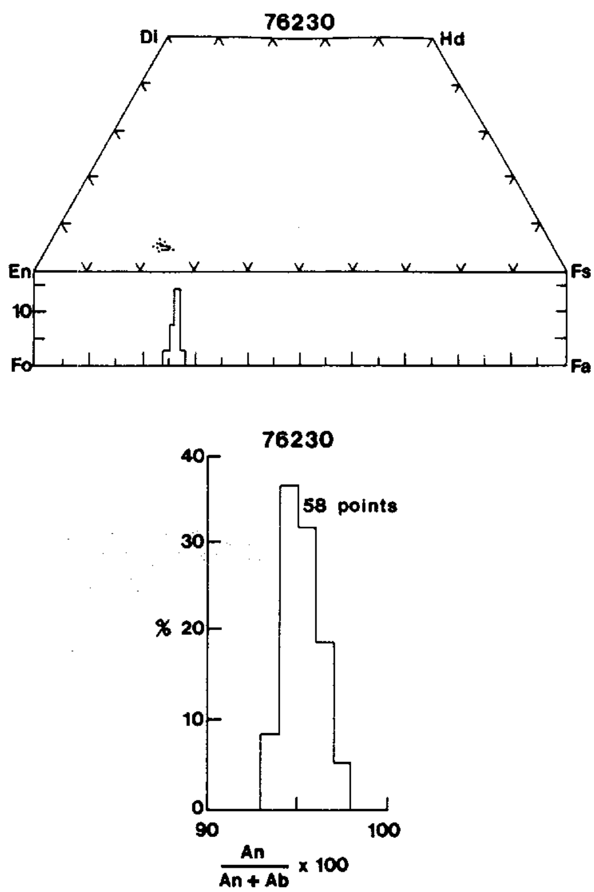


Figure 4: Pyroxene, olivine, and plagioclase composition diagram for 76230, which is a chip of 76235. The minerals are homogeneous in this rock (see Simonds, 1975).

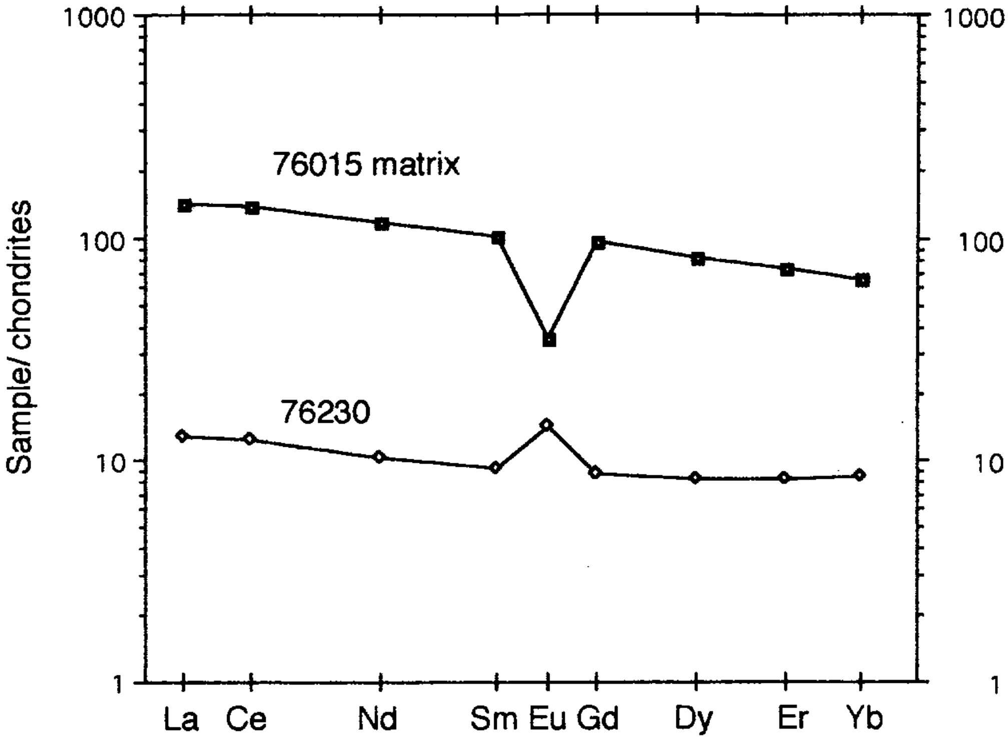


Figure 5: Normalized rare earth element abundances for 76230 (76235) compared to the boulder matrix (76015). Data are from Hubbard et al. (1975).

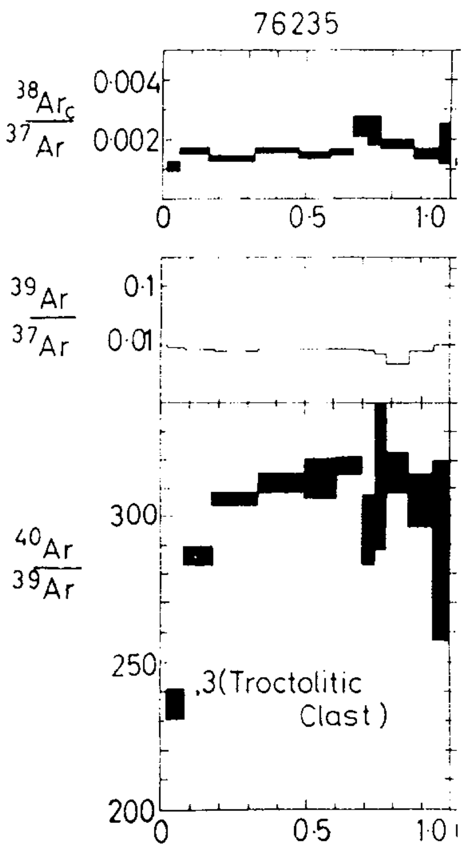


Figure 6: Ar-Ar release diagram for 76235. From Cadogan and Turner (1976).

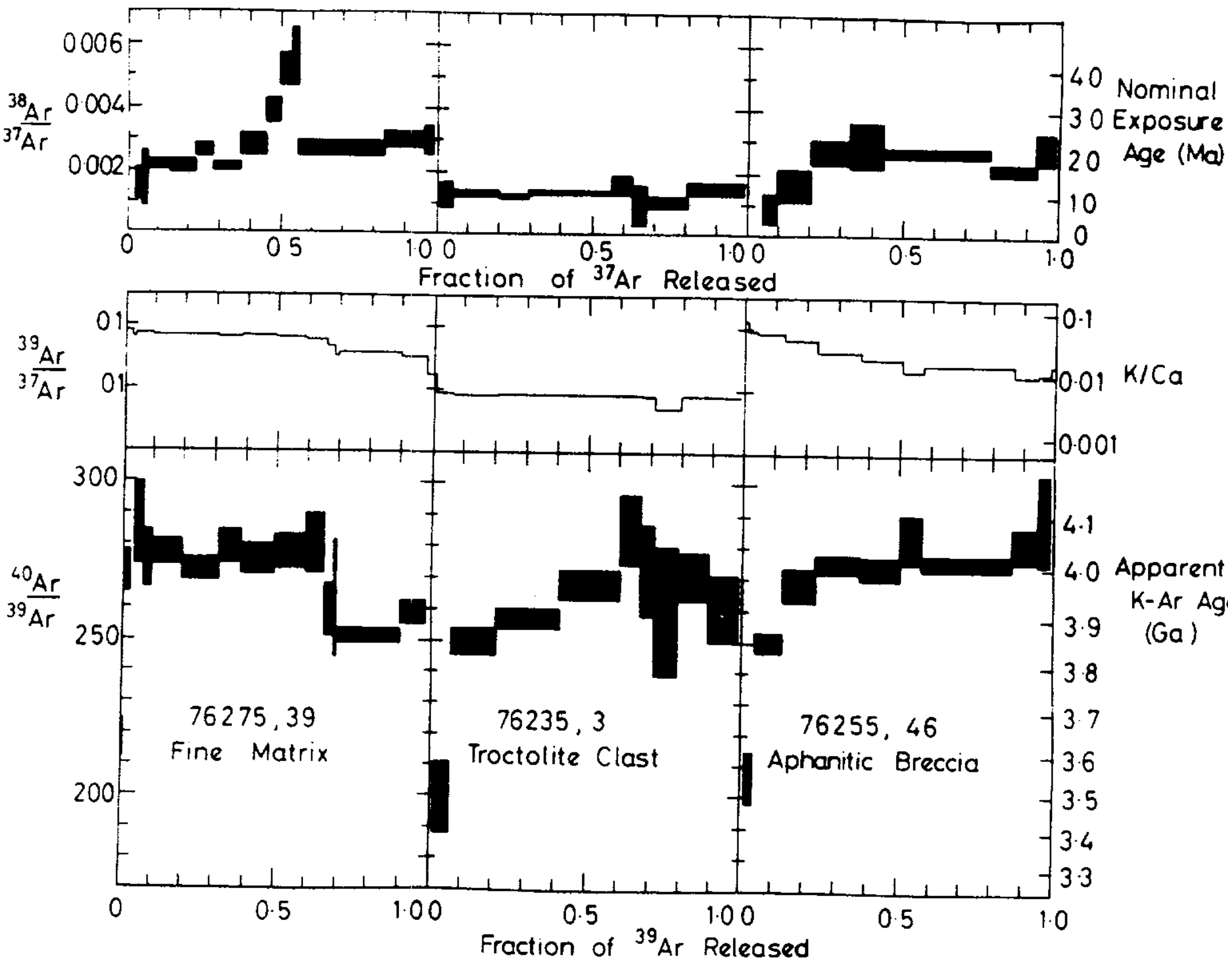


Figure 7: Ar-Ar release diagram for 76235. From Cadogan and Turner (1976).

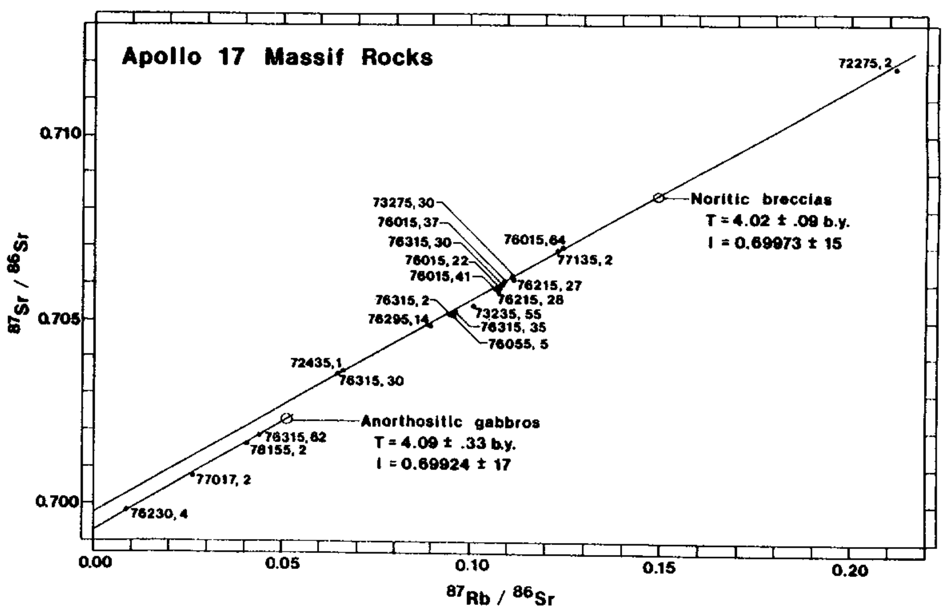


Figure 8: Rb-Sr whole-rock isochrons from Phinney consortium (1981). Clast 76230 is not equilibrated with the matrix of the boulder.

Table 1: Whole-rock chemistry of 76235.
a) LSPET (1973); b) Hubbard et al. (1974); c)Wiesmann and Hubbard (1975)

Split	**76230,4 (a, b, c)**
Technique	**XRF, IDMS**
SiO_2 (wt%)	44.52
TiO_2	0.20
Al_2O_3	27.01
Cr_2O_3	0.11
FeO	5.14
MnO	0.06
MgO	7.63
CaO	15.17
Na_2O	0.35
K_2O	0.06
P_2O_5	0.05
S	0.03
Nb (ppm)	3.2
Zr	42
U	0.20
Th	0.72
Sr	146
Rb	0.448
Li	11.0
Ba	50.2
Zn	2
Ni	166
La	3.04
Ce	7.54
Nd	4.64
Sm	1.34
Eu	0.805
Gd	1.70
Dy	2.02
Er	1.31
Yb	1.37
Lu	0.202
Ge (ppb)	
Ir	
Au	

Table 2: Trace element data for 76235. Concentrations in ppb.
From Higuchi and Morgan (1975).

	Sample 76235,9 clast		Sample 76235,9 clast
Ir	22.5	Ag	0.66
Os		Br	9.6
Re	1.69	In	
Au	6.66	Bi	0.15
Pd		Zn (ppm)	1.2
Ni (ppm)	379	Cd	0.63
Sb	1.47	Tl	0.097
Ge	328	Rb (ppm)	0.448
Se	38	Cs	29.5
Te	2.6	U	190

Table 3: Rb-Sr composition of 76230.
(same as 76235)
Data from Nyquist et al. (1974).

Sample	76230,4
wt (mg)	78.1
Rb (ppm)	0.448
Sr (ppm)	145.9
$^{87}Rb/^{86}Sr$	0.0089 ± 2
$^{87}Sr/^{86}Sr$	0.69982 ± 7
T_B	5.60 ± 0.65
T_L	6.12 ± 0.66

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903
(Apollo 16 anorthosites for T = 4.6 b.y.)

76236

Feldspathic Granulitic Impactite
19.18 g, ~4 x 2 x 2 cm

INTRODUCTION

Sample 76236 is a part of 76235. It was chipped from the same light-colored clast in the boulder at Station 6. This fragment has a thin brown patina with micrometeorite craters on the surface (Fig. 1).

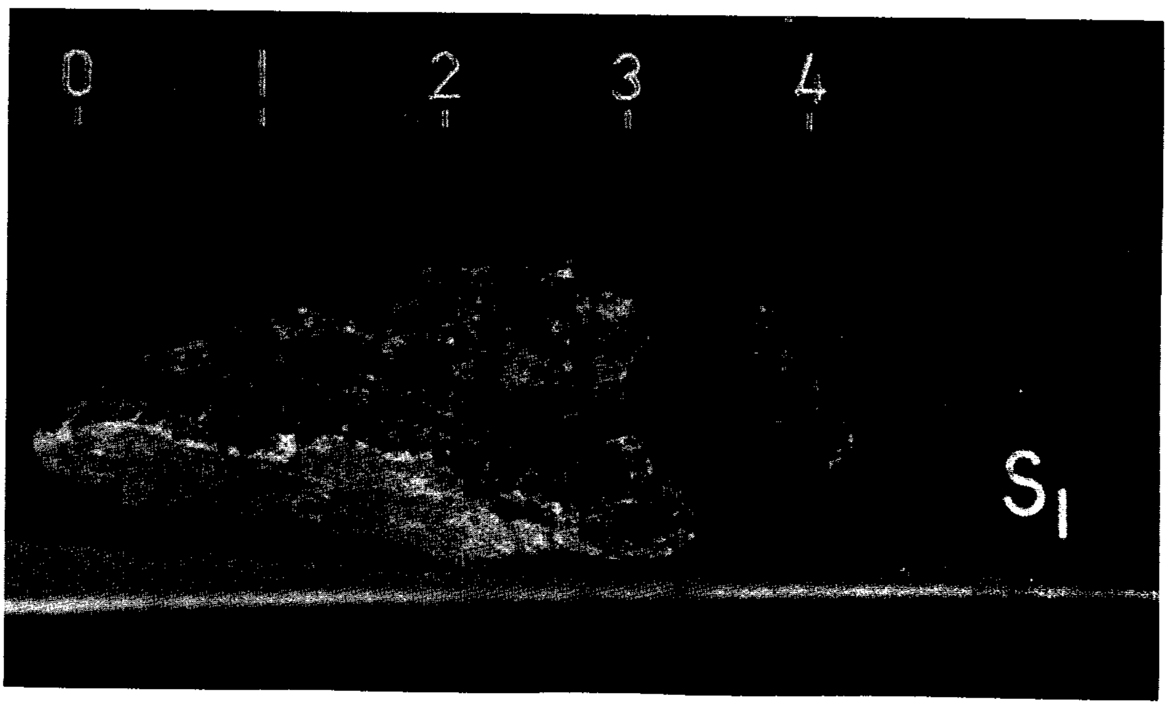


Figure 1: Feldspathic granulitic impactite 76236. Cube is 1 cm. S73-16725.

76237
Feldspathic Granulitic Impactite
10.31 g, ~4 x 2 x 2 cm

INTRODUCTION

Sample 76237 is a part of 76235. It was chipped from the same light-colored clast in the boulder at Station 6. This fragment has a thin brown patina with micrometeorite craters on the surface (Fig. 1).

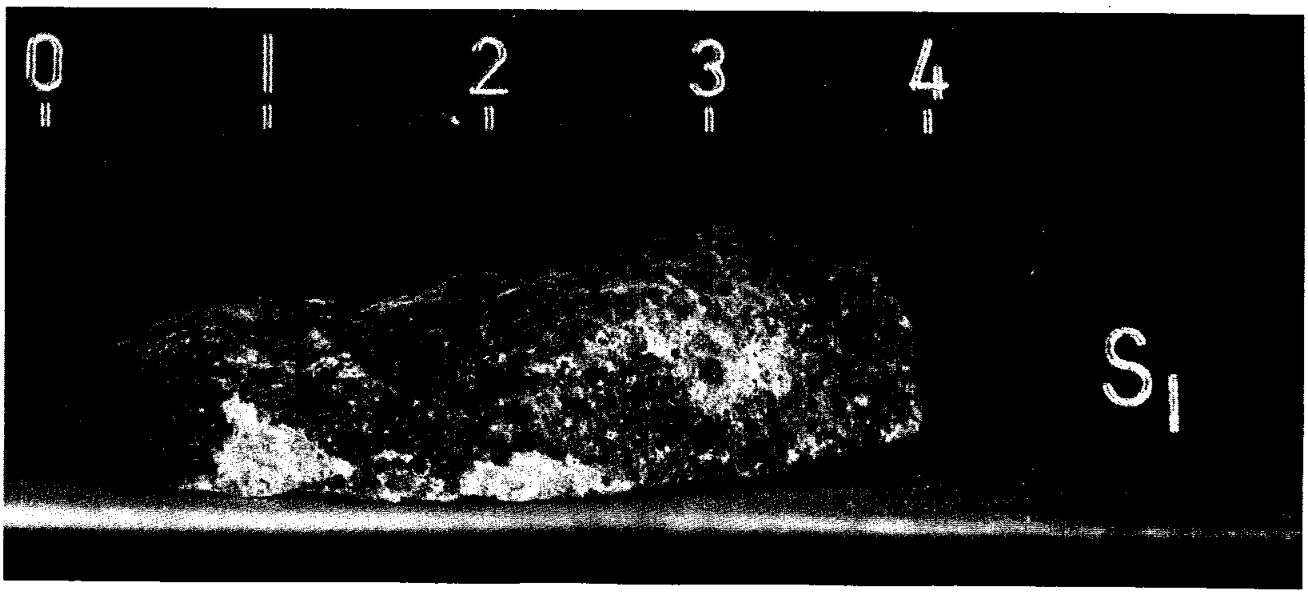


Figure 1: Feldspathic granulitic impactite 76237. Cube is 1 cm. S73-16719.

76238

Feldspathic Granulitic Impactite
8.21 g, ~3 x 2 x 2 cm

INTRODUCTION

Sample 76238 is a part of 76235. It was chipped from the same light-colored clast in the boulder at Station 6. This fragment has a thin brown patina with micrometeorite craters on the surface (Fig. 1).

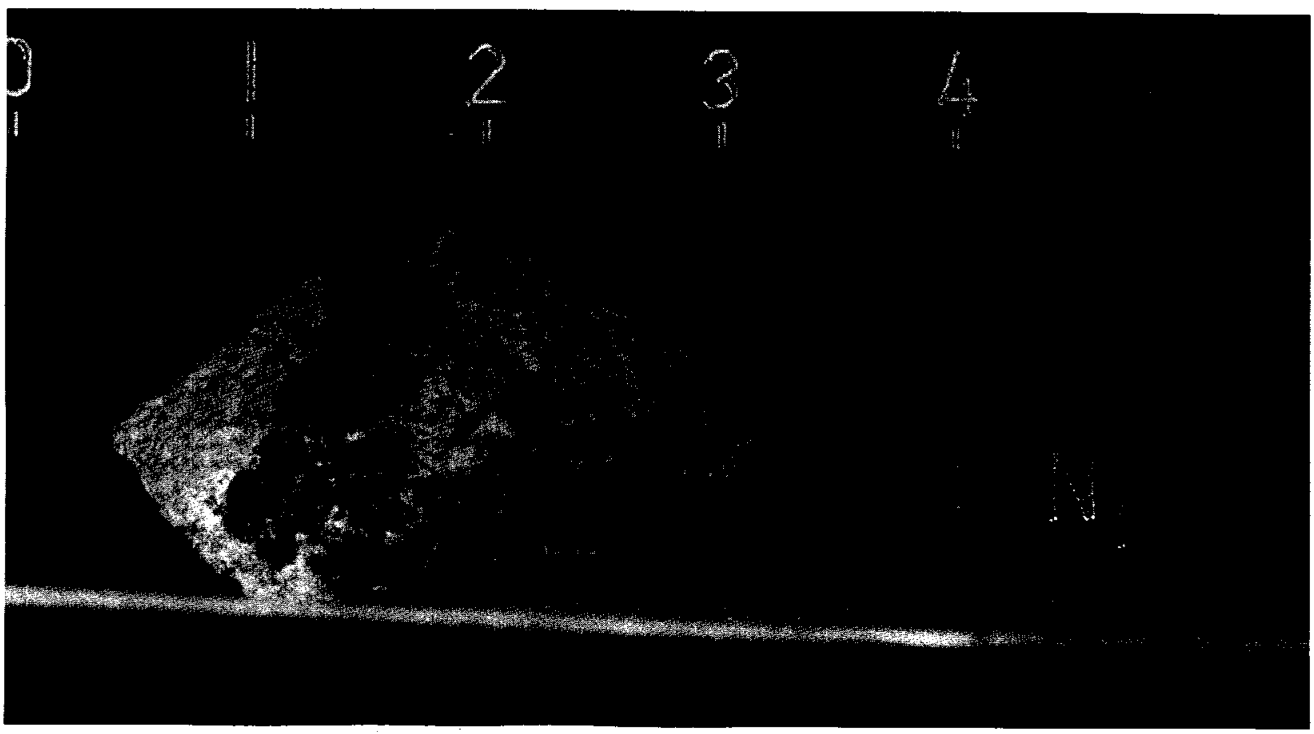


Figure 1: Feldspathic granulitic impactite 76238. Cube is 1 cm. S73-16717.

76239
Feldspathic Granulitic Impactite
6.23 g, ~3 x 2 x 2 cm

INTRODUCTION

Sample 76239 is a part of 76235. It was chipped from the same light-colored clast in the boulder at Station 6. This fragment has a thin brown patina with micrometeorite craters on the surface (Fig. 1).

Figure 1: Feldspathic granulitic impactite 76239. Cube is 1 cm. S73-16712.

76245
Impact Melt Breccia
8.24 g, 3 x 2 x 1 cm

INTRODUCTION

Sample 76245 is a tan-grey, vesicular impact melt breccia from the permanently shadowed soil under the overhang of Block 4 of the Station 6 Boulder. All surfaces appear to be pitted (Fig. 1).

PETROGRAPHY

No thin section or chemical data are available.

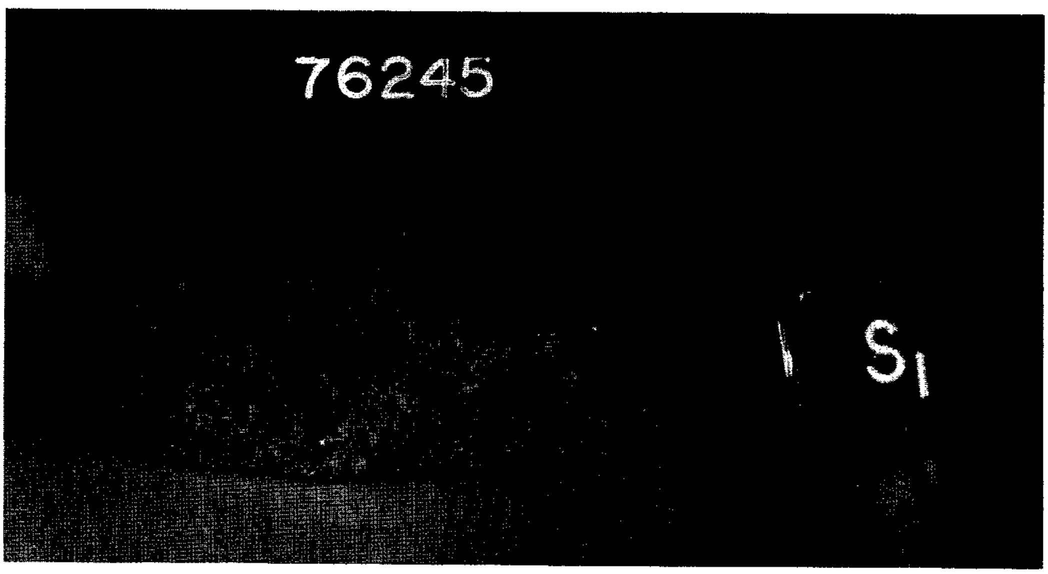


Figure 1: Impact melt breccia 76245. Cube is 1 cm. S73-17976.

76246

Impact Melt Breccia
6.5 g, 2 x 2 x 2 cm

INTRODUCTION

Sample 76246 is a tan-grey, vesicular impact melt breccia from the permanently shadowed soil under the overhang of Block 4 of the Station 6 Boulder (Fig. 1).

PETROGRAPHY

No thin section or chemical data are available.

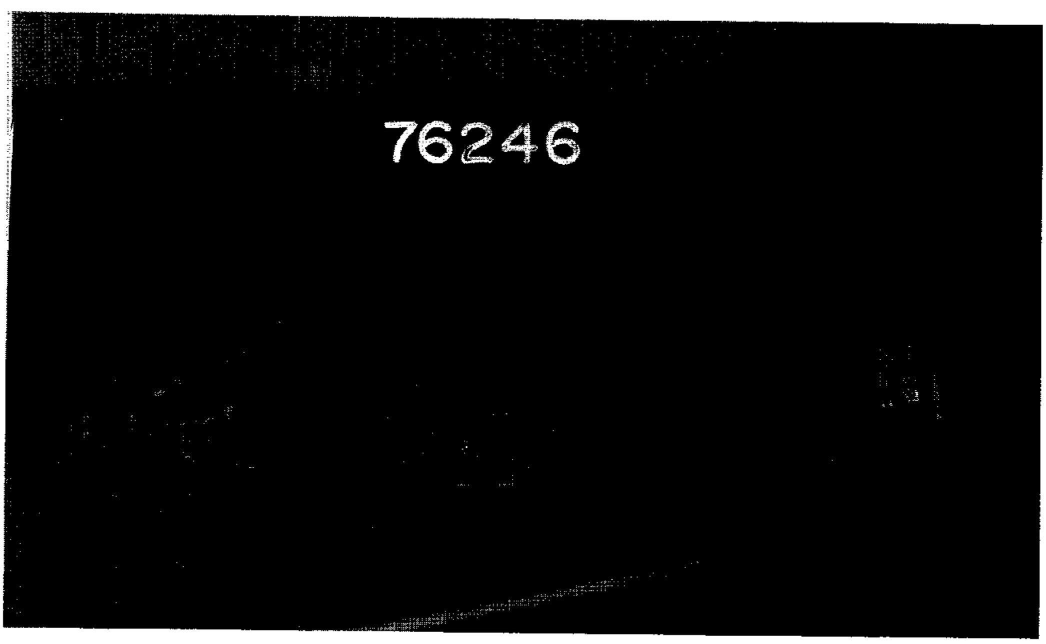


Figure 1: Impact melt breccia. Cube is 1 cm. S73-17977.

76255
Banded Impact Melt Breccia
406.6 g, 11 x 8 x 6 cm

INTRODUCTION

Sample 76255 was chipped by the astronauts from across the contact between unit C and a large (1 m) clast seen in the surface photography of Block 1 of the large boulder at Station 6 (Fig. 1). According to Phinney (1981), the sample contains mostly crushed material from the clast, but from the maps of the sawn surface of the slab of 76255, it is obvious that the contact zone is quite mixed and that more than one clast was sampled.

Cautionary note: The exact details in the literature pertaining to which analyses are from which lithology are very confusing (at the time of compiling this catalog, it would require a research project by a new consortium to figure this out!). Please note the change in numbering of the lithologies between Warner et al. (1976) and Phinney (1981). See also Ryder and Norman (1979).

PETROGRAPHY

Sample 76255 is a banded impact melt breccia with a large clast of crushed norite and several small white clasts (Fig. 2). According to Warner et al. (1976), the matrix of 76255 is the finest-grained, most clast-laden, impact-melt polymict breccia sampled from the boulder at Station 6. The texture of the matrix is subophitic with pyroxene and olivine oikocrysts, small spherical vesicles, and abundant mineral and lithic clasts. Warner et al. give the mineralogical mode of the matrix as 45% plagioclase (An_{82-95}), 32% olivine (Fo_{73-77}), 12% pigeonite ($Wo_7En_{70}Fs_{23}$), 2% augite ($Wo_{38}En_{50}Fs_{12}$), and 3% ilmenite. However, the matrix is variable with finer-grained, dark material intermixed with coarser-grained light material. The plagioclase inclusions in the breccia matrix are very calcic (An_{95}) (Fig. 3).

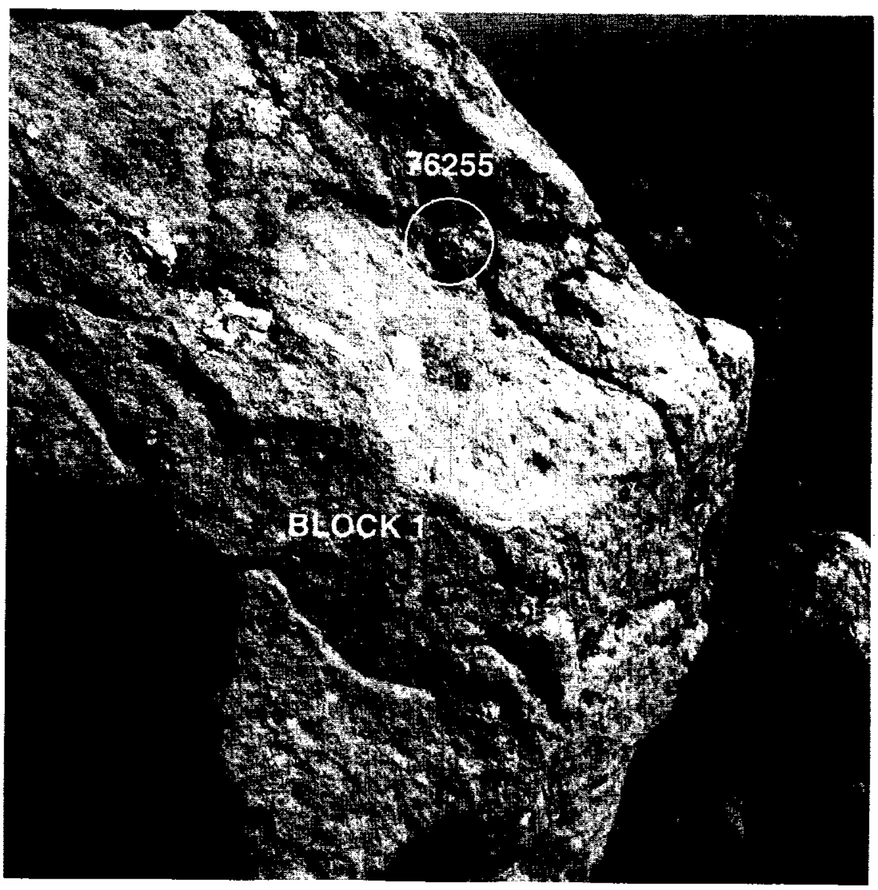


Figure 1: Photo of boulder surface showing large clasts in boulder matrix. 76255 was taken from one of these clasts (Wolfe and others, 1981). AS17-140-21443.

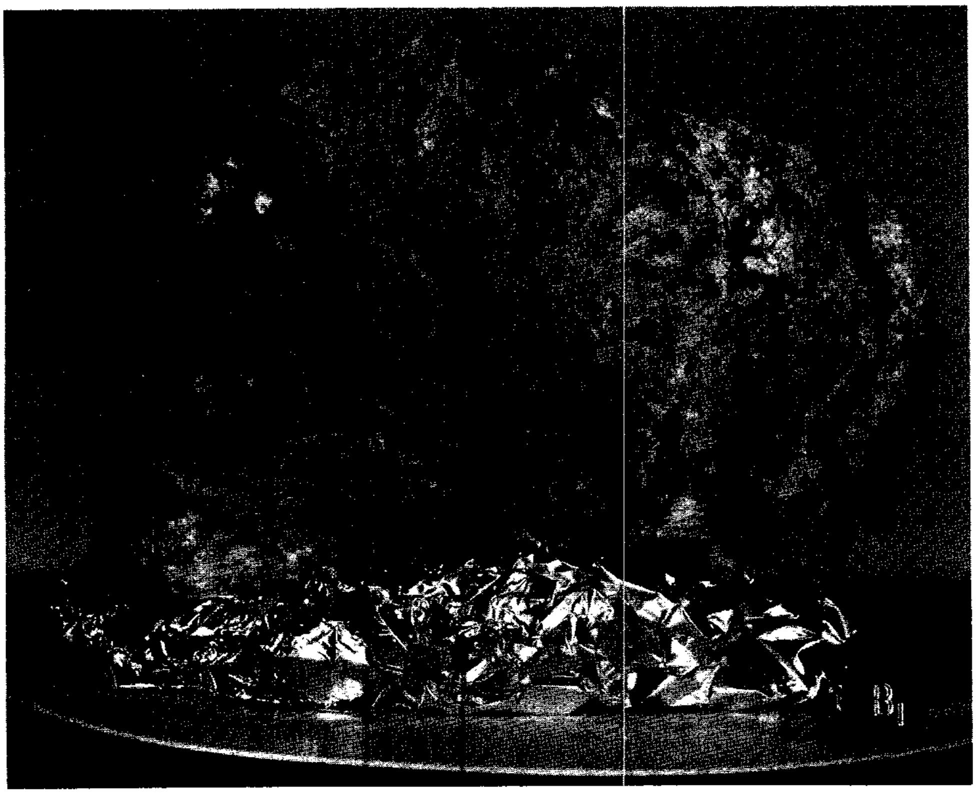


Figure 2: Mugshot of 76255 showing banded nature of sample. Note the crushed appearance of the norite clast (center) and the white powder on the bottom surface. Scale is 1 cm. S72-56415.

Warner et al. (1976) have described the large crushed norite clast (called unit 3 in Warner et al. and unit 4 in Phinney, 1981). It has been crushed to a seriate texture with fragments ranging in size from 2 μm to over 2 mm (Fig. 4). Because this crushed norite appears to be permeated with breccia matrix, Warner et al. claimed that clean separations of the norite clast were not possible for geochemical and age dating experiments. The mineralogical mode is 41% plagioclase (An_{87}), 31% pigeonite ($Wo_8En_{61}Fs_{31}$), and 9% augite ($Wo_{37}En_{45}Fs_{34}$). The pyroxenes in the norite are coarsely exsolved (see below). The composition of pyroxenes and plagioclase in the norite clast are shown in Fig. 5.

Warner et al. also studied a 3 x 5 mm clast of gabbro that was broken off of 76255 (Phinney, 1981). It consists of large (2 mm) oscillatory-zoned plagioclase, large euhedral augite prisms that have exsolved thin lamellae of low-Ca pyroxene, and interstitial anhedral pigeonite masses with exsolved augite lamellae. The cores of the plagioclase are An_{89} while the rims are An_{75}. The large pyroxenes are $Wo_{36}En_{48}Fs_{16}$ and $Wo_{10}En_{61}Fs_{29}$, respectively (Fig. 6).

A 0.8 x 1.2 cm shocked troctolite clast has been studied by Warner et al. and others. It consists of 77% large (1 mm) euhedral plagioclase (An_{95}) and 23% crushed olivine (Fo_{89}) fragments up to 0.7 mm.

Two basalt clasts with mineralogies suggestive of mare affinities were reported by Warner et al. (1976). Because these clasts are enclosed within the boulder, which is dated at ~ 3.96 b.y., they must be at least that old, indicating that mare volcanism began before this time. These basalt clasts were too small to analyze in bulk, but mineral compositions are given in Fig. 7.

James and Flohr (1982) have also studied the clasts in this breccia. They group the norite and the gabbro clasts in their category of Mg-gabbronorites. Jolliff et al. (1993) have plotted the plagioclase vs. pyroxene composition of these clasts (Fig. 8).

MINERAL CHEMISTRY

Using the pyroxene data of Takeda and Miyamoto (1977), Anderson and Lindsley (1982) calculate a pyroxene equilibrium temperature of 800 °C. Takeda and Miyamoto have also studied the cooling rate of the inverted pyroxene in 76255. A deep-seated origin is indicated for the norite clast.

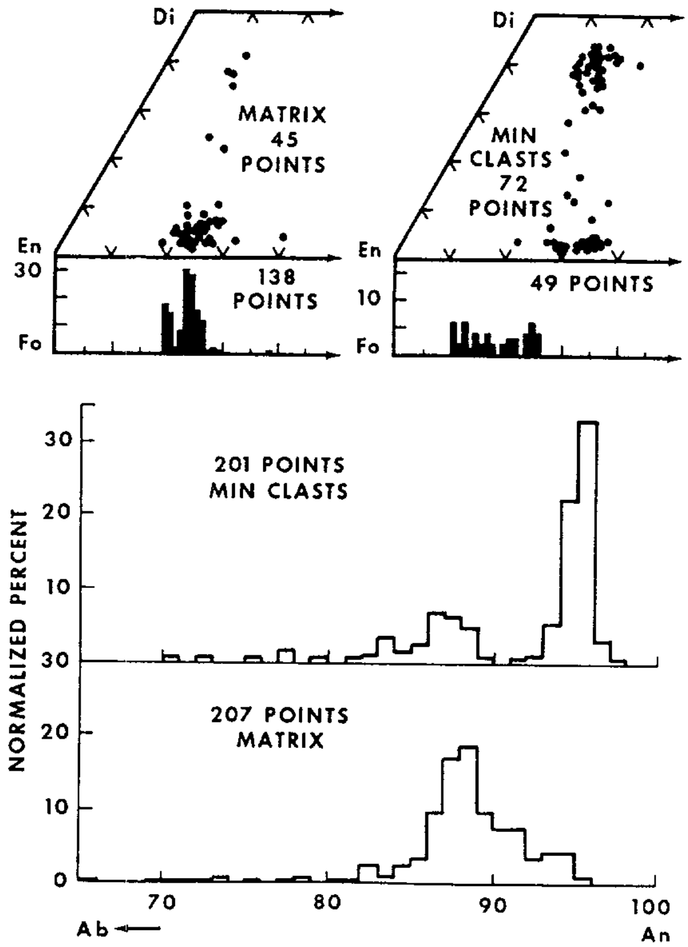


Figure 3: Pyroxene, olivine, and plagioclase compositions in 76255 matrix (Warner et al., 1976).

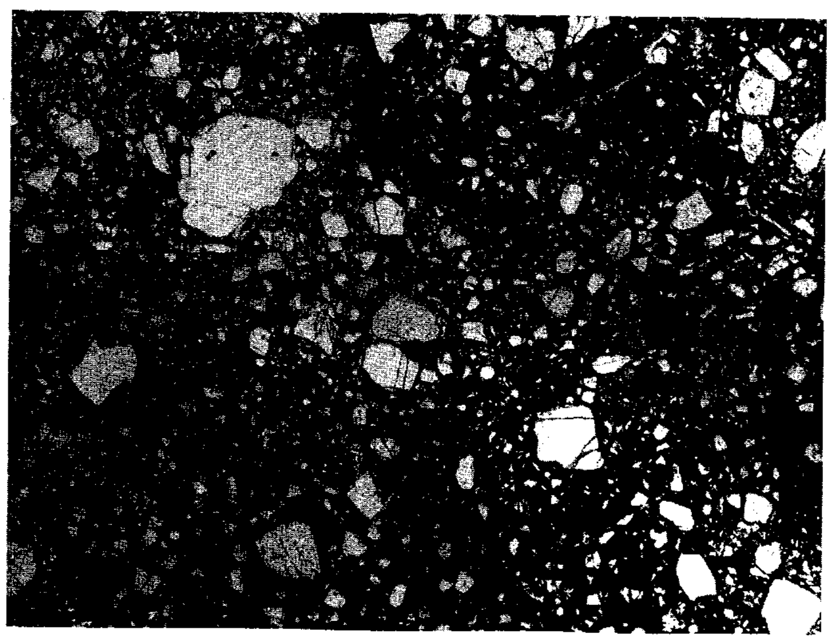


Figure 4: Photomicrograph of 76255,76 showing clastic texture of norite clast. Field of view is 4 x 5 mm.

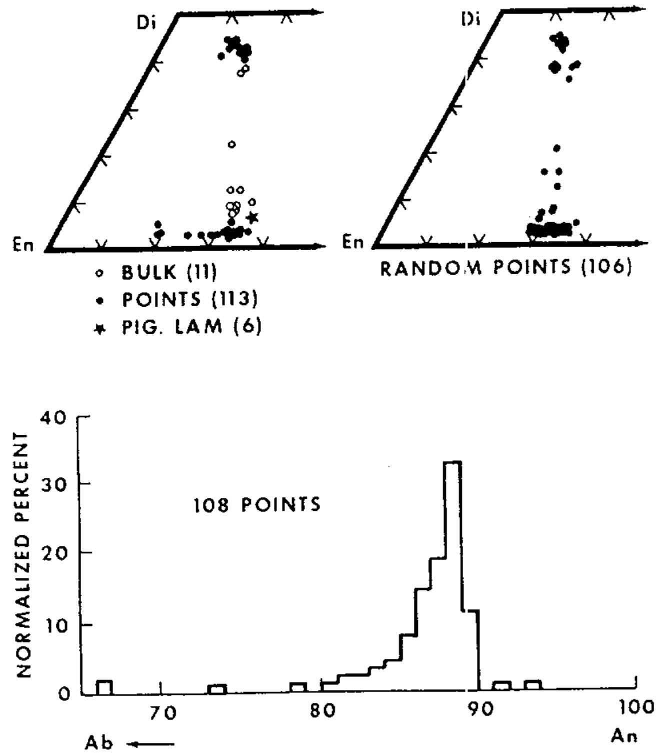


Figure 5: Pyroxene, olivine, and plagioclase compositions in 76255 norite clast.

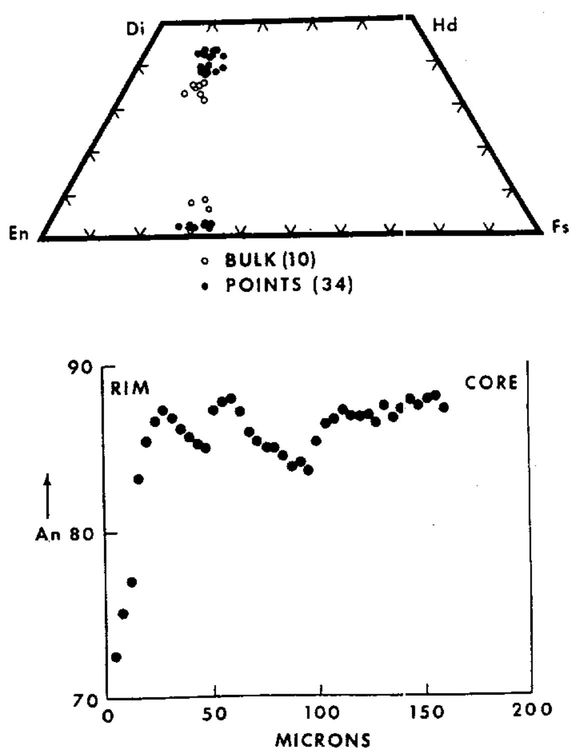


Figure 6: Pyroxene compositions in 76255 gabbro clast. From Warner et al. (1976).

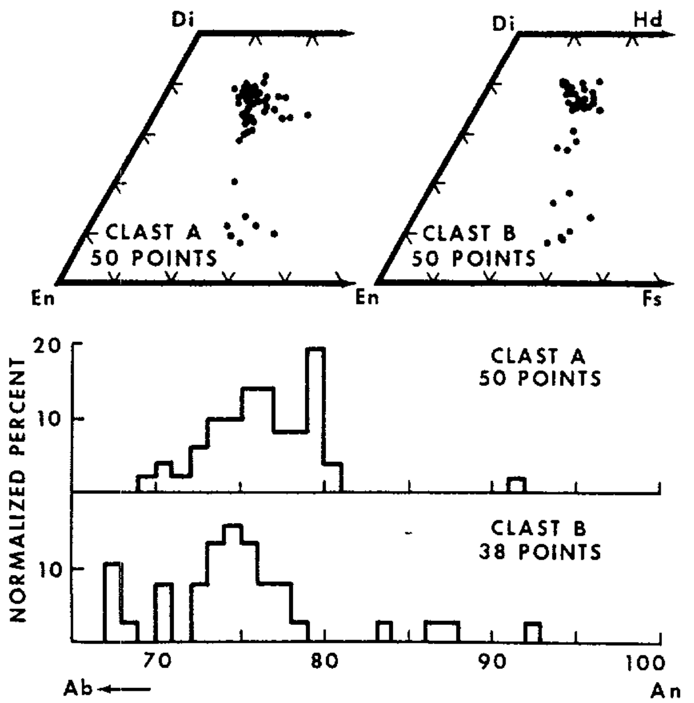


Figure 7: Pyroxene and plagioclase compositions in 76255 basalt clasts.

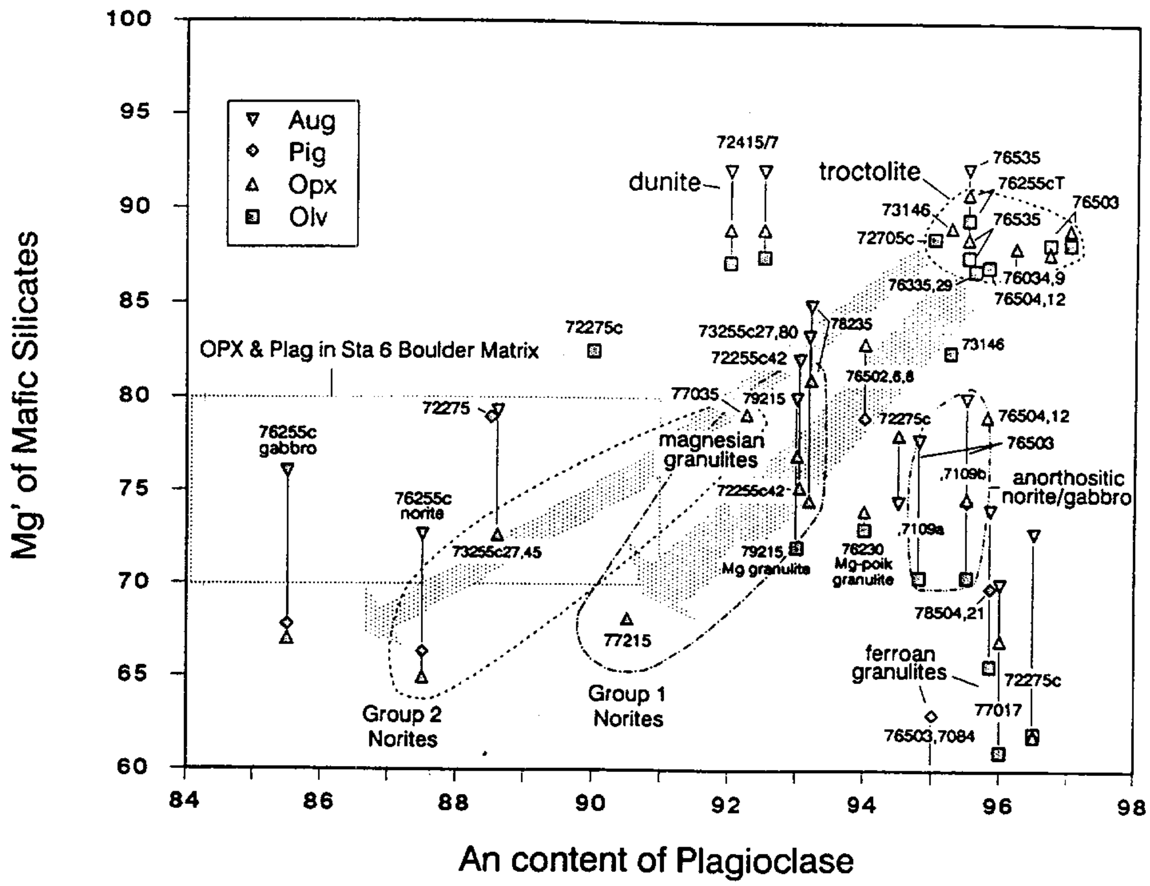


Figure 8: Composition of pyroxene and plagioclase compared with other plutonic clasts. From Jolliff et al. (1993).

Smith et al. (1980), Steele et al. (1980), and Bersch et al. (1991) have also reported analysis of minerals in 76255.

WHOLE-ROCK CHEMISTRY

Table 1 gives the major element analysis by Rhodes (unpublished in Phinney, 1981). Gros et al. (1976) and Wolf and Anders (1979) have analyzed the trace elements of the various clasts for the Phinney consortium (Table 2). Warren (1978, 1984, and 1986) has made several attempts to analyze the trace element content of the large norite clast (Table 3 and Fig. 9). Additional analyses are needed of carefully controlled samples.

SIGNIFICANT CLASTS

Several different clasts have been analyzed—see especially Ryder and Norman (1979), Phinney (1981), and Warren (1993).

Warner et al. (1976) first described the large clast (300 g?) of cataclastic norite in 76255. Ryder and Norman (1979) and Phinney (1981) have attempted to summarize what was known about this important clast. Warner et al. reported that the clast is permeated with "pods and septa of material identical to the boulder's impact melt matrix." However, Gros et al. (1976) found that at least part of this norite clast was free of meteorite contamination (note that they apparently misnamed it as "troctolite"). Warren et al. (1986) attempted to reanalyze this clast, but found that their split was contaminated with "countless small dark aphanitic pods." However, their analysis also showed that this clast is a "possibly pristine" gabbronorite (James and Flohr, 1983; Warren, 1993).

The small clast of gabbro (~0.5 g) studied by Warner et al. (1976) has a coarse cumulate texture (Fig. 10) with oscillatory zoned plagioclase (An_{89-75}), augite ($Wo_{36}En_{48}$) with exsolved thin lamellae of low-Ca pyroxene, and interstitial pigeonite ($Wo_{10}En_{61}$) with exsolved thick lamellae. The location of this clast on 76255 is uncertain, but it is not from the slab as indicated by Warner et al. Sections ,71 ,72 and ,73 were derived from 76255,50, which was from the external surface of 76255.

RADIOGENIC ISOTOPES

76255,46 yielded a very well-defined Ar plateau age of 4.02 ± .04 b.y. (Cadogan and Turner, 1976) with no characteristic decrease in apparent age in the high-temperature gas release (Fig. 11). This age appears to be older than the ages determined for other samples of this boulder (*see table and discussion of Station 6 Boulder, page 5*).

Bogard has analyzed the rare gas isotopes in 76255 (see unpublished data in Phinney, 1981).

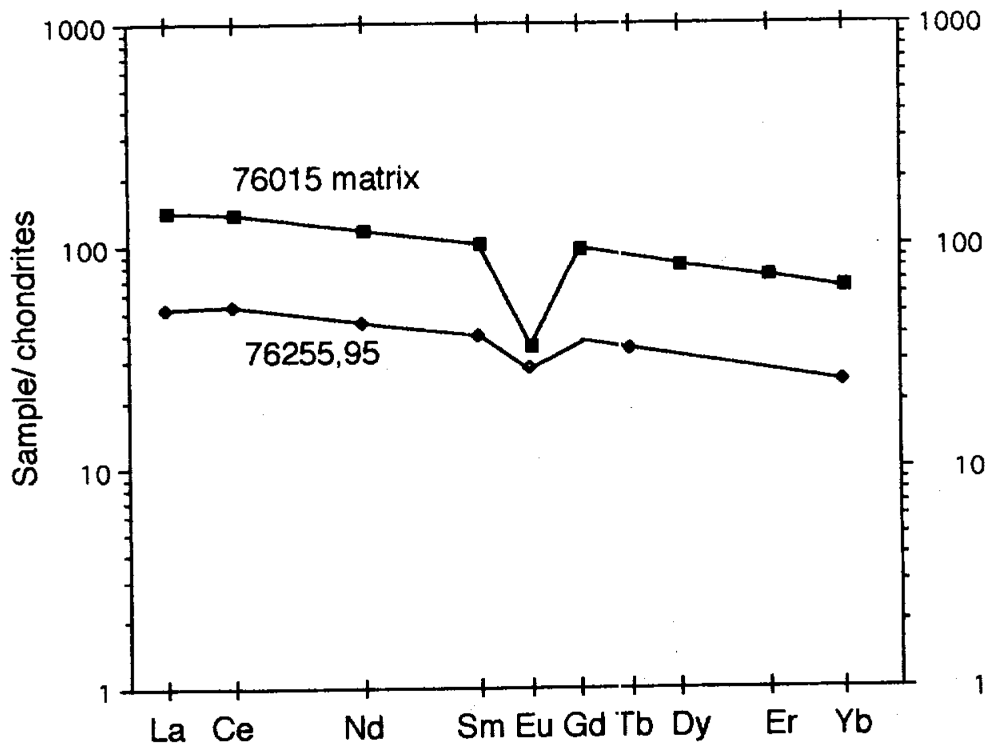


Figure 9: Normalized rare earth element diagram for norite clast in 76255 compared to boulder matrix. According to Warner et al. (1976) and Warren et al. (1986), this clast may contain some matrix material.

Figure 10: Photomicrograph of gabbro clast in 76255,72. Field of view is 2 mm.

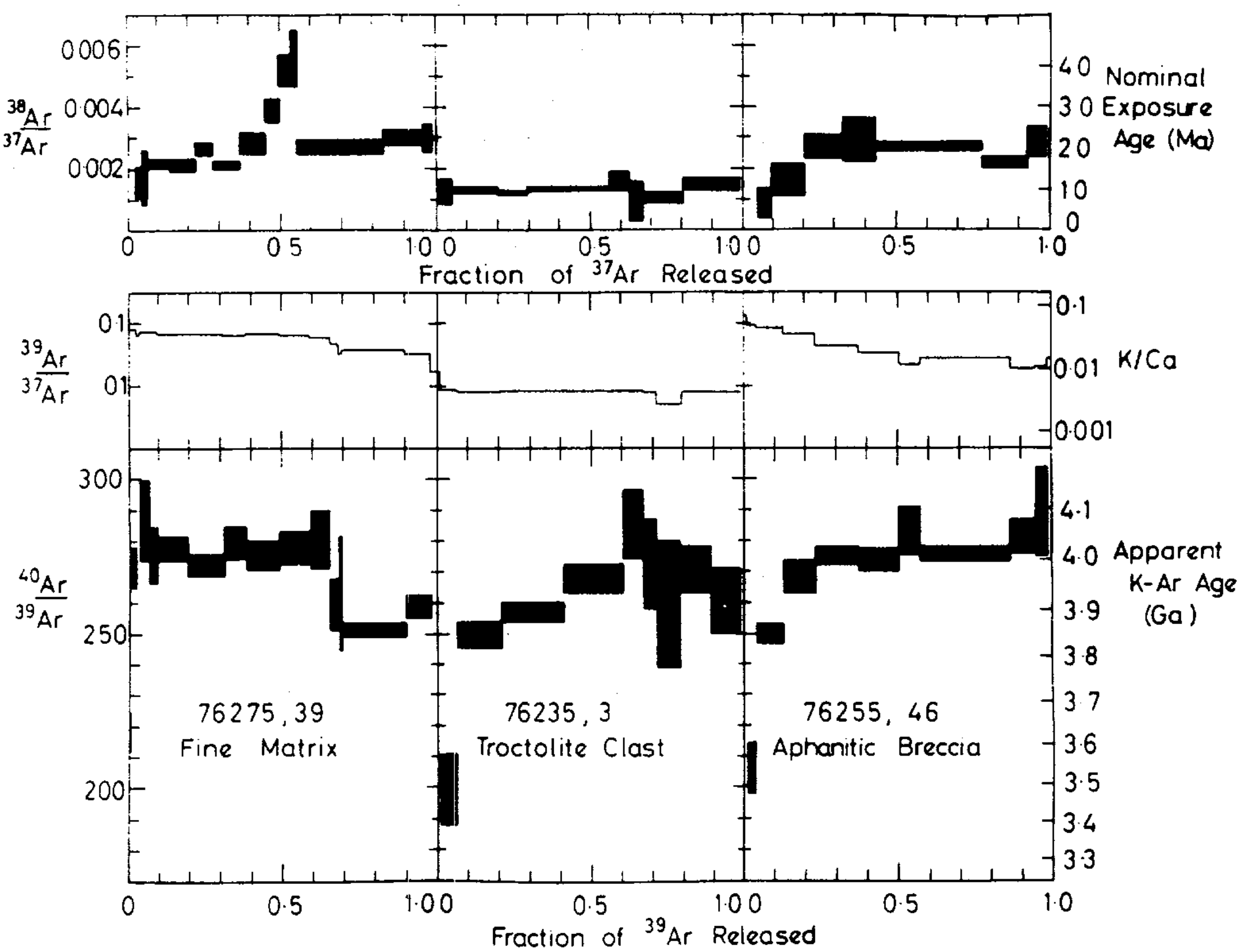


Figure 11: Ar-Ar plateau age for 76255. From Cadogan and Turner (1976).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Some of the Apollo 17 samples (including 76255) provided a unique opportunity to study the energy spectrum (and potential angular anisotropy) of the incident proton flux from the August 1972 solar flare (Rancitelli et al., 1974; Keith et al., 1974). Table 4 compares the induced activity of 76255 with other samples of the boulder.

MAGNETIC STUDIES

Gose et al. (1978) have carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder. The direction of magnetization after alternating field demagnetization of breccia sample 76255 was found to be scattered. Gose et al. propose that the large scatter of magnetization direction for 76255 implies the predominance of pre-impact magnetization in this sample.

PROCESSING

A slab and a column were cut from this rock (see lithology maps and diagrams in Phinney, 1981). The distribution of samples is recorded in Phinney (1981) and Ryder and Norman (1979).

The largest remaining piece of 76255 weighs 166 g. There are 15 thin sections.

Table 1: Whole-rock chemistry of 76255.
From Rhodes (unpublished, reported in Phinney, 1981).

Split **Technique**	**,38** **XRF** **norite**	**,44** **XRF** **matrix**	**,51** **XRF** **matrix and clast**	**,55** **XRF** **clast**	**,58** **XRF** **clast**
SiO_2 (wt%)	50.61	45.45	46.94	59.68	43.84
TiO_2	0.75	1.60	1.66	1.37	0.25
Al_2O_3	15.37	18.91	19.04	15.89	25.15
Cr_2O_3					0.04
FeO	9.8	7.40	7.21	9.36	4.23
MnO	0.19	0.11	0.13	0.17	
MgO	11.14	13.88	11.86	11.23	11.02
CaO	11.05	11.78	12.47	11.17	14.20
Na_2O	0.74	0.68	0.76	0.73	0.40
K_2O	0.37	0.17	0.18	0.32	0.08
P_2O_5	0.03	0.24	0.22	0.01	
S	0.09	0.03	0.03	0.03	

Table 2: Trace element compositions of 76255. Concentrations in ppb.
a) Gros et al. (1976); d) Wolf and Anders (1979)

	Sample 76255,47 (a) matrix	Sample 76255,52 (a) matrix	Sample 76255,56 (a, d) clast	Sample 76255,57 (a, d) clast
Ir	1.13	1.21	0.042	0.019
Os	1.11	1.91	0.035	<0.03
Re	0.132	0.112	0.028	0.0068
Au	0.843	0.38	0.178	0.0093
Pd	<2.5	<2.5	<0.7	<4.3
Ni (ppm)	90	62	31	<15
Sb	2.2	0.2	0.11	2.4
Ge	34.2	9.6	6.6	2.2
Se	41	19	49	0.6
Te	1.6	2.5	1.1	5.9
Ag	12.9	1.29	0.7	0.34
Br	35.9	15.8	9.2	7.8
In	0.61	9.76	0.3	0.77
Bi	0.31	0.37	0.2	<2
Zn (ppm)	2.4	2.3	2	0.5
Cd	8.2	6.4	2	67.5
Tl	0.89	1	0.96	5.4
Rb (ppm)	5.36	3.68	12.8	0.19
Cs	184	175	842	6.3
U	3150	1170	445	19

Table 3: Composition of 76255.
a) Warren and Wasson (1978); b) Warren et al. (1986)

	Sample 76255,58 (a)	Sample 76255,95 (b)	Sample 76255,95 (b)
Na (%)	0.347	0.509	0.495
Mg (%)	6.13	7.3	
Al (%)	13.8	8.9	
Si (%)	20.6	22.8	
K (%)		0.158	0.124
Ca (%)	10.7	8.3	8.3
Sc (ppm)	4.7	17.3	16.2
Ti (%)	0.16	0.5	
Cr (ppm)	461	1310	1320
Mn (ppm)	367	1010	975
Fe (%)	3.3	6.3	6
Co (ppm)	19.4	14.3	16.2
Ni (ppm)	<70	23	13
Zn (ppm)	53.2		
Ga (ppm)	4.81	4.2	4
Ge (ppb)	22	1.3	
Zr (ppm)	150	120	196
Cd (ppm)	6.4		
In (ppm)	<5		
Ba (ppm)	240	184	178
La (ppm)	16.1	12.1	13.7
Ce (ppm)	38	32	37
Nd (ppm)	24	20.2	22.2
Sm (ppm)	5.4	5.8	6.3
Eu (ppm)	1.77	1.57	1.55
Tb (ppm)	0.94	1.23	1.34
Yb (ppm)	3.4	4	4.3
Lu (ppm)	0.46	0.63	0.68
Hf (ppm)	3	3.8	4.3
Ta (ppm)	0.27	0.41	0.42
Re (ppb)		0.017	
Ir (ppb)	0.63	0.077	
Au (ppb)	10.8	0.139	0.05
Th (ppm)	1.3	1.4	1.58
U (ppm)	0.38	0.38	0.38

Table 4: Solar flare induced activity from large solar flare, August 1972.
a) Keith et al., (1974); b) Rancitelli et al., (1974); c) O'Kelley et al., (1974)

	Sample 76215 (a)	Sample 76255 (b)	Sample 76275 (b)	Sample 76295 (b)	Sample 76295 (c)
dpm/Kg					
^{26}Al	56 ± 3	79 ± 4	110 ± 3	71 ± 4	67 ± 5
^{22}Na	60 ± 4	71 ± 4	100 ± 3	64 ± 3	54 ± 4
^{54}Mn	22 ± 17	38 ± 9	103 ± 20	69 ± 26	38 ± 15
^{56}Co	45 ± 6	37 ± 4	86 ± 9	35 ± 5	41 ± 7
^{46}Sc	5 ± 3	3.9 ± 1.2	7 ± 2	6.4 ± 2.6	5 ± 2
^{48}V					
Natural activity					
Th (ppm)	4.6	2.33	5.69	5.76	
U (ppm)	1.27	.58	1.40	1.55	
K (ppm)		2900	2250	2300	

76265

Impact Melt Breccia
1.75 g, 2 x 1.5 x 0.7 cm

INTRODUCTION

Sample 76265 is a vesicular, greenish-grey, impact melt rock from the soil between the blocks of the Station 6 Boulder (Fig. 1).

This sample has not been studied and there are no thin sections.

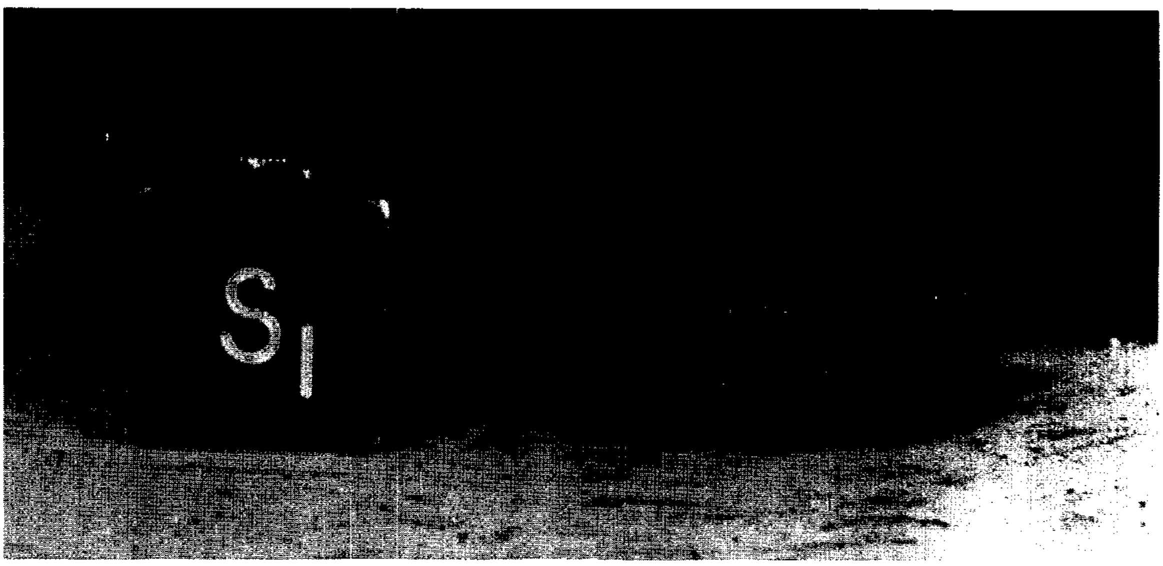


Figure 1: Sample 76265. Cube is 1 cm. S73-21767.

76275
Impact Melt Breccia
55.93 g, 6.8 x 4 x 3 cm

INTRODUCTION

Sample 76275 was chipped from Block 1 of the big boulder at Station 6 (Wolfe and others, 1981; Heiken et al., 1973). It contains distinct clasts of white feldspar (or anorthosite) in a dark, fine-grained, clastic matrix. This sample has not been well studied.

PETROGRAPHY

Sample 76275 is a clast-bearing, nonvesicular, blue-grey breccia (Fig. 1). The modal mineralogy of 76275 is about 50% plagioclase, 40% low-calcium pyroxene, with minor amounts of augite, olivine, ilmenite, armalcolite, and metallic iron. The texture of the fine grain matrix of 76275 is poikilitic to subophitic and similar to that of 76295 (Simonds, 1975; Simonds et al., 1974). The matrix is finer-grained than for the other samples of the large boulder (Fig. 2). The grain size of matrix feldspar is <10 µm, pyroxene <25 µm. The matrix consists of low-calcium pyroxene ($Wo_4En_{60-73}Fs_{19-26}$), minor augite ($Wo_{30-40}En_{44-57}Fs_{12-15}$), olivine ($Fo_{70-76}$), and feldspar ($An_{81-97}$) (Fig. 3).

Misra et al. (1976) have studied the complex metallic nickel-iron particles included in 76275 (Fig. 4).

WHOLE-ROCK CHEMISTRY

Phinney (1981) and Simonds and Warner (1981) report preliminary major element data for matrix and clasts in 76275 (Table 1). The blue-grey matrix, tan matrix, and vesicular clast all appear to have compositions like those of the matrices of the rest of the samples of the large Station 6 Boulder. Higuchi and Morgan (1975) find that the trace siderophile element composition of all the samples of the Station 6 Boulder form a tight grouping (meteorite group 2) on compositional diagrams. Sample 76275 has a higher abundance of these meteoritic elements than the matrices of 76015 and 76215 (Table 2, Gros et al., 1976).

Figure 1: Sample 76275, showing light and dark clasts in an aphanitic blue-grey matrix. Cube is 1 cm. S73-15081.

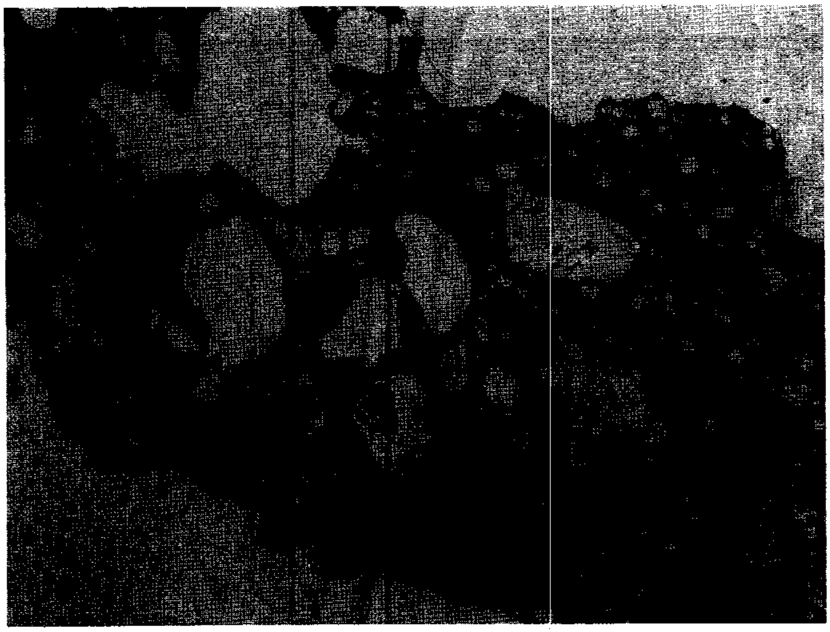


Figure 2: Photomicrograph of matrix of 76275,56. Vesicles are not typical. Field of view is 4 x 5 mm.

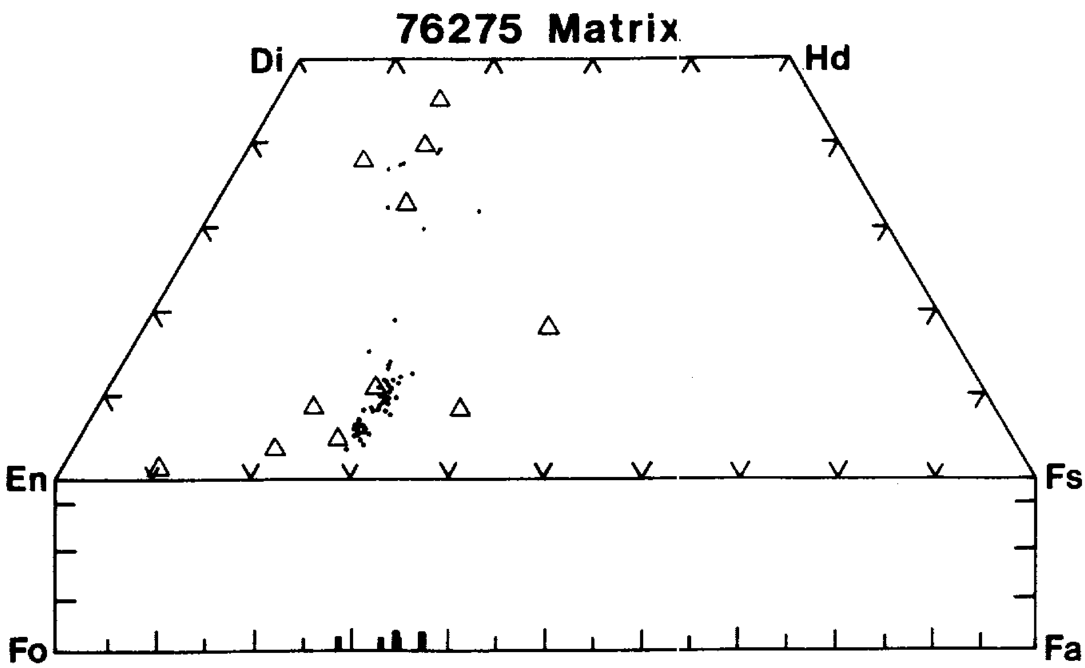


Figure 3: Electron microprobe analyses of minerals in matrix of 76275. From Phinney (1981).

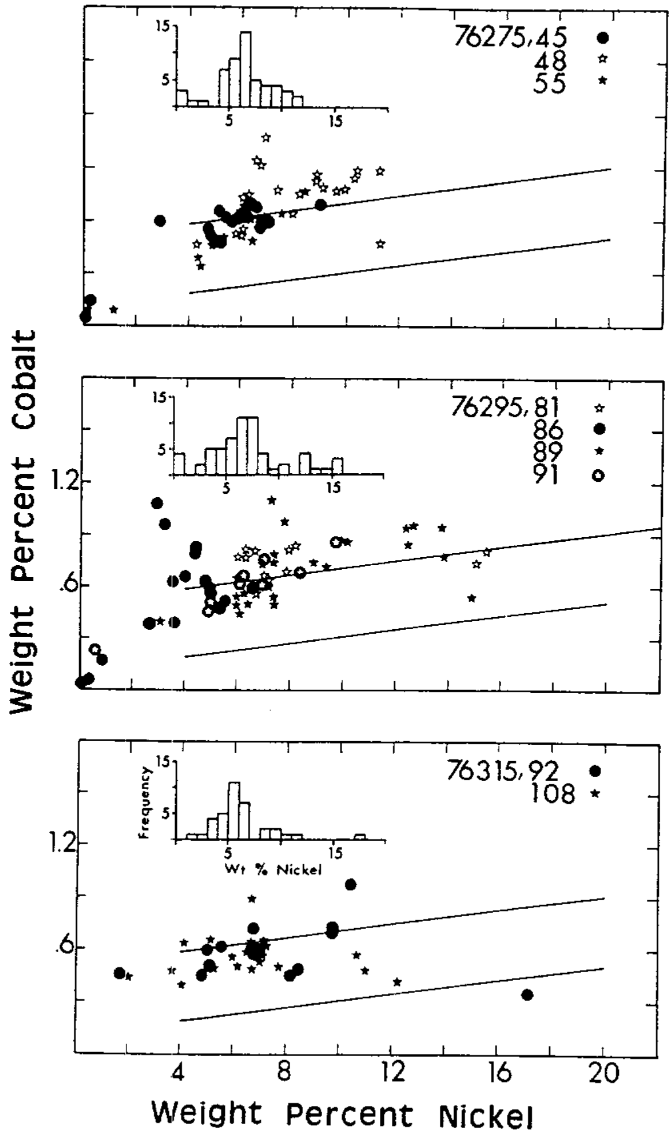


Figure 4: Ni vs. Co analysis of iron grains in 76275 compared with other Station 6 breccia samples. By Misra et al. (1976).

SIGNIFICANT CLASTS

Several large, white clasts with distinct boundaries can be seen in the photos of the broken surface of 76275 (Fig. 1). These obvious clasts deserve to be studied.

RADIOGENIC ISOTOPES

Cadogan and Turner (1975) determined an Ar plateau age of 4.02 ± 0.04 b.y. for 76275 (Fig. 5). This is somewhat older than the other Ar ages for this boulder.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

The Apollo 17 samples (including 76275) provided a unique opportunity to study the energy spectrum (and potential angular anisotropy) of the incident proton flux from the August 1972 solar flare (Rancitelli et al., 1974; Keith et al., 1974). Table 3 compares the induced activity of 76275 with other samples of the boulder.

MAGNETIC STUDIES

Gose et al. (1978) have carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder. The direction of magnetization after alternating field demagnetization of breccia sample 76275 was found to be scattered for this clast-rich sample. Gose et al. propose that the natural remanent magnetization of impact melt breccias is the vector sum of two magnetizations, a pre-impact magnetization and a partial thermoremanence acquired during breccia lithification. The large scatter of magnetization direction of 76275 implies the predominance of pre-impact magnetization in this sample.

PROCESSING

The processing of sample 76275 was delayed and the Phinney consortium did not complete their analyses (Phinney, personal communication).

The largest remaining piece (,0) weighs 38 g. There are 16 thin sections.

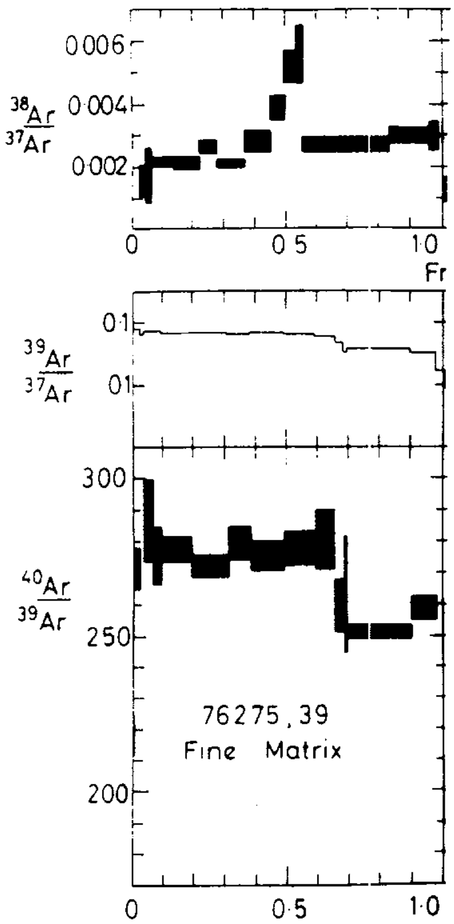


Figure 5: Ar-Ar release diagram of matrix of 76275. From Cadogan and Turner (1976).

Table 1: Whole-rock chemistry of 76275.
From Simonds and Warner (1981) and Phinney (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst)

Split Technique	,24 EMP tan matrix	,32 EMP vesicular clast	,38 EMP blue-grey clast
SiO_2 (wt%)	47.14	47.16	46.67
TiO_2	1.65	1.43	1.36
Al_2O_3	18.7	17.68	18.63
Cr_2O_3	0.15	0.19	0.19
FeO	8.54	8.91	8.41
MnO			
MgO	9.22	11.20	10.85
CaO	12.06	11.30	11.37
Na_2O	0.72	0.70	0.70
K_2O	0.34	0.22	0.28

Table 2: Trace element data for 76275. Concentrations in ppb.
From Gros et al. (1976).

	Sample 76275,33 (a)		Sample 76275,33 (a)
Ir	7.76	Ag	1.22
Os	8.6	Br	72.7
Re	0.725	In	12.4
Au	5.1	Bi	<0.5
Pd	19.8	Zn (ppm)	4
Ni (ppm)	387	Cd	8.8
Sb	2	Tl	1.4
Ge	383	Rb (ppm)	3.67
Se	125	Cs	196
Te	9.8	U	2350

Table 3: Solar flare induced and natural activity of 76275 compared with other samples.
From large solar flare, August 1972.
a) Keith et al. (1974); b) Rancitelli et al. (1974); c) O'Kelley et al., (1974)

	Sample 76215 (a)	Sample 76255 (b)	Sample 76275 (b)	Sample 76295 (b)	Sample 76295 (c)
dpm/Kg					
^{26}Al	56 ± 3	79 ± 4	110 ± 3	71 ± 4	67 ± 5
^{22}Na	60 ± 4	71 ± 4	100 ± 3	64 ± 3	54 ± 4
^{54}Mn	22 ± 17	38 ± 9	103 ± 20	69 ± 26	38 ± 15
^{56}Co	45 ± 6	37 ± 4	86 ± 9	35 ± 5	41 ± 7
^{46}Sc	5 ± 3	3.9 ± 1.2	7 ± 2	6.4 ± 2.6	5 ± 2
^{48}V					
Natural activity					
Th (ppm)	4.6	2.33	5.69	5.76	
U (ppm)	1.27	.58	1.40	1.55	
K (ppm)		2900	2250	2300	

76285

Agglutinate of Dark Matrix Breccia Fragments
2.208 g, 3 x 1.5 x 1.5 cm

INTRODUCTION

This fragment (76285) was collected from the soil between the boulder blocks at Station 6. This soil was collected as a comparison with 76245, which was permanently shadowed.

PETROGRAPHY

A dark brown glass splash (agglutinate) holds several dark brown matrix breccia fragments together (Fig. 1). This breccia may be a soil breccia rather than a highlands impact melt. This fragment has not been studied, and there are no thin sections.

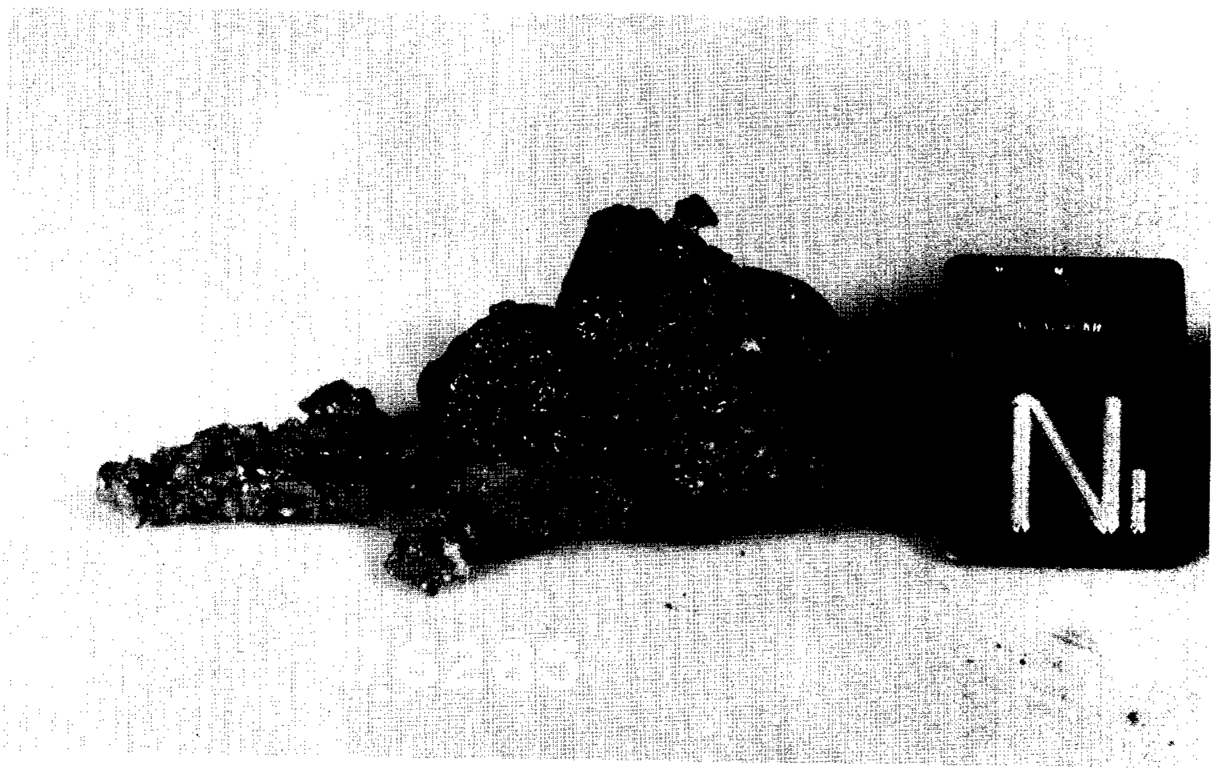


Figure 1: Sample 76285. Cube is 1 cm. S73-20182.

Figure 2: The other side of 76285. S73-20181.

76286
Impact Melt Breccia
1.704 g, 1.5 x 1 x 1 cm

INTRODUCTION

This small rock fragment was collected from a trench in the soil between the blocks of the big boulder at Station 6. Although it was called a "brecciated troctolite" in the original catalog, it is instead a typical impact melt breccia (Fig. 1).

PETROGRAPHY

The binocular description by Butler (1973) indicated that this rock originally had a relatively coarse grain size (1 to 3 mm?). However, the thin section allocated to Warren et al. (1978) showed a "fine-grained, polymict texture" that is very similar to the boulder samples 76215 and 76015 (Fig. 2). This vesicular poikilitic impact melt breccia is reported by Warren et al. to have about 51% plagioclase (An_{85-95}), 26% orthopyroxene ($Wo_{3-5}En_{72-77}$ Fs_{19-25}), and ~13% olivine (Fo_{70}).

WHOLE-ROCK CHEMISTRY

Warren and Wasson (1978) analyzed a piece of 76286 and found that it had a composition very similar to the samples of the big boulder at Station 6 (Fig. 3). Sample 76286 had high Ir and is nonpristine (Table 1).

There are no other data on this small fragment.

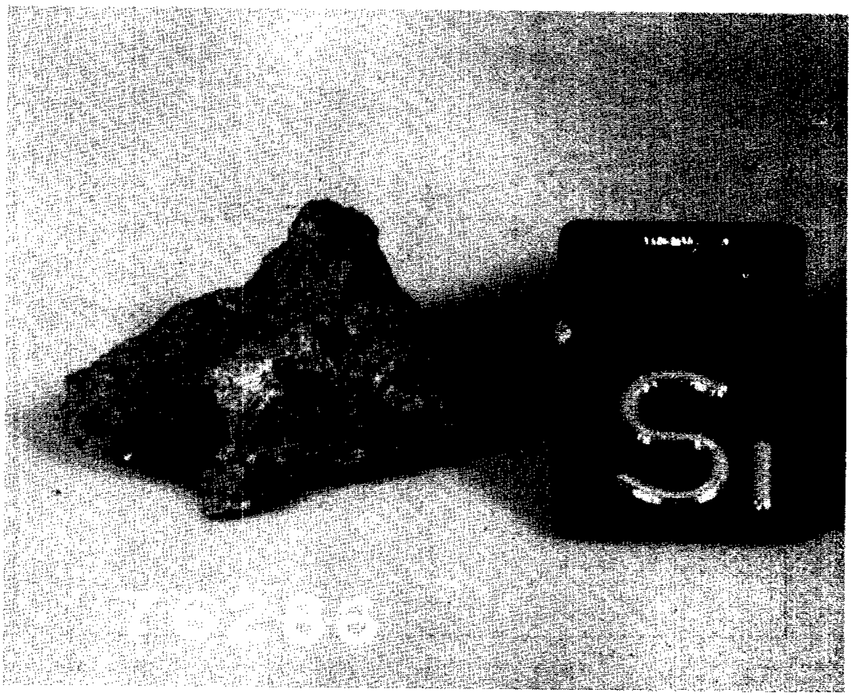


Figure 1: Poikilitic matrix, blue-grey impact melt rock 76286. Cube for scale = 1 cm. S73-20181.

Figure 2: Photomicrograph of 76286,3, illustrating clastic poikilitic texture and large vesicle. Field of view is 4 x 5 mm.

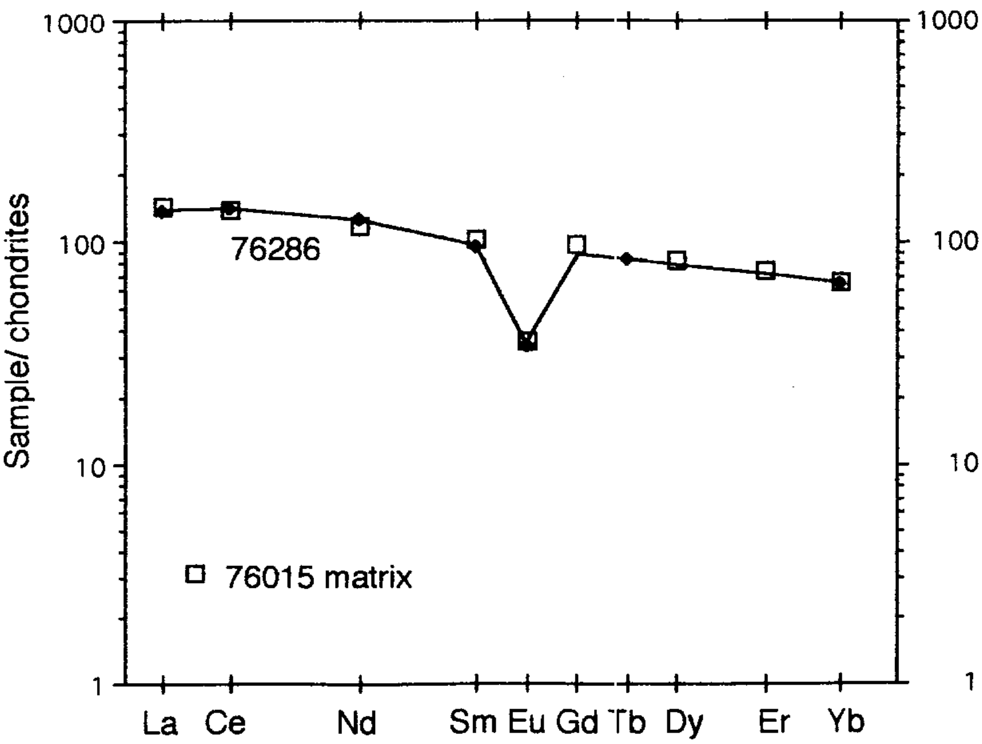


Figure 3: Normalized rare earth element diagram for 76286, with data from 76015 for comparison.

Table 1: Chemical data for 76286.
From Warren and Wasson (1978).

	Sample 76286,1
Na (%)	0.499
Mg (%)	7.55
Al (%)	9.53
Si (%)	22
K (%)	0.232
Ca (%)	7.8
Sc (ppm)	16.7
Ti (%)	0.94
Cr (ppm)	1330
Mn (ppm)	917
Fe (%)	7.1
Co (ppm)	13.8
Ni (ppm)	57
Zn (ppm)	2.44
Ga (ppm)	4.82
Ge (ppb)	445
Zr (ppm)	500
Cd (ppm)	8.4
In (ppm)	<50
Ba (ppm)	384
La (ppm)	32.1
Ce (ppm)	83
Nd (ppm)	56
Sm (ppm)	14
Eu (ppm)	1.92
Tb (ppm)	3
Yb (ppm)	10.4
Lu (ppm)	1.45
Hf (ppm)	11.3
Ta (ppm)	1.34
Re (ppb)	0.27
Ir (ppb)	1.4
Au (ppb)	0.77
Th (ppm)	5.2
U (ppm)	1.5

76295
Impact Melt Breccia
260.7 g, 10 x 6 x 3.5 cm

INTRODUCTION

Sample 76295 was chipped from Block 1 of the big boulder at Station 6 (Wolfe and others, 1981; Heiken et al., 1973). It is a non-vesicular, crystalline matrix breccia with a blue-grey color (similar to 76275). Light and dark clasts have a distinct outline with the matrix (Fig. 1), and the fine grain size of the matrix of this sample and that of 76275 form an important argument of the thermal model of Simonds (1975) and Onorato et al. (1976) for the genesis of impact melt breccias.

PETROGRAPHY

Sample 76295 is a banded, clast-bearing, nonvesicular, blue-grey breccia with aphanitic matrix. The modal mineralogy of 76295 is about 50% plagioclase, 40% low-calcium pyroxene, with minor amounts of augite, olivine, ilmenite, armalcolite, and metallic iron. The texture of the fine grain matrix of 76295 is subophitic (Simonds et al., 1974). The matrix consists predominantly of low-calcium pyroxene ($Wo_4En_{60-73}Fs_{19-26}$), minor augite ($Wo_{30-40}En_{44-57}Fs_{12-15}$), olivine ($Fo_{70-76}$), and feldspar ($An_{81-97}$). The grain size of matrix feldspar is <15 µm, pyroxene 10-25 µm (Fig. 2).

Banded areas of aphanitic tan matrix are included in the aphanitic blue-grey matrix (Fig. 3). There are only minor differences between the mineralogy of the tan areas and that of the blue-grey matrix (Fig. 4). There appears to be significantly more olivine in the blue-grey portions and more augite in the tan

Figure 1: Freshly broken surface of impact melt breccia 76295. Scale is 1 cm. S72-56409.

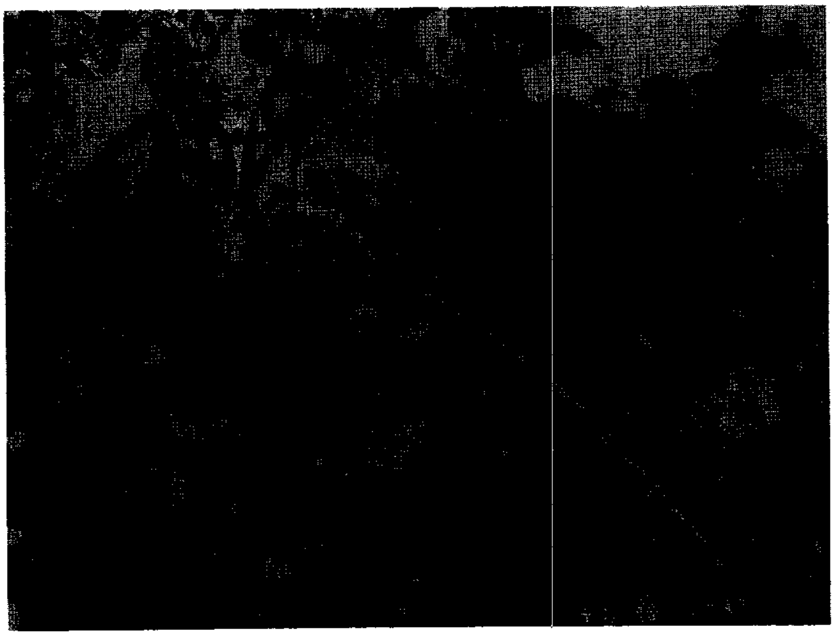


Figure 2: Photomicrograph of 76295,85, showing fine grain aphanitic matrix and vesicular basalt clast. Field of view is 4 x 5 mm.

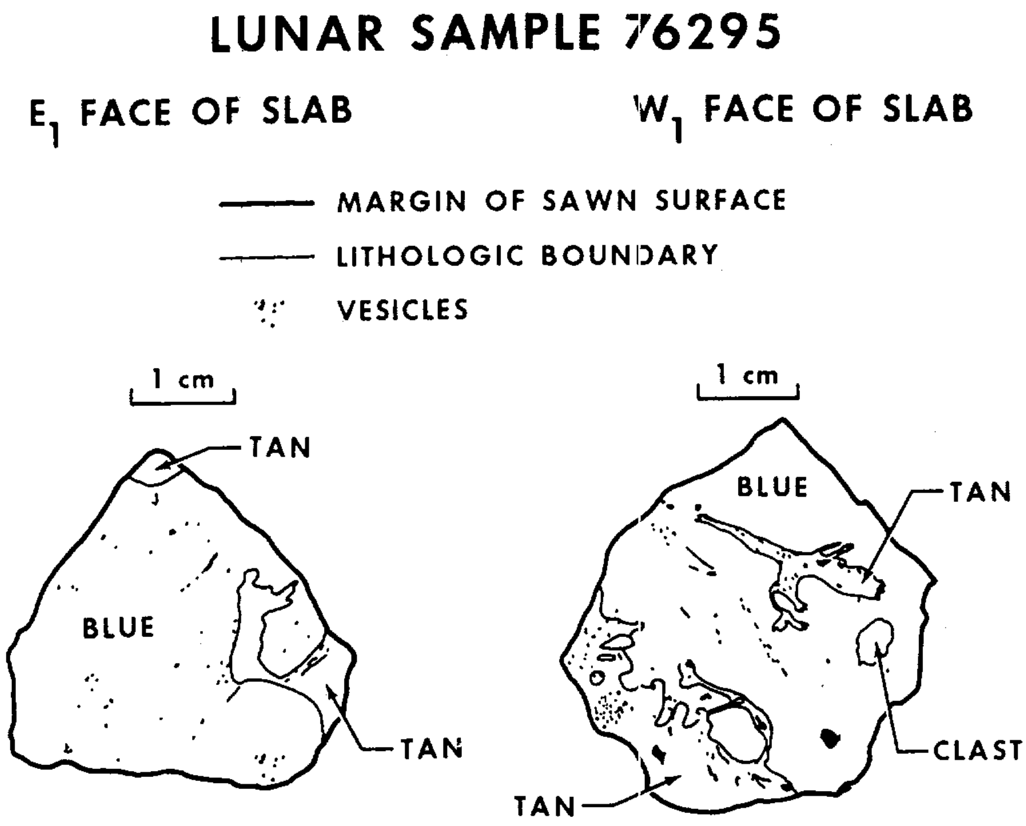


Figure 3: Maps of two slab surfaces through sample 76295.

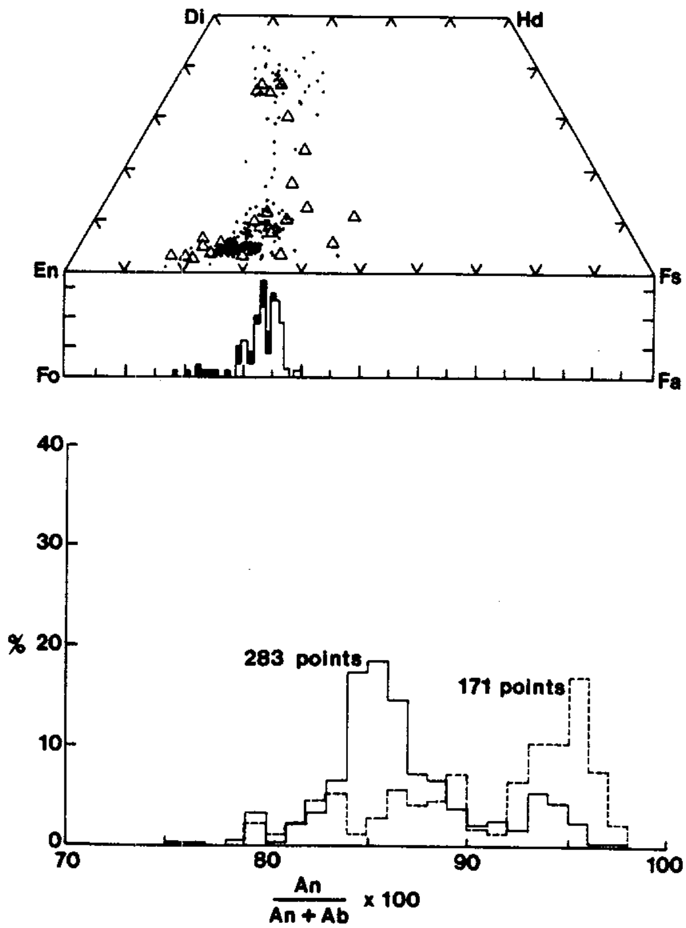


Figure 4: Mineral composition of blue-grey matrix and tan-grey clast veins in 76295. From Phinney (1981).

areas, but this is not well documented. Rare rounded clasts (50 μm) of pink spinel are found in the blue-grey subophitic matrix (Simonds, 1975).

Norman et al. (1993) have compared the composition of minerals in LKFM clasts in 76295 with minerals in similar clasts in 76315 (Fig. 5). They conclude that the clast population in 76295 is dominated by "Mg-suite norites, troctolites and gabbronorites." Minor-element abundances in both olivine and pyroxene are unlike those found in lunar rocks of the ferroan anorthosite suite.

Misra et al. (1976) have studied the complex metallic nickel-iron particles included in 76295.

WHOLE-ROCK CHEMISTRY

The matrix of 76295 is homogeneous and apparently similar to that of the other samples of this boulder (Fig. 6). Unpublished chemical data are reported in Phinney (1981). There is no difference between the REE composition of the tan matrix and that of the blue-grey matrix (Table 1). Higuchi and Morgan (1975) find that the trace siderophile element composition of the matrix of 76295 is within the tight grouping of the Station 6 Boulder (meteorite group 2) on the Ir-Au-Re compositional diagram, but that the Ir-Au-Re ratios of the 76295 clasts are distinctly different (Fig. 7). The 76295 matrix has a higher abundance of these meteoritic elements than the matrix for 76015 and 76215 (Table 2). Some data for 76295 are also given in Simonds and Warner (1981).

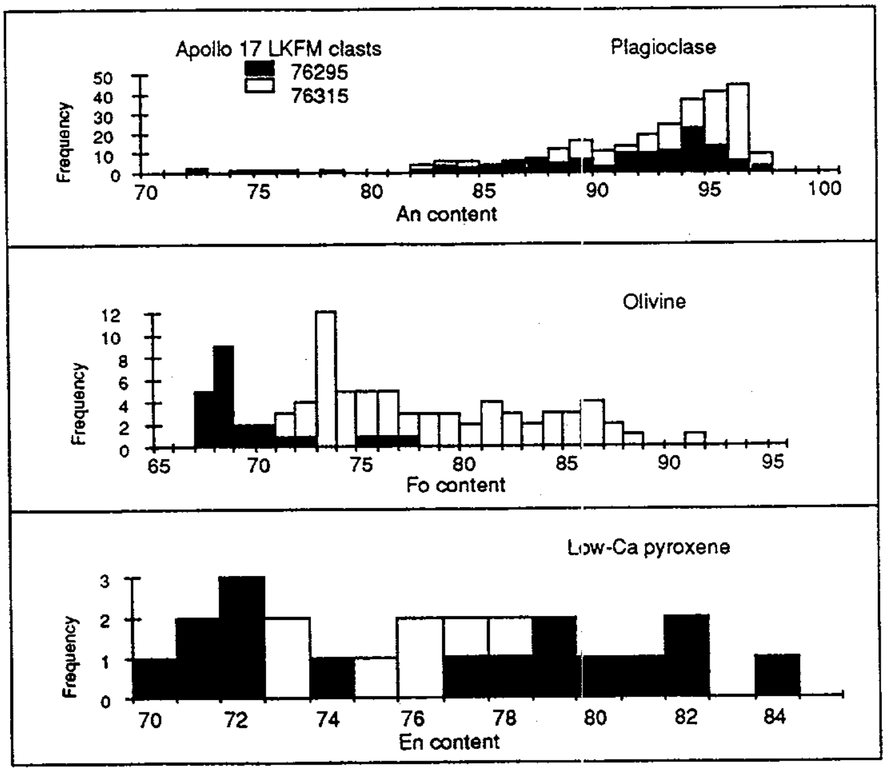


Figure 5: Histograms of plagioclase, olivine, and pyroxene compositions of clasts in 76295 and 76315. From Norman et al. (1993).

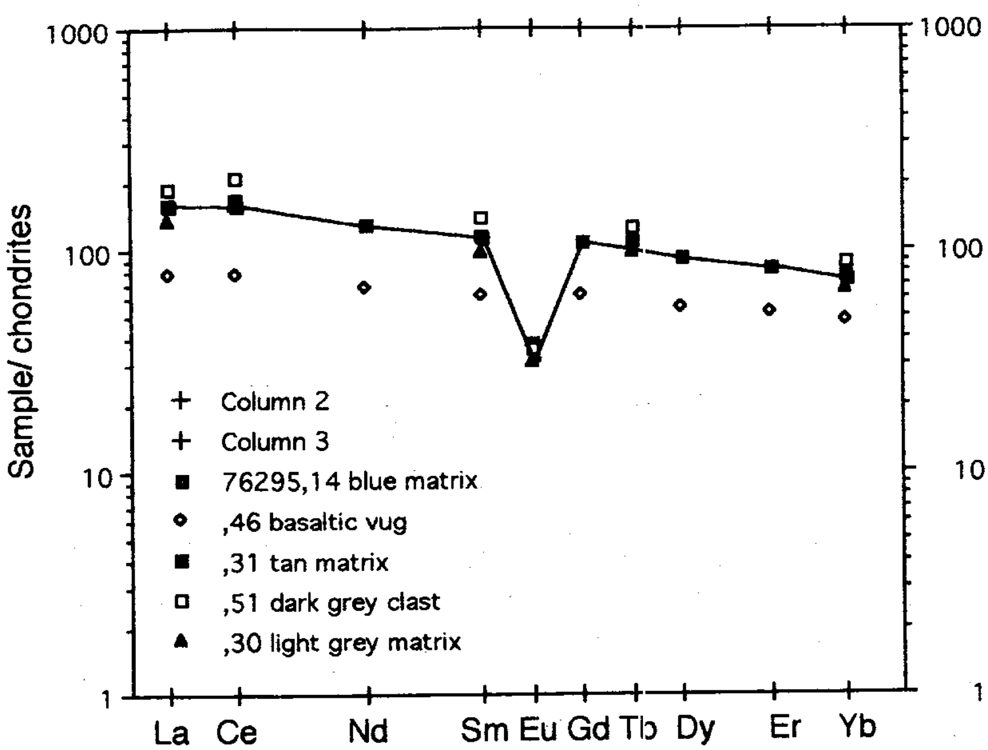


Figure 6: Normalized rare earth element diagram for matrices and clasts in breccia 76295. The blue-grey and tan matrices have the same exact composition. The dark grey clast has higher REE and the basalt is lower. The basalt is not like a mare basalt.

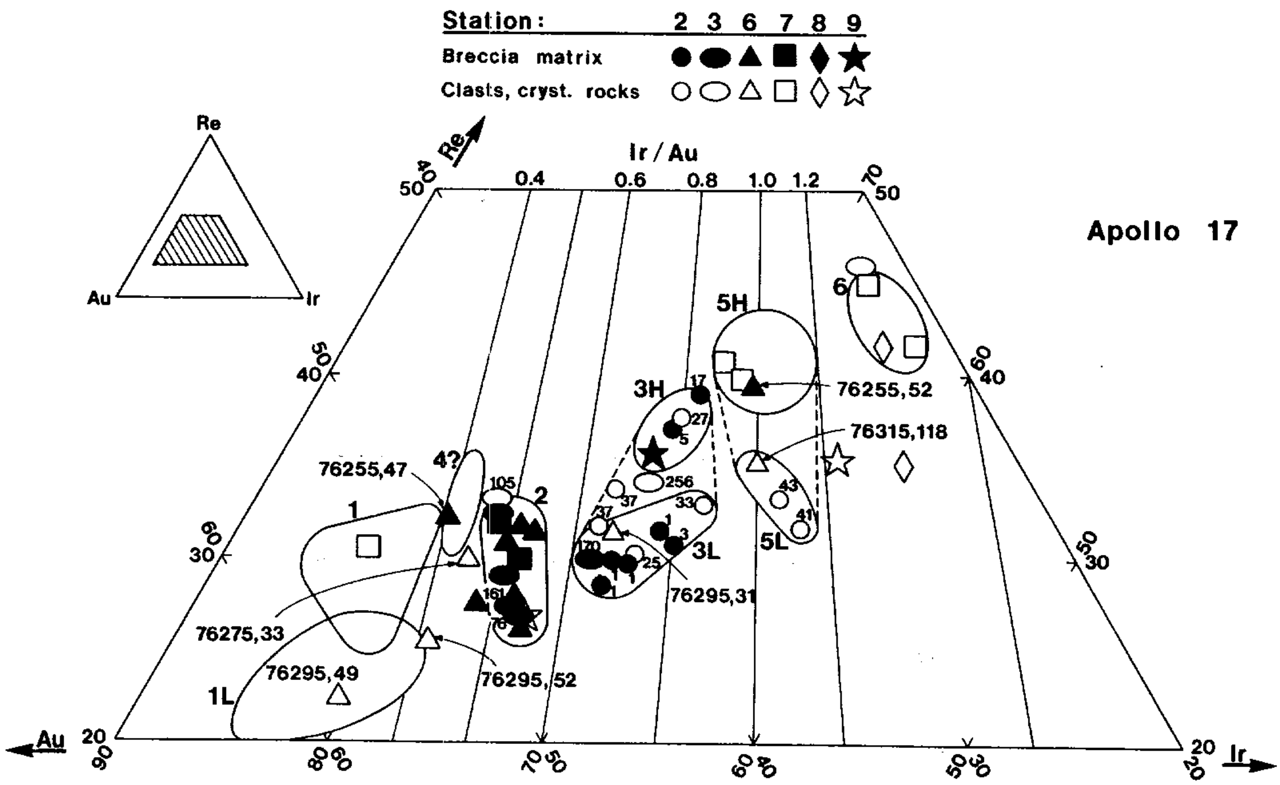


Figure 7: Ir-Au-Re diagram from Higuchi and Morgan (1975), showing that the 76295 clasts are slightly different from the breccia matrix (group 2).

SIGNIFICANT CLASTS

The dark grey and light grey aphanitic clasts analyzed by Phinney (1981) are, respectively, subophitic and poikilitic melt rocks quite similar to the fragments that form the matrix of the boulder. They have slightly higher KREEP contents than the matrix (Fig. 6).

Four small vuggy basalt clasts (similar to the large basaltic vug in 76015) occur in 76295. Because of their high porosity, these "clasts" appear to be vug fillings. Their texture is that of an intersertal basalt, but with pore spaces in place of mesostasis (Fig. 2). Plagioclase occurs as subhedral grains up to 300 µm long with inclusions of pyroxene, K-feldspar, opaques, and a silica phase concentrated at the rims (Phinney, 1981). Fig. 8 gives the mineral compositions of a porous basalt clast (from Simonds, 1975). The composition of the porous basaltic clast (see Table 1) is quite exotic, with preferential enrichment in the volatile elements such as Rb relative to U (Simonds, 1975).

Simonds (1975) also studied the mineral composition of a "troctolite" clast in 76295 (Fig. 9).

RADIOGENIC ISOTOPES

Cadogan and Turner (1976) determined the crystallization age of two samples of 76295 by the ^{39}Ar-^{40}Ar plateau technique. The tan matrix yielded an intermediate temperature plateau age of 3.95 ± 0.04 b.y., and the blue-grey matrix yielded one of 3.96 ± 0.04 b.y. Both exhibited appreciable high-temperature decreases in ^{40}Ar over the last 30% release (Fig. 10).

Unpublished U-Th-Pb data by Leon Silver were reported in Phinney (1981).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Some of the Apollo 17 samples (including 76295) provided a unique opportunity to study the energy spectrum (and potential angular anisotropy) of the incident proton flux from the August 1972 solar flare (Rancitelli et al., 1974; Keith et al., 1974).

Bogard et al. (1974; see unpublished data in Phinney, 1981) have determined the noble gas abundances in 76295.

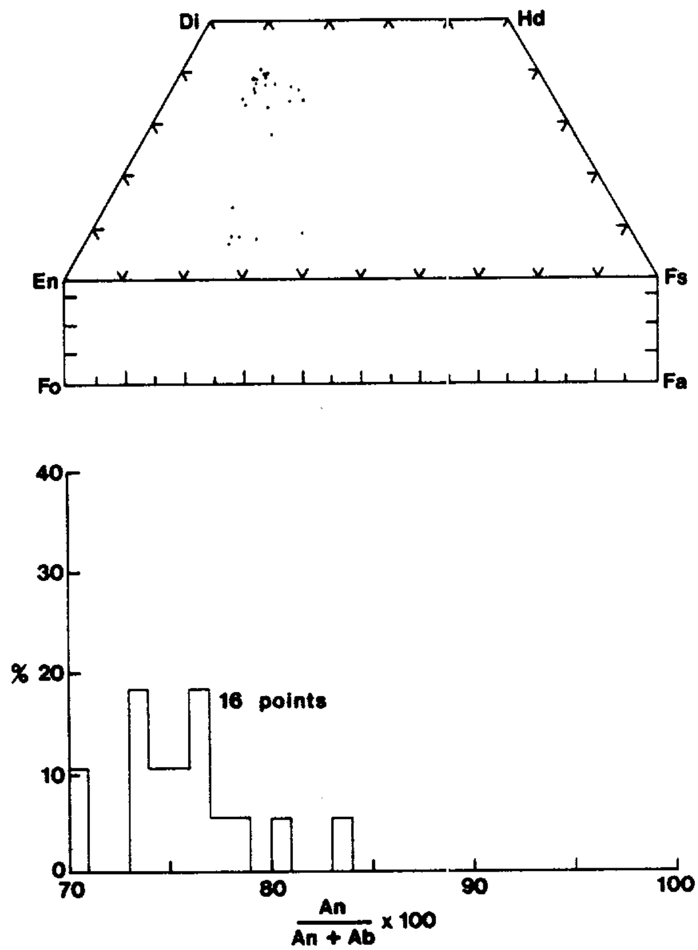


Figure 8: Microprobe analyses of minerals in a porous basaltic clast in 76295. From Simonds (1975).

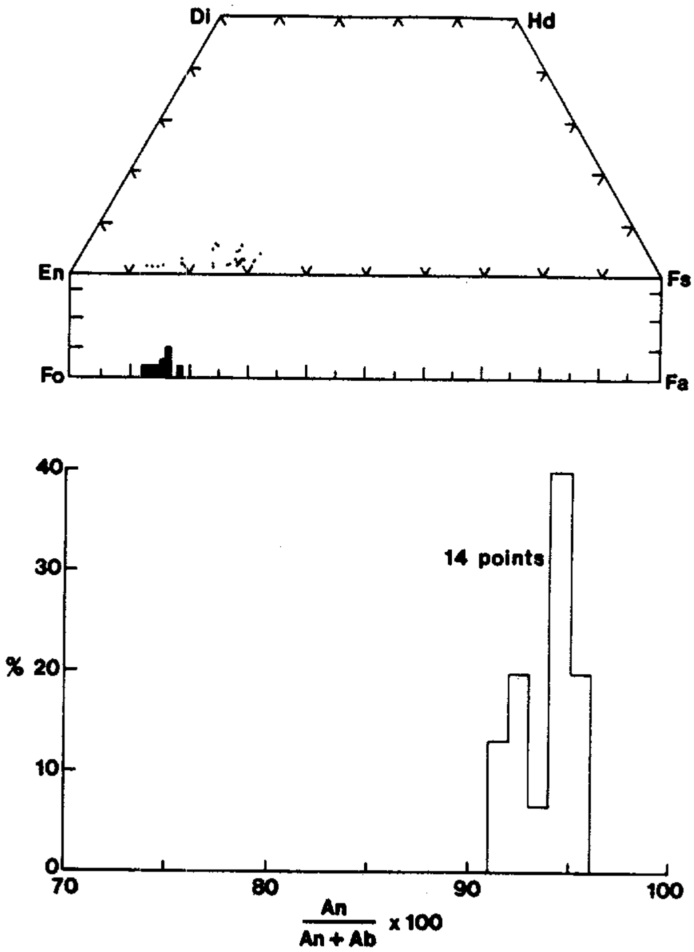


Figure 9: Microprobe analyses of minerals in a "troctolite" clast in breccia 76295. From Phinney (1981).

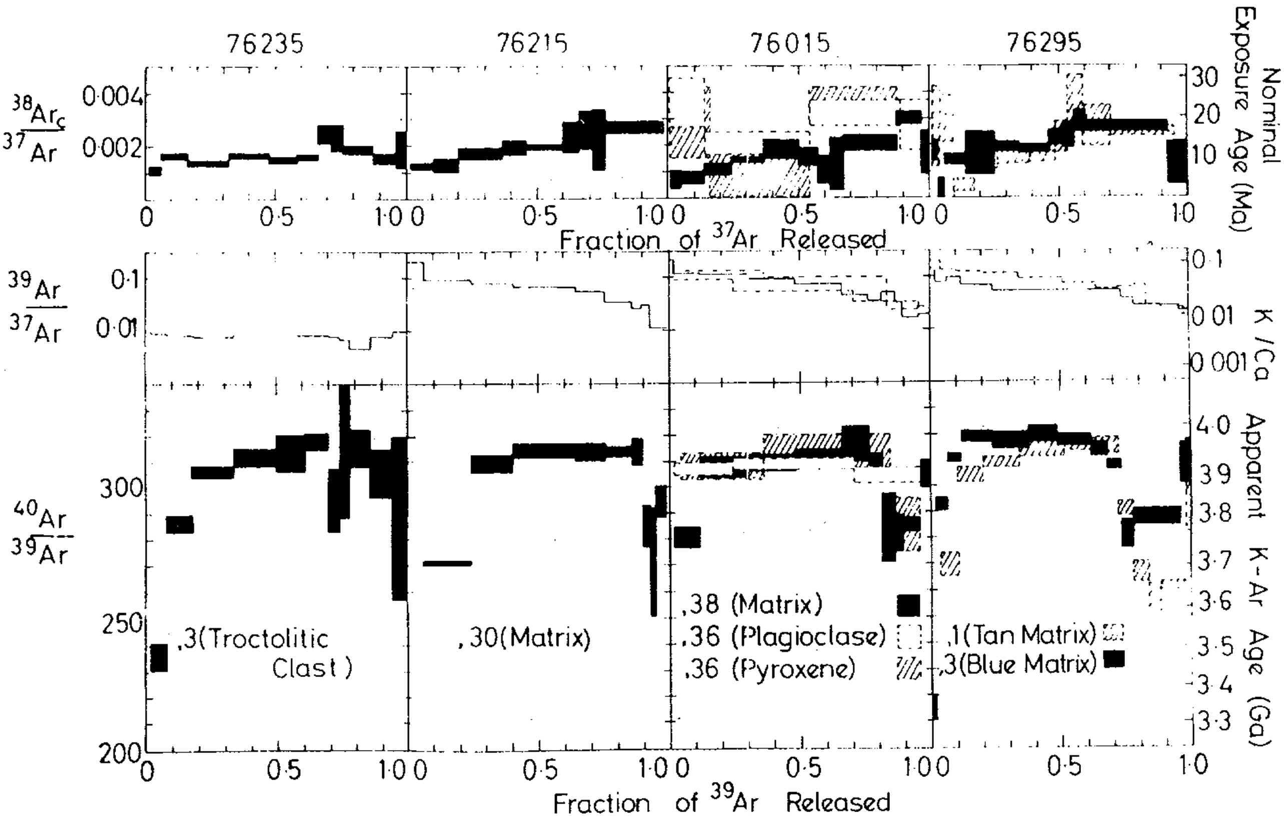


Figure 10: Ar-Ar release diagram for 76295 matrix. By Cadogan and Turner (1976).

MAGNETIC STUDIES

Gose et al. (1978) have carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder. The direction of magnetization after alternating field demagnetization of breccia sample 76295 was found to be scattered for this clast-rich sample. Gose et al. propose that the large scatter of magnetization direction of 76295 implies the predominance of pre-impact magnetization in this sample. Brecher (1976) is convinced that alignment of magnetism follows the direction of foliation and is caused by "textural remanent magnetization."

PROCESSING

A slab and a column were cut from this rock (see lithology maps and diagrams in Phinney, 1981).

Table 1: Whole-rock chemistry of 76295.
a) Simonds (1975); b) Wiesmann and Hubbard (1975); c) Phinney (1981)

Split Technique	,14 (a, b) IDMS blue matrix	,46 (b, c) fused bead basaltic vug	,31 ,35 (c) INAA tan matrix	,51 (c) INAA dark grey clast	,30 (c) INAA light grey clast
SiO_2 (wt%)	47.03	48.11	47.55	46.89	47.04
TiO_2	1.39	1.80	1.64	1.50	1.36
Al_2O_3	18.25	16.95	17.67	18.67	18.98
Cr_2O_3	–	0.17	0.17	0.17	0.16
FeO	9.09	9.17	9.05	8.79	8.44
MnO	–				
MgO	10.78	9.72	9.78	9.66	9.64
CaO	11.54	11.22	11.49	11.69	11.95
Na_2O	0.76	0.7	0.74	0.71	0.66
K_2O	0.26	0.6	0.29	0.23	0.28
P_2O_5	0.32				
S	0.06				
Nb (ppm)					
Zr	541	232			
Hf	–	–	13.2	16.3	12.4
Ta			1.9	2.4	1.7
U	1.83	0.66			
Th	6.12	2.01	5.6	7.6	5.2
Sr	–	191			
Rb	5.43	20.47			
Li	19.4	20.5			
Ba	376	334			
Ni			160	220	170
Co			19.9	28	23
Sc			17.8	18.2	16.7
La	37.8	18.2	37.5	44.2	31.8
Ce	95.7	46.6	102	127	95.8
Nd	60.0	31.1			
Sm	16.9	9.22	17	20.4	14.3
Eu	1.91	2.08	2.11	2.01	1.77
Gd	21.3	12.4			
Tb			3.91	4.56	3.56
Dy	22.3	13.3			
Er	13.2	8.06			
Yb	12.0	7.6	12.2	14.1	10.8
Lu	–	1.07	1.71	1.95	1.49

Table 2: Trace element data for 76295 matrix and clast. Concentrations in ppb.
From Higuchi and Morgan (1975).

	Sample 76295,31 clast	Sample 76295,34 matrix	Sample 76295,37 matrix	Sample 76295,49 basalt	Sample 76295,52 clast
Ir	5.98	6.1	7.88	3.18	5.42
Os					
Re	0.48	0.486	0.566	0.267	0.456
Au	2.65	3.43	4.36	2.91	3.93
Pd					
Ni (ppm)	179	218	250	146	203
Sb	1.03	1.68	393	1.84	2.11
Ge	198	374	316	321	423
Se	75	132	103	235	68
Te	2.4	4.62	4.9	5.81	1.9
Ag	0.87	5.09	4.55	1.03	1.2
Br	23.5	27.9	78.7	30.5	37.5
In					
Bi	0.46	0.8	0.97	0.4	0.56
Zn (ppm)	2.3	2.5	27.1	2.2	2.6
Cd	1.88	1	6.56	1.13	1.28
Tl	0.44	0.64	1.41	0.99	0.33
Rb (ppm)	3.31	4.22	9.2	12.5	1.75
Cs	192	297	151	649	110
U	1620	1320	1910	760	1940

76305–76307

Feldspathic Granulitic Impactites
76305 = 4.01 g, 76306 = 4.25 g, 76307 = 2.49 g

INTRODUCTION

Samples 76305, 76306, and 76307 are parts of 76235. They were chipped from the same light-colored clast in the boulder at Station 6. These fragments have a thin brown patina with micrometeorite craters on the surface (Fig. 1).

The magnetization of sample 76307 has been studied by Gose et al. (1978).

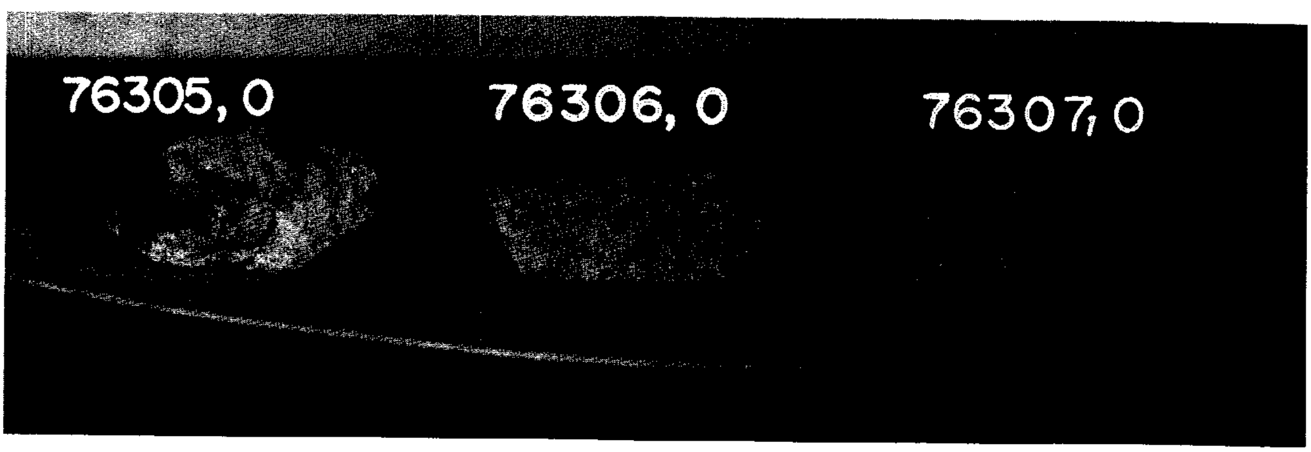


Figure 1: Feldspathic granulitic impactite 76305, 76306, and 76307. Cube is 1 cm. S73-16711.

76315

Micropoikilitic Impact Melt Breccia
671.1 g, 10 x 12 x 4.5 cm

INTRODUCTION

Sample 76315 was chipped from the side of the big boulder at Station 6 (Fig. 1). This blue-grey breccia sample is part of lithology AB, which is mapped as a "transitional zone" on Block 2 by Heiken et al. (1973). Sample 76315 is a micro-poikilitic impact melt breccia that has been studied by many investigators. It is typical of the other samples of the big boulder *(see the introduction section on the boulder at Station 6).*

PETROGRAPHY

The surface of 76315 was covered with patina (Fig. 2) to such an extent that the underlying lithology could not be discerned except on the freshly broken B1 face (Fig. 3). The broken surface was composed of dark grey breccia with a large irregular patch of "pink-grey" material and a 1 x 2 cm light grey clast (Phinney, 1981).

A distinct foliation is apparent in the slab of 76315 due to variations in matrix color, and trains of minute vesicles occur in the matrix. Along one edge of the slab and parallel to the foliation are white patches referred to as "clast 1" by Phinney (1981). However, this brecciated clast was apparently squeezed along the direction of foliation, forming a zone of weakness along which the rock was fractured during sampling from the boulder. The "clast 1" was found to be disappointingly small in volume.

The modal mineralogy of the matrix of 76315 is about 50% plagioclase and 40% low-calcium pyroxene with minor amounts of augite, olivine, ilmenite, armalcolite, and metallic iron (Fig. 4). The texture of the matrix of 76315 is micropoikilitic and similar to the matrix of the other samples of the large boulder (Simonds et al., 1974). The matrix consists dominantly of low-calcium pyroxene ($Wo_4En_{60-73}Fs_{19-26}$), minor augite ($Wo_{30-40}En_{44-57}Fs_{12-15}$), olivine ($Fo_{70-76}$), and feldspar ($An_{81-97}$). The grain size of matrix feldspar is ~10 μm; pyroxene is 25-30 μm. Histograms of matrix

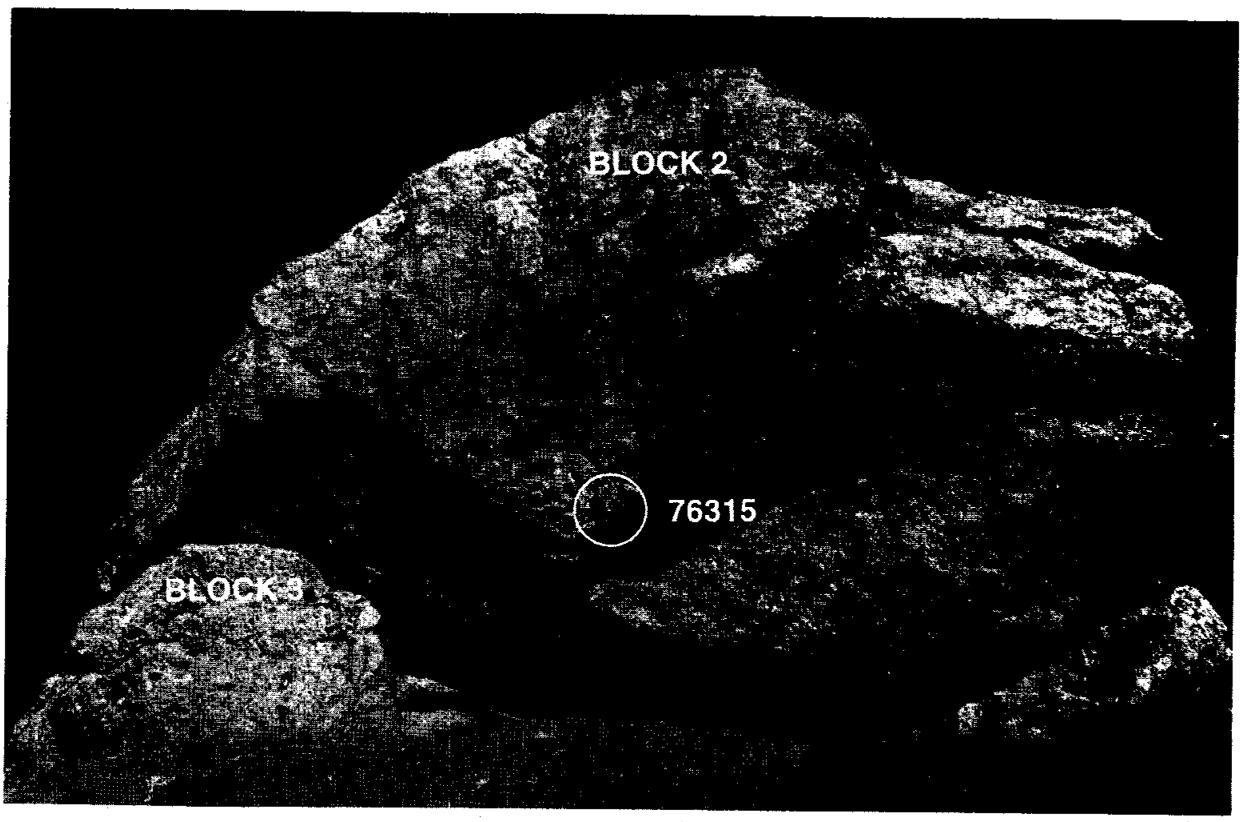


Figure 1: Photo of the downhill side of Block 2 of the Station 6 Boulder where sample 76315 was chipped. AS17-140-21436.

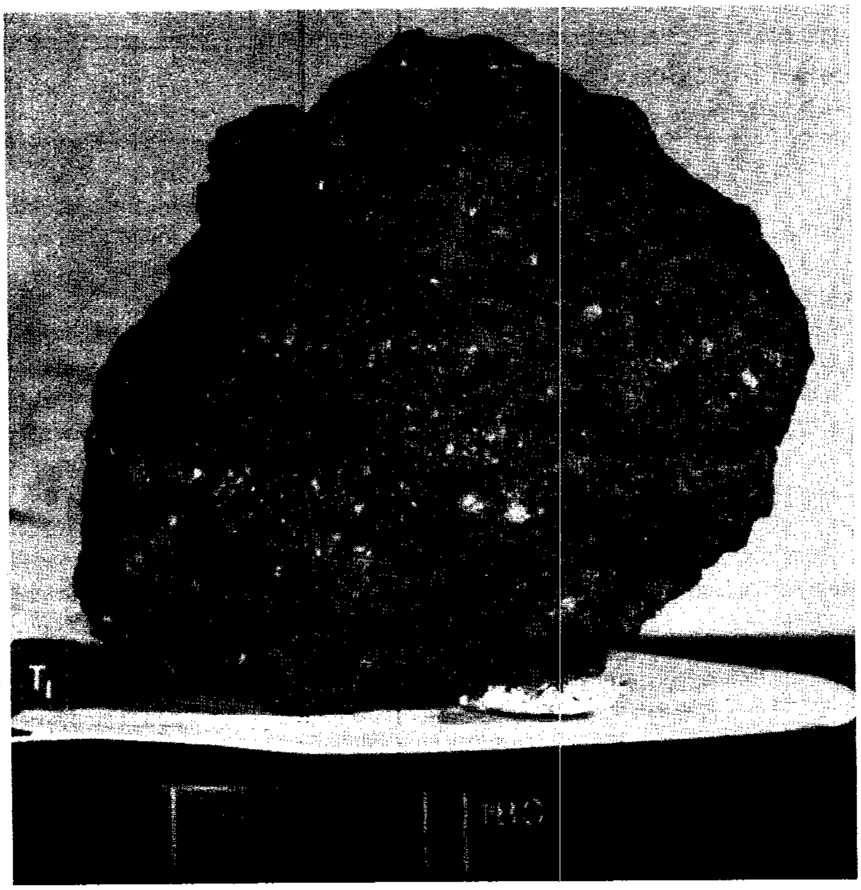


Figure 2: Exterior surface of 76315, showing thick patina and many micrometeorite pits. Scale is 1 cm. S73-17108.

mineral compositions (Fig. 5) from widely separated regions, including subophitic and micropoikiltic regions, showed similar compositions (Simonds et al., 1974).

Simonds et al. (1974) studied numerous small lithic clasts in 20 thin sections of 76315, including two poikilitic 70-80% feldspar fragments, three granulitic 70-80% feldspar fragments, one crushed feldspar or anorthosite fragment, three intersertal feldspar-pyroxene-olivine fragments, one crushed olivine or dunite, one poikilitic 50-60% feldspar fragment, two crushed spinel-olivine fragments, one crushed troctolite fragment, and three aphanitic feldspathic fragments. Among the mineral clasts in 76315, pyroxenes and olivine fragments range in Mg/Fe ratios above and below the composition of the matrix pyroxene (Simonds et al., 1974). The clast population in 76315 has also been studied by Norman et al. (1993).

Misra et al. (1976) have studied the complex metallic nickel-iron particles included in 76315.

WHOLE-ROCK CHEMISTRY

Simonds (1975) gives the chemical composition of 76315 and two of its clasts (Table 1). Morgan et al. (1974) and Gros et al. (1976) have determined the siderophile and trace element abundance of matrix and clasts in 76315 (Table 2). Jovanovic and Reed (1975) have determined F, Cl, I, Li, U, Ru, and Os in external and internal pieces of 76315. Allen et al. (1975) have reported heavy element abundances.

James (1994) has carefully reviewed the volatile and siderophile elements in Apollo 17 melt rock. There is remarkable similarity in the patterns of these elements in the matrices of all these samples.

SIGNIFICANT CLASTS

Clast 1 (,52) was a thin white rind along the side of the sample. The white rind's mineral mode, mineral composition, bulk composition, and textural data are reported in Simonds (1975) (Fig. 6). This granulitic clast has ~70% plagioclase (An_{95}), ~15% pigeonite ($Wo_{3-5}En_{83}Fs_{12}$), and ~15% olivine (Fo_{82}). See also the REE diagram (Fig. 7).

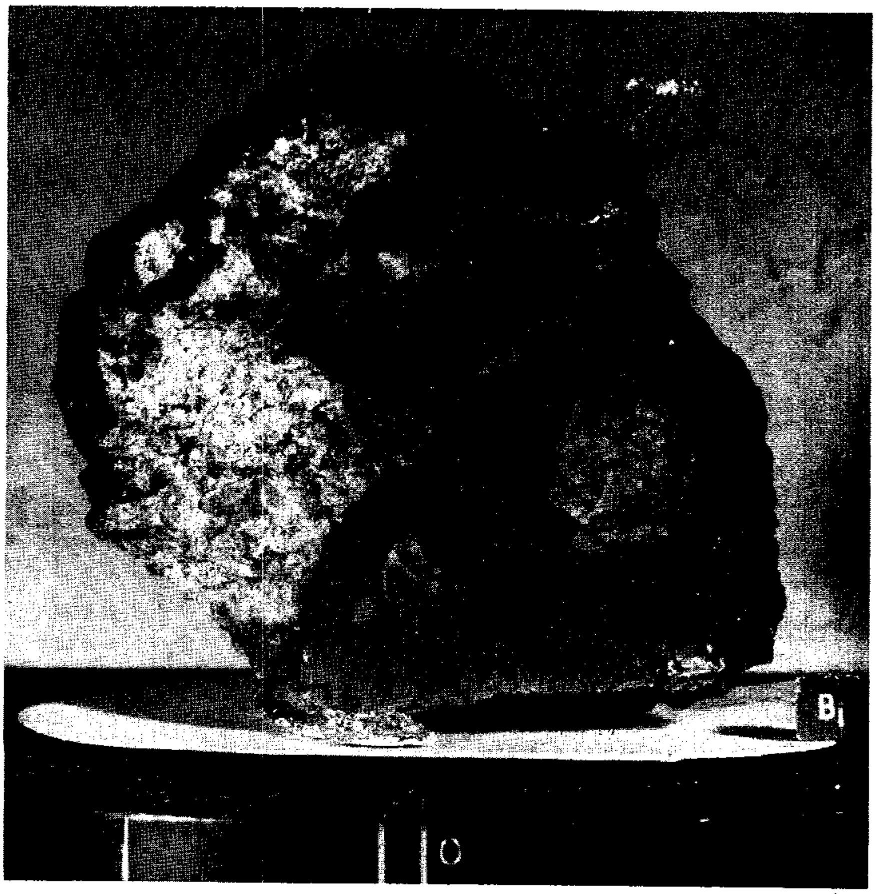


Figure 3: Freshly broken surface of 76315 showing two large, prominent clasts. The large pinkish-white clast (clast 1) was found to be very thin. The light grey clast (clast 2) was found to have a coarse poikilitic texture. The large pinkish-white clast was apparently a zone of weakness where the fragment broke from the boulder. Scale is 1 cm. S73-17109.

Figure 4: Photomicrograph of a portion of thin section 76315,111 illustrating aphanitic, poikilitic clast in aphanitic, micropoikilitic matrix. Field of view is 4 x 5 mm.

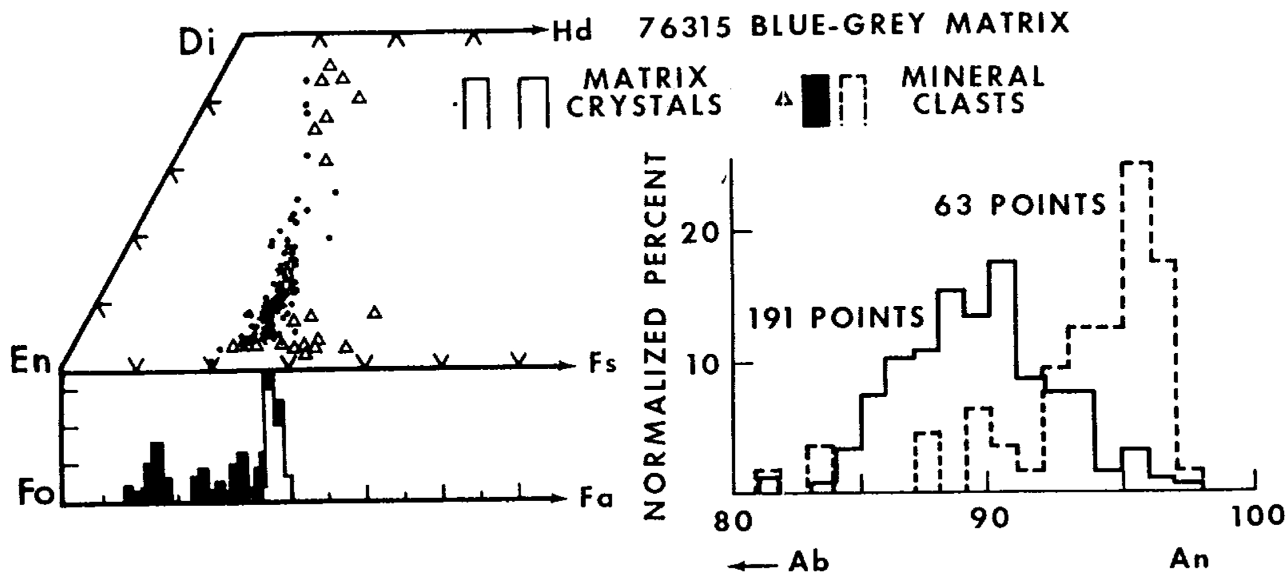


Figure 5: Composition of minerals in matrix of 76315 (from Simonds et al., 1974). Note the Ca-rich plagioclase and Mg-rich pyroxene mineral inclusions in the matrix.

Clast 2 (,62) was a light grey, poikilitic-texture, "anorthositic" clast with ~70% plagioclase (An_{95}), ~17% pigeonite ($Wo_{3-5}En_{78}Fs_{18}$), and ~13% olivine (Fo_{75}). The minerals in this clast were found to be very homogeneous in composition (Fig. 6).

RADIOGENIC ISOTOPES

Turner and Cadogan (1975 and 1976) report a well-defined Ar plateau age of 3.98 ± .04 b.y. for the matrix of 76315. The white anorthositic clast (,61) appears to have retained Ar from an older event (Fig 8) in the highest temperature release.

Nyquist et al. (1974) report Rb-Sr data for several splits of matrix from 76315 and note that the Rb-Sr systematics are probably partially reset by the Serenitatus impact event (Table 3). Unpublished U-Th-Pb data by Leon Silver were also reported in Phinney (1981).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Concordant ^{81}Kr-Kr and cosmic ray track ages from sample 76315 show that the Station 6 Boulder tumbled or rolled to the present position at the base of the North Massif 22 m.y. ago (Crozaz et al., 1974a). The incorrect 11 m.y. exposure age originally reported by Heiken et al. (1973) becomes consistent with the 22 m.y. age when one takes into account the fact that this sample was from the side of the boulder and only exposed to half the sky. Apparently, Heiken et al. incorrectly used production rates calculated on the basis of assumed 2π geometry (see discussion in Arvidson et al., 1975).

Turner and Cadogan (1975) reported a poorly defined Ar exposure age of around 13 m.y.

Bogard et al. (1974) have studied the rare gases in a large number of subsamples of 76315 (see unpublished data reported in Phinney, 1981).

MAGNETIC STUDIES

Pearce et al. (1974) and Gose et al. (1978) have carefully studied the remanent magnetization of 26 subsamples from the Station 6 Boulder. The direction of magnetization of sample 76315 (from unit AB) was difficult to determine because the high metallic iron content caused it to be very susceptible to the acquisition of an anhysteretic magnetism or a viscous magnetization. However, the direction of magnetization of this sample is more uniform

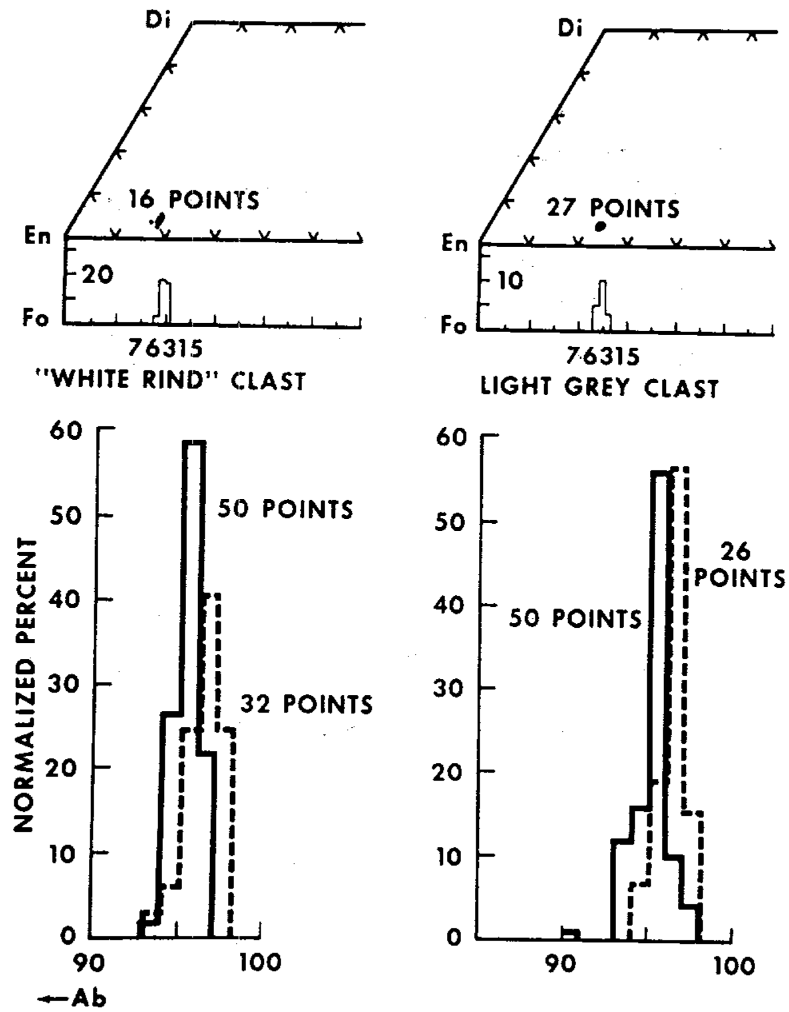


Figure 6: Plagioclase, olivine, and pyroxene composition in white-rind clast 1 and light grey clast 2 from 76315 (Simonds, 1975).

than for the more clast-rich samples. Nagata (1975) has reported the intensity of saturation magnetization for 76315. Brecher (1976) has proposed textural remanence in 76315. Stephenson et al. (1974) also attempted to determine the lunar magnetic field paleointensity using 76315.

SURFACE STUDIES

Adams and Charette (1975) have determined the reflectance spectra of the surface of 76315 and report that the spectra of poikilitic rocks are similar to KREEP with a slight upturn at the high wavelength (Fig. 9). It would be interesting to determine the difference in spectra for patina covered surfaces as compared with fresh surfaces of lunar rocks. The lack of a significant pyroxene adsorption band at 0.9 μm may be due to the thick glass patina on the surface of 76315.

PROCESSING

A slab and a column were cut from this rock (see lithology maps and diagrams in Phinney, 1981).

Samples of 76315 were allocated for several studies of "physical properties." Gold et al. (1976) determined "electrical properties." Housley et al. (1976) have determined the ferromagnetic resonance. Hoffman et al. (1974) have determined the iron distribution by Mössbauer spectroscopy.

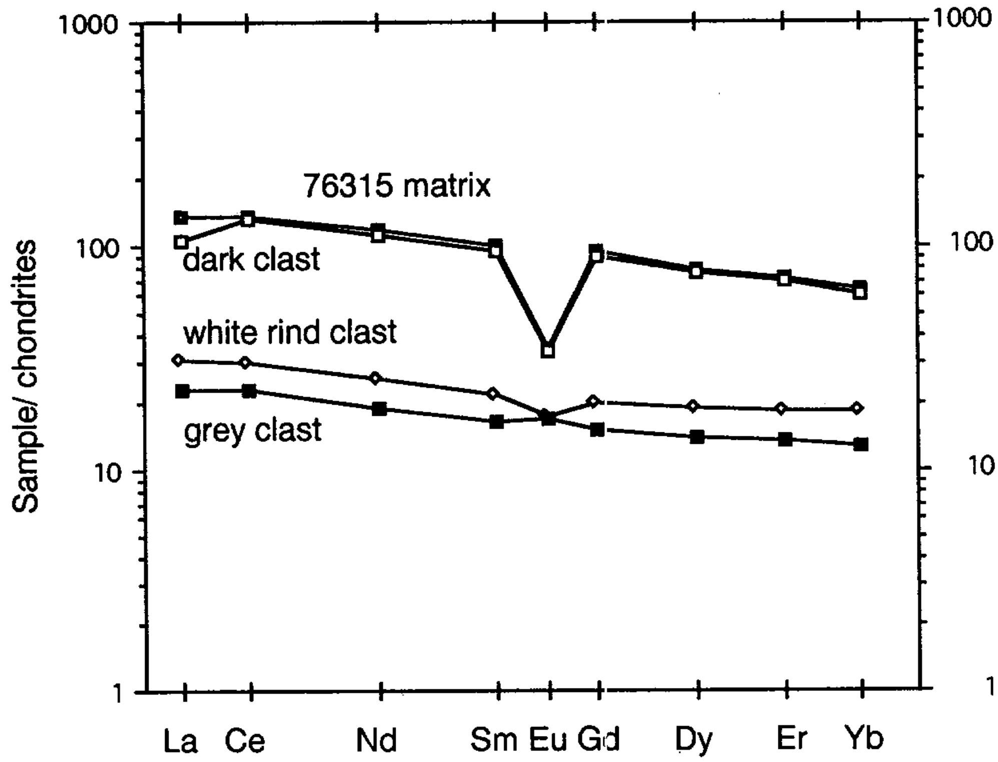


Figure 7: Normalized rare earth element diagram for matrix and clasts 1 and 2 in 76315.

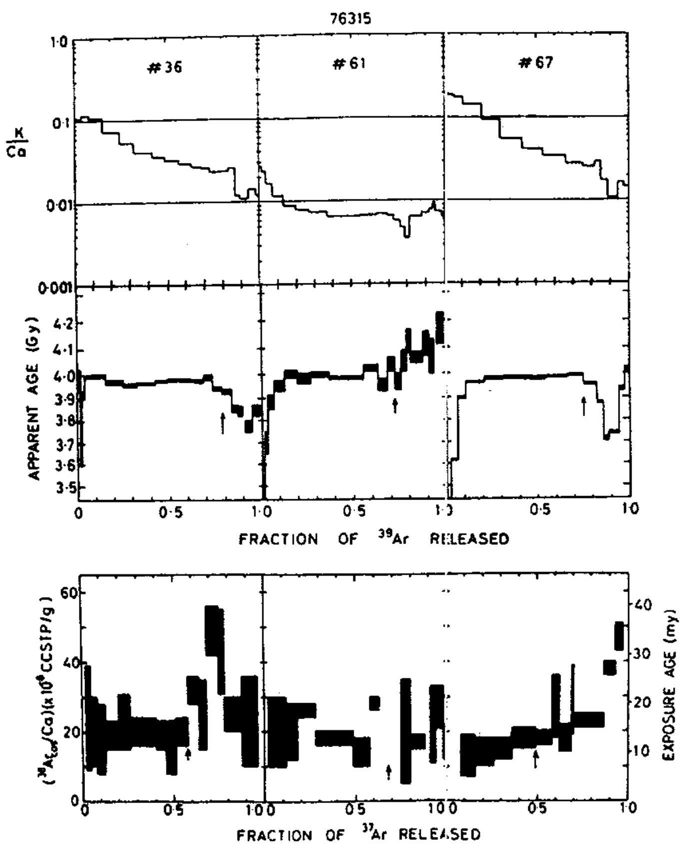


Figure 8: Ar-Ar plateau age of matrix and clasts in 76315. From Turner and Cadogan (1975).

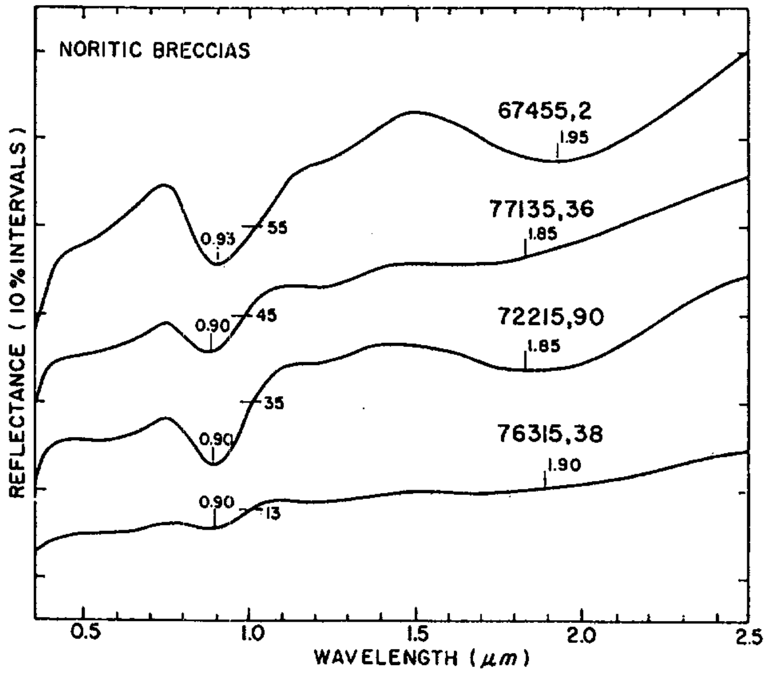


Figure 9: Reflectance spectra of 76315. By Adams and Charette (1975).

Table 1: Whole-rock and clast chemistry of 76315.
a) LSPET (1973); b) Rhodes et al. (1974a); c) Hubbard et al. (1974); Wiesmann and Hubbard (1975)

Split Technique	,2 (a, c) XRF, IDMS	,30M (b, c) XRF, IDMS matrix	,30,3 (b, c) XRF, IDMS clast	,35M (b, c) XRF, IDMS matrix	,52 (b, c) XRF, IDMS clast	,62 (b, c) XRF, IDMS clast
SiO_2 (wt%)	45.82	45.64	46.45	46.21	48.57	45.10
TiO_2	1.47	1.50	1.43	1.50	0.32	0.36
Al_2O_3	18.01	17.53	18.18	18.14	17.91	26.37
Cr_2O_3	0.19	0.19	0.20	0.19	0.12	0.11
FeO	8.94	9.53	8.83	8.95	7.66	5.29
MnO	0.11	0.13	0.13	0.12	0.13	0.07
MgO	12.41	12.50	12.34	12.02	13.84	7.46
CaO	11.06	10.97	11.30	11.32	10.36	15.12
Na_2O	0.57	0.70	0.64	0.60	0.47	0.47
K_2O	0.27	0.26	0.22	0.26	0.15	0.10
P_2O_5	0.29	0.30	0.29	0.29	0.12	0.06
S	0.08	0.08	0.07	0.07	0.00	0.04
Nb (ppm)	33	33	32	33	–	
Zr	477	485	465	522	105	95
Hf	12.5	–	11.9	–	–	5.3
U	1.52	1.47	1.36	2.52	0.34	0.343
Th	5.2	5.36	5.23	5.69	1.34	1.234
Y	111	113	107	111	–	
Sr	180	175	172	174	115	153
Rb	5.88	6.56	3.85	5.78	3.73	2.336
Li	14.6	15.6	14.1	13.9	11.8	9.5
Ba	359	349	366	337	129	72.8
Zn	4	3	2	4	–	
Ni	149	77	82	74	–	
La	30.1	32.9	24.7	31.6	7.33	5.41
Ce	84.6	84.0	78.6	82.3	18.4	13.7
Nd	53.5	53.5	50.2	52.7	11.5	8.6
Sm	15.1	15.1	14.1	14.8	3.2	2.42
Eu	2.00	1.97	1.88	1.95	0.971	0.94
Gd	18.9	18.5	17.6	18.8	3.93	2.99
Dy	19.9	19.7	18.3	19.1	4.59	3.39
Er	11.7	11.5	11.0	11.4	2.91	2.14
Yb	11.0	10.6	10.0	10.4	2.98	2.07
Lu	–	–	–		.455	0.30

Table 2: Trace element data for 76315. Concentrations in ppb.
a) Gros et al. (1976); b) Morgan et al. (1974)

	Sample (a) 76315,118 clast	Sample (b) 76315,73 matrix	Sample (b) 76315,74
Ir	18.6	5.42	5.97
Os	20.9		
Re	1.85	0.507	0.575
Au	6.41	3.21	3.48
Pd	22.6		
Ni (ppm)	423	256	260
Sb	0.85	1.49	1.54
Ge	57.7	346	354
Se	71	100	107
Te	3.4	4.04	5.1
Ag	0.72	0.84	0.88
Br	39.2	48	44
In	4.61		
Bi	0.44	0.098	0.28
Zn (ppm)	2	3.1	3.4
Cd	12.1	5	6.4
Tl	1.6	0.31	0.34
Rb (ppm)	2.73	5.91	5.9
Cs	110	250	250
U	355	1540	1490

Table 3: Rb-Sr composition of 76315.
Data from Nyquist et al. (1974).

Sample	76315,2	,35M	,30C3	,30M	,52	,62
wt (mg)	52.4	49.2	66.7	51.6	38.9	52.5
Rb (ppm)	5.88	5.78	3.85	6.56	3.73	2.34
Sr (ppm)	179.5	174.4	171.5	174.8	115.2	153.1
$^{87}Rb/^{86}Sr$	0.0948 ± 8	0.0960 ± 8	0.0650 ± 6	0.1086 ± 9	0.0937 ± 9	0.0441 ± 5
$^{87}Sr/^{86}Sr$	0.70515 ± 5	0.70521 ± 7	0.70351 ± 10	0.70595 ± 5	0.70491 ± 6	0.70185 ± 5
T_B	4.45 ± 0.08	4.44 ± 0.09	4.72 ± 0.14	4.40 ± 0.08	4.33 ± 0.08	4.35 ± 0.13
T_L	4.50 ± 0.08	4.49 ± 0.09	4.80 ± 0.14	4.46 ± 0.08	4.40 ± 0.08	4.46 ± 0.13

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

76335

Cataclastic Troctolite
502.89 g, largest piece 8 x 6.5 x 5 cm

INTRODUCTION

Sample 76335 is a pristine, friable "anorthosite" that was collected from the regolith about 15 meters from the Station 6 Boulder (LMP—"It's pretty fragile ... very white—looks like a crushed anorthosite"). It was returned in the BSLSS bag (which received rough handling on the return from the Moon). Fig. 1 shows the pieces of 76335 in a tray. The residue in the BSLSS bag (76330) contained additional pieces of this sample.

76335 is a poorly studied, potentially important piece of the original lunar crust that deserves additional study (Ryder and Norman, 1979). All of the thin sections are from one piece and may, or may not, be representative!

PETROGRAPHY

Warren and Wasson (1978) estimate the mineral mode of 76335 is 88% plagioclase ($An_{95.6}$) and 12% olivine ($Fo_{86.8}$). Bersch et al. (1991) also report minor low-Ca pyroxene. The plagioclase and olivine are shocked, but Warren and Wasson report that "the rock shows vestigial cumulate texture" with intact plagioclase grains up to 4 mm in dimension and relict olivine at least 2 mm across. The olivine has been crushed (Fig. 2).

MINERAL CHEMISTRY

The olivine and plagioclase compositions have been plotted in Fig. 3. Precise mineral compositions for olivine and low-Ca-pyroxene are given in Bersch et al. (1991). Ryder et al. (1980) report the composition of metal grains.

WHOLE-ROCK CHEMISTRY

Warren and Wasson (1978) have determined the composition of 76335 (Table 1). It is free of meteoritic contamination and low in trace element abundance (Fig. 4).

RADIOGENIC ISOTOPES

So far, no one has attempted to date 76335.

Note: Weight discrepancy with original catalog; additional pieces were selected from the fines in the BSLSS bag.

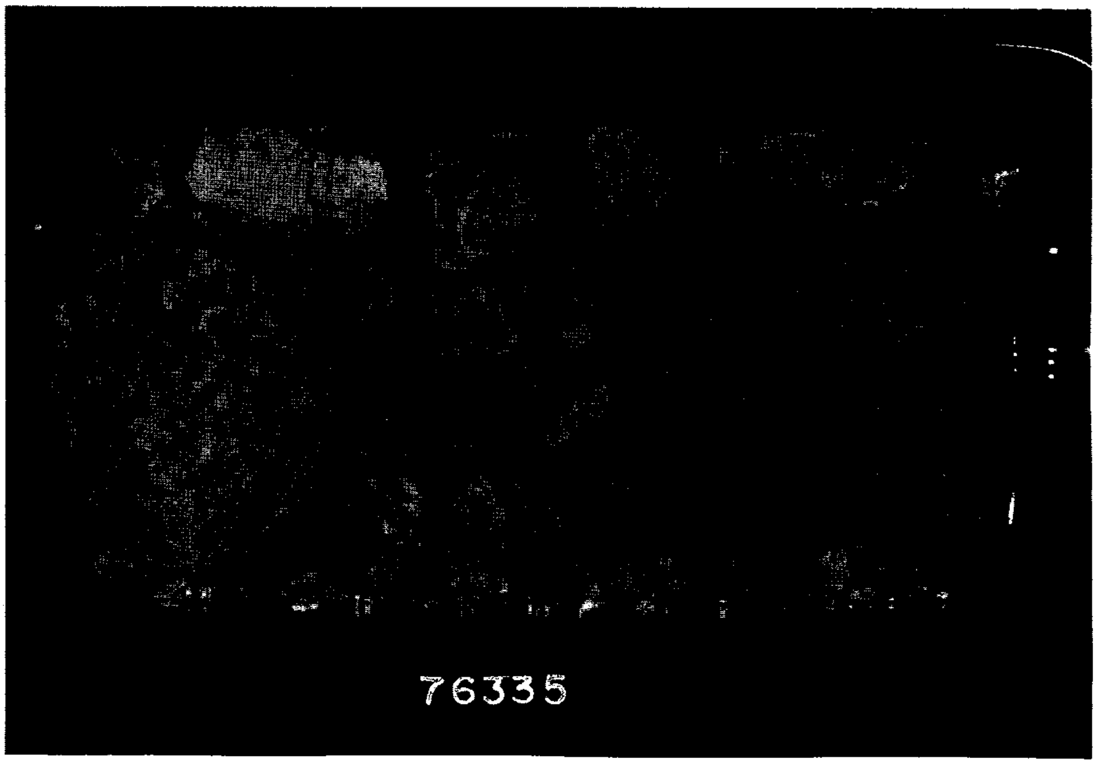


Figure 1: Tray full of 76335. S73-19384.

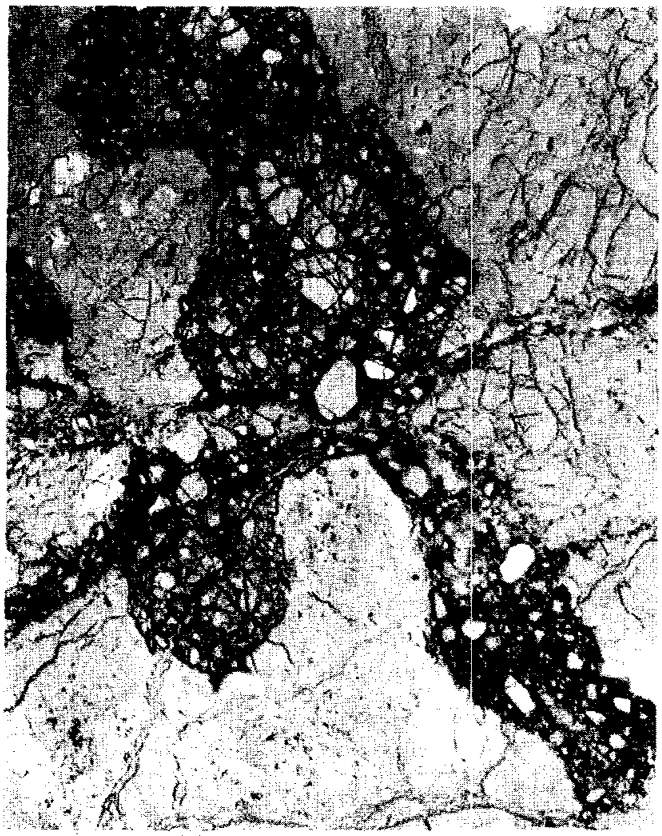


Figure 2: Photomicrograph of thin section 76335,28. Field of view is 2 x 3 mm.

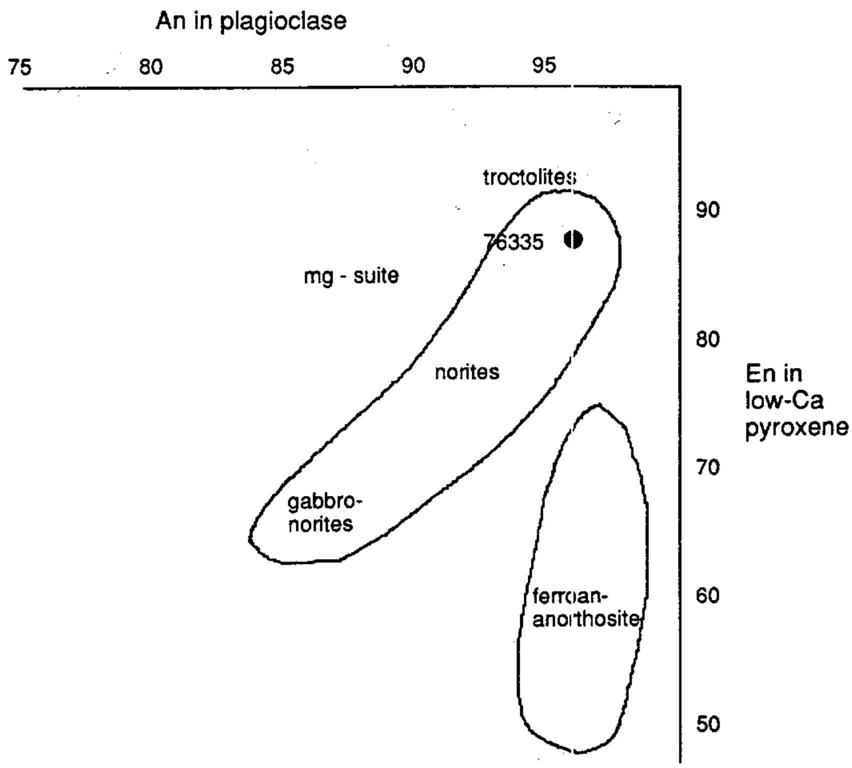


Figure 3: Diagram of plagioclase composition and olivine composition.

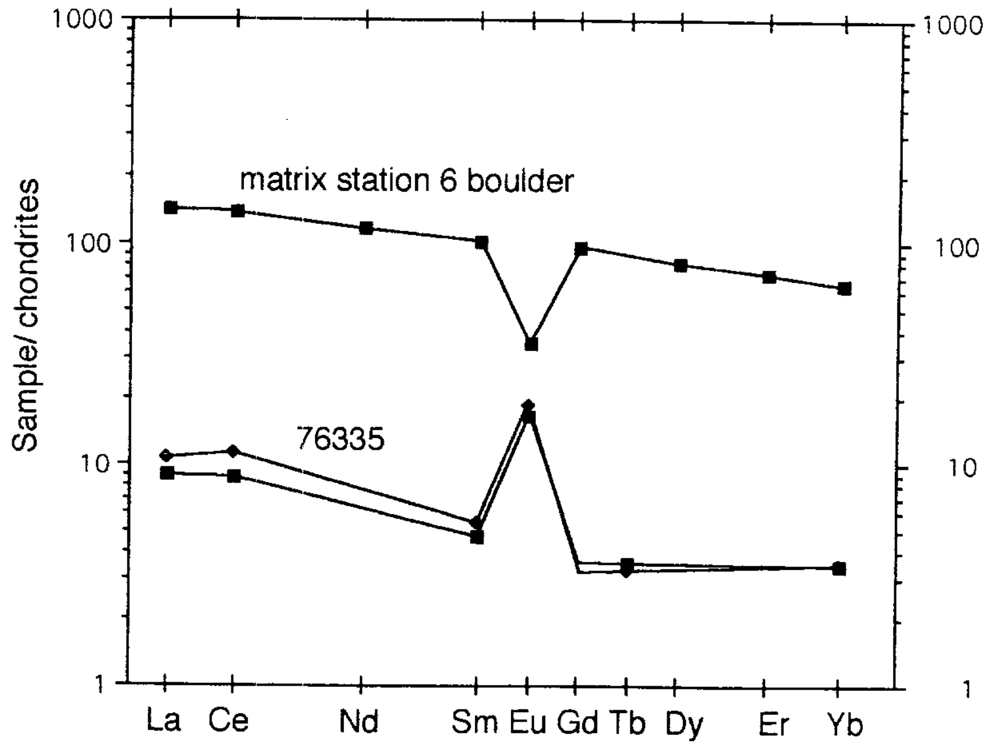


Figure 4: Normalized rare earth element diagram for 76335. Data by Warren and Wasson (1977).

Table 1: Composition of 76335.
From Warren and Wasson (1978).

	Sample 76335,38	Sample 76335,38
Na (%)	0.239	0.228
Mg (%)	5.4	6.2
Al (%)	16.5	14.6
Si (%)		20.3
K (%)	0.03	
Ca (%)	12	10.7
Sc (ppm)	1.33	1.72
Ti (%)		0.04
Cr (ppm)	356	408
Mn (ppm)	202	286
Fe (%)	1.75	2.3
Co (ppm)	13.1	15.6
Ni (ppm)	20.4	<20
Zn (ppm)	3.1	0.38
Ga (ppm)	3.5	3.15
Ge (ppb)	10.2	1.1
Zr (ppm)	160	
Cd (ppm)	5.2	8.7
In (ppm)	0.078	<1.1
Ba (ppm)	56	46
La (ppm)	2.47	2.12
Ce (ppm)	6.7	5.3
Nd (ppm)		
Sm (ppm)	0.8	0.7
Eu (ppm)	1.03	0.91
Tb (ppm)	0.12	0.13
Yb (ppm)	0.56	0.56
Lu (ppm)	0.073	0.082
Hf (ppm)	0.4	0.45
Ta (ppm)		
Re (ppb)		
Ir (ppb)	0.013	0.13
Au (ppb)	0.089	0.013
Th (ppm)		0.16
U (ppm)		0.1

76505
Micropoikilitic Impact Melt Breccia
4.69 g, 1.6 x 1.4 x 1.5 cm

INTRODUCTION

The original catalog by Butler (1973) describes 76505 as a "light greenish-grey breccia" and the rake sample catalog by Phinney et al. (1974) describes 76505 as an "annealed crystalline breccia." *Simonds and Warner (1981) and Simonds et al. (1975) mistakenly claim that 76505 is a "vitric matrix soil breccia," but correctly report that it has high Al and low Ti.*

PETROGRAPHY

Sample 76505 was sieved from highlands soil 76501. It is a coherent, light grey fragment (Fig. 1). Thin sections of sample 76505 show that it is a very fine-grained, micropoikilitic impact melt rock with only a trace of ilmenite (Fig. 2). The mode is roughly 55% plagioclase and 45% low-Ca pyroxene. Section ,8 also has a small patch of "granitic melt" surrounding a small vesicle.

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) report a preliminary analysis of 76505 by fused bead electron microprobe analysis (Table 1) *(these unpublished analyses are suspect because fusion may not have been complete).*

CLAST ?

The original catalog reported a second, darker lithology, but this turned out to be nothing more than some soil packed in a large vesicle of the feldspathic impact melt rock (Fig. 1).

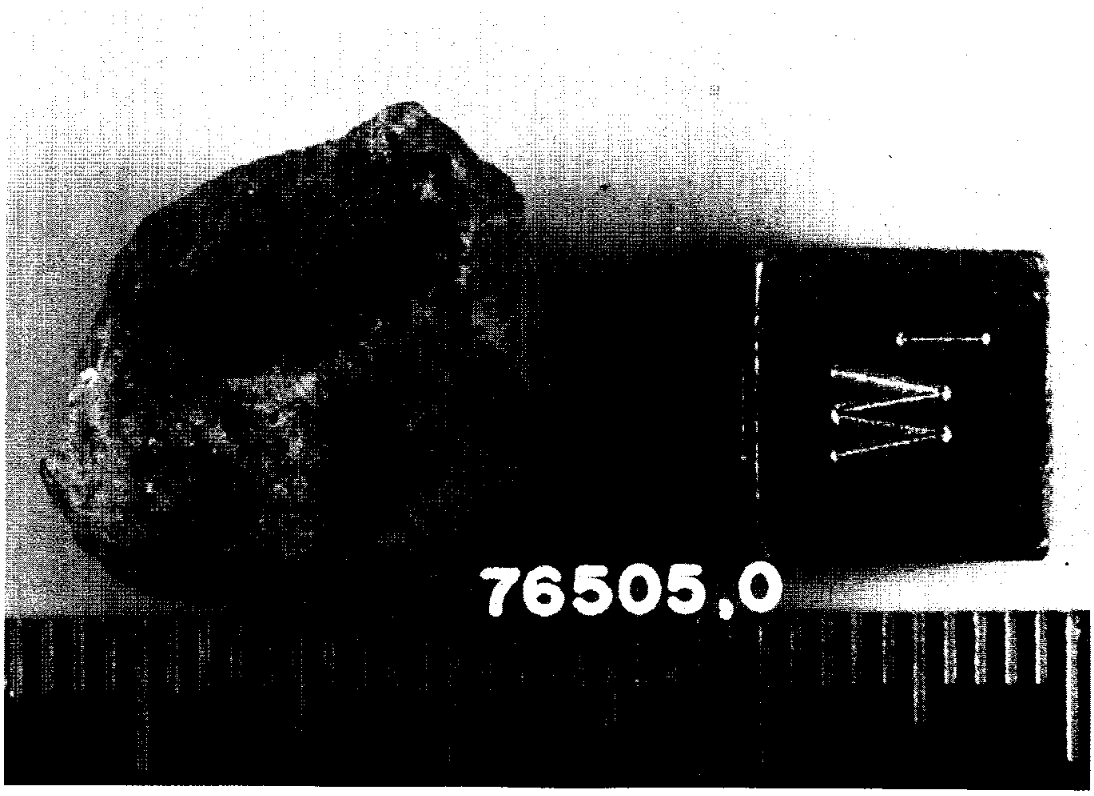


Figure 1: Photograph of light grey sample 76505. Scale bar is marked in 1 mm. S74-20167.

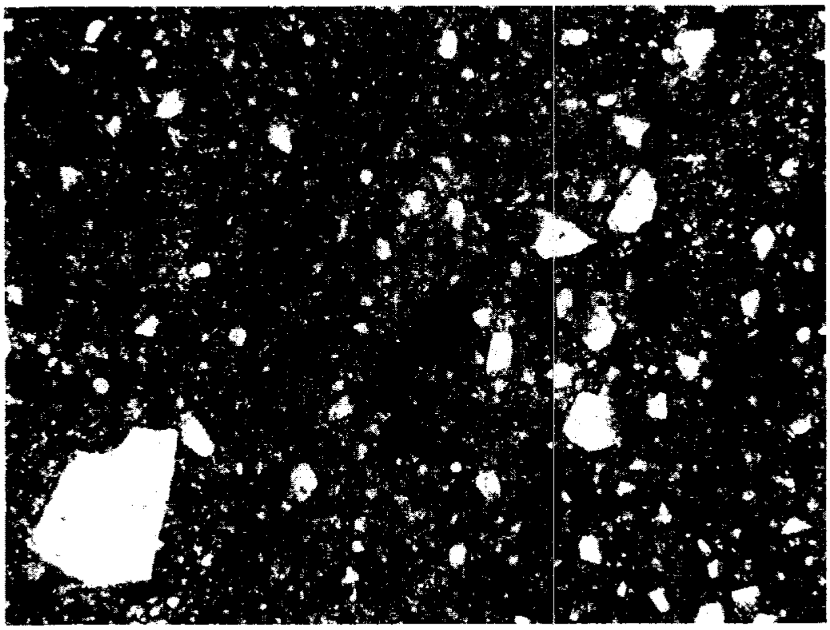


Figure 2: Photomicrograph of a portion of thin section 76505,8. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76505.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split Technique	,2 EMP
SiO_2 (wt%)	46.85
TiO_2	1.54
Al_2O_3	18.64
Cr_2O_3	0.19
FeO	7.82
MnO	
MgO	11.13
CaO	11.26
Na_2O	0.88
K_2O	0.29
P_2O_5	

76506
Dark Matrix Regolith Breccia
2.81 g, ~1.3 x 1 x 1 cm

INTRODUCTION

This sample was sieved from soil 76501. It is a regolith breccia with a brown glass matrix and a high percentage of mare component. It is clearly a lithified mare soil. *Simonds and Warner mistakenly label the analysis of 76506 as "clast-bearing fine grained micropoikilitic impact melt rock."*

PETROGRAPHY

Sample 76506 is a dark matrix regolith breccia (Fig. 1). Using SEM petrography, Phinney et al. (1976) term 76506 a friable microbreccia with 35% porosity. Thin sections show that this sample contains abundant orange glass beads and broken glass fragments (Fig. 2). It contains numerous mare basalt clasts and abundant ilmenite and was derived from the mare surface. However, it also contains small white clasts of feldspathic material from the lunar highlands (Fig. 2).

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) report an analysis with 4.6% TiO_2 and 11% FeO (Table 1).

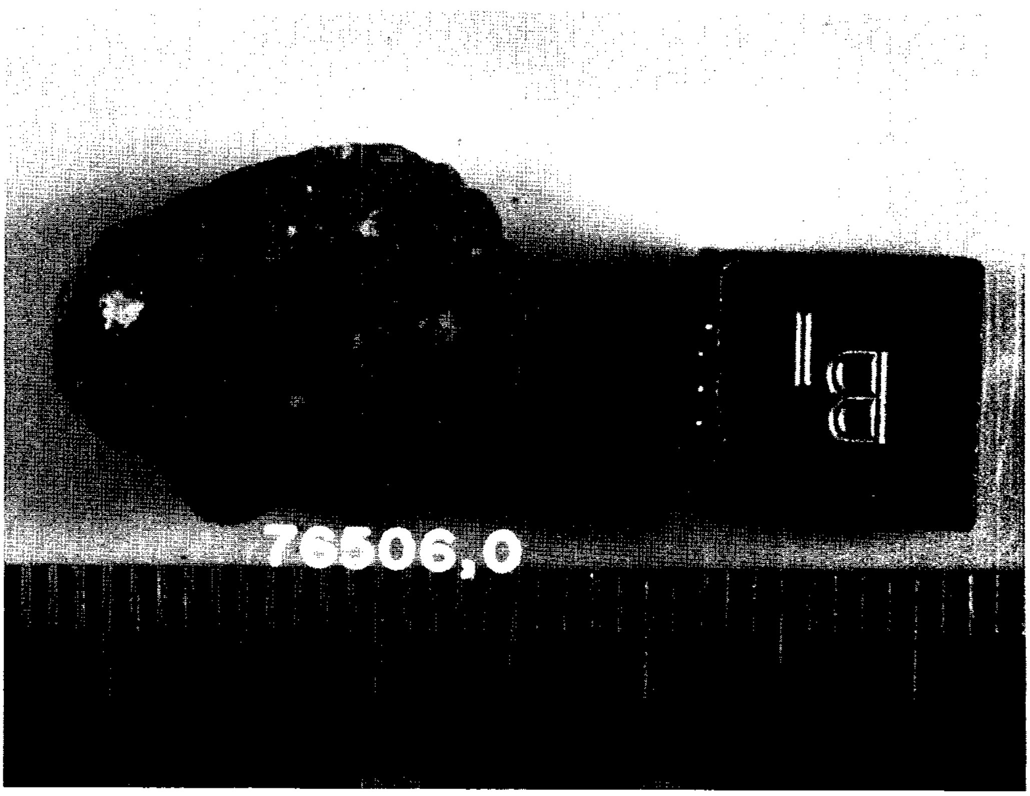


Figure 1: Photograph of 76506. Scale bar is in mm. S74-20168.

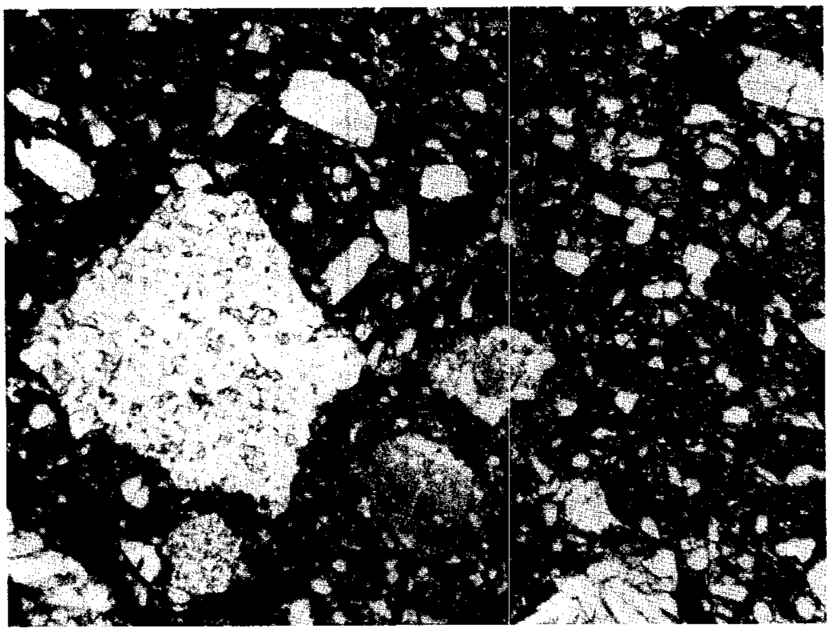


Figure 2: Photomicrograph of thin section 76506,7. Dark matrix contains orange glass. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76506.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split **Technique**	**,2** **EMP**
SiO_2 (wt%)	42.94
TiO_2	4.64
Al_2O_3	16.74
Cr_2O_3	0.30
FeO	11.08
MnO	
MgO	10.36
CaO	11.73
Na_2O	0.49
K_2O	0.12

Rake Samples from Station 6

The collection of samples by raking the soil and shaking out the fine material has proven to be one of the best ways to sample the lunar surface. Fig. 1 shows the rake used on the Moon. It has wires spaced at 1 cm in the scoop so that everything less than 1 cm will shake out. The Station 6 rake sample was taken from the rim of a small (~10 m) subdued crater about 20 meters west of the large boulders (Fig. 2).

The rake samples collected at Station 6 were originally cataloged by Butler (1973) and Phinney et al. (1975). They are also discussed in Wolfe and others (1981). A large soil sample, 76501, was also collected at the same location, and the coarse fines (4 mm-1 cm) sieved from it were cataloged by Meyer (1973). Jolliff et al. (1993) are studying the 2-4 mm coarse fines from the North Massif (Fig. 3). Sample 76505 and 76506 were sieved from soil 76501.

A surprisingly large amount of mare material from the valley floor is found included in this rake sample, considering that this site was located on the talus of the North Massif. The Station 6 rake sample was important because it collected 76535 (a pristine troctolite), which has become our most interesting sample of the Moon.

The rake samples were returned in SCB 4/558. The residue from this bag is numbered 76530. A summary of the rock types found in this rake sample is given in Table 1.

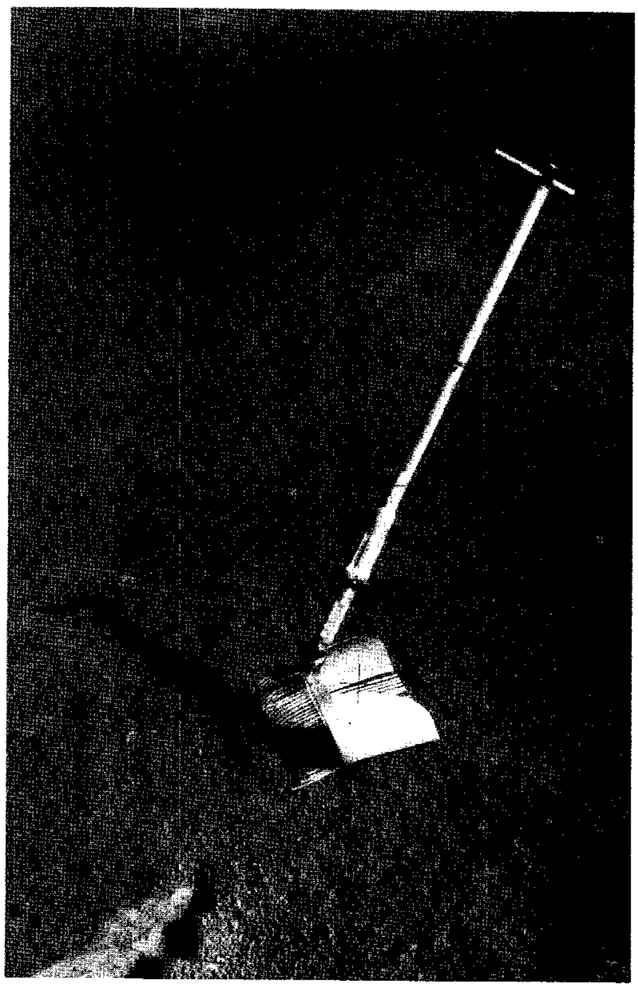


Figure 1: Rake used to collect samples. Wires spaced at 1 cm. AS17-142-21706.

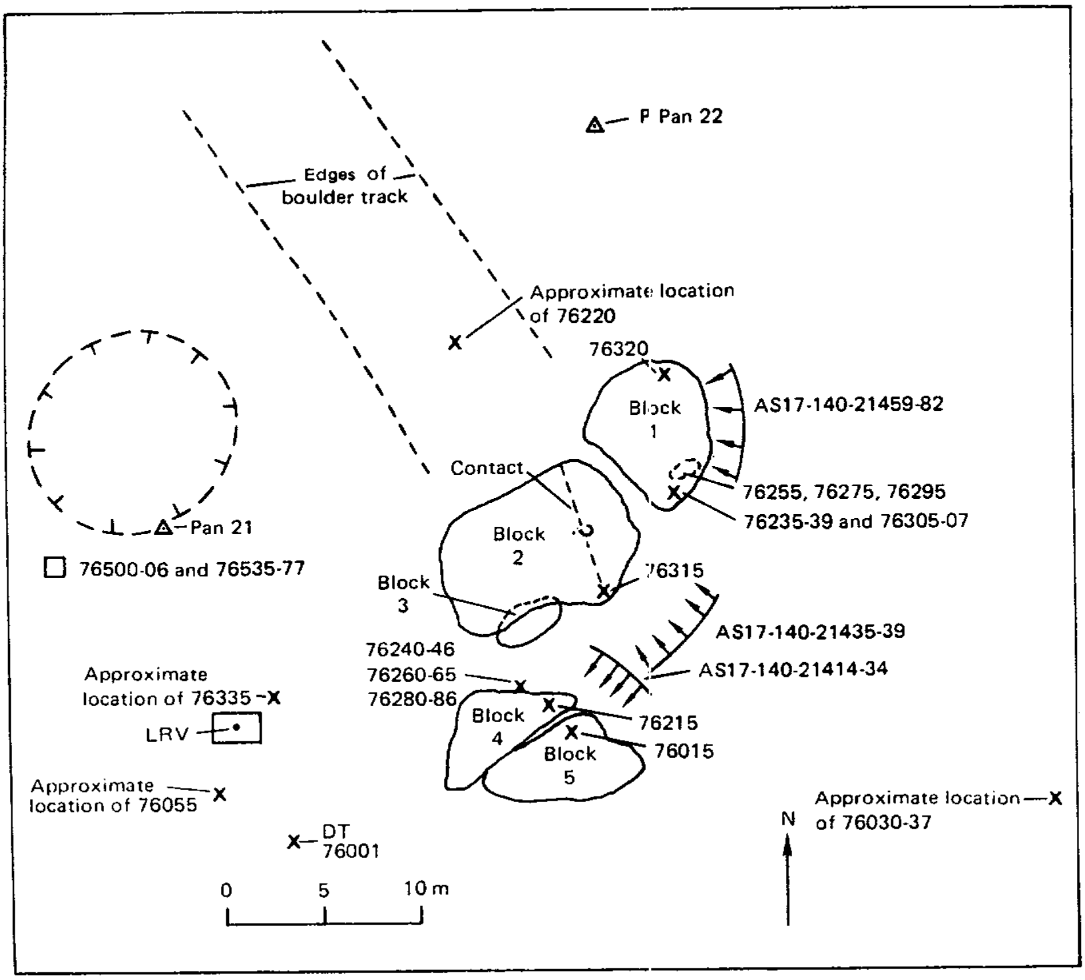


Figure 2: Sketch map of Station 6 showing the location of the area where the rake samples were collected.

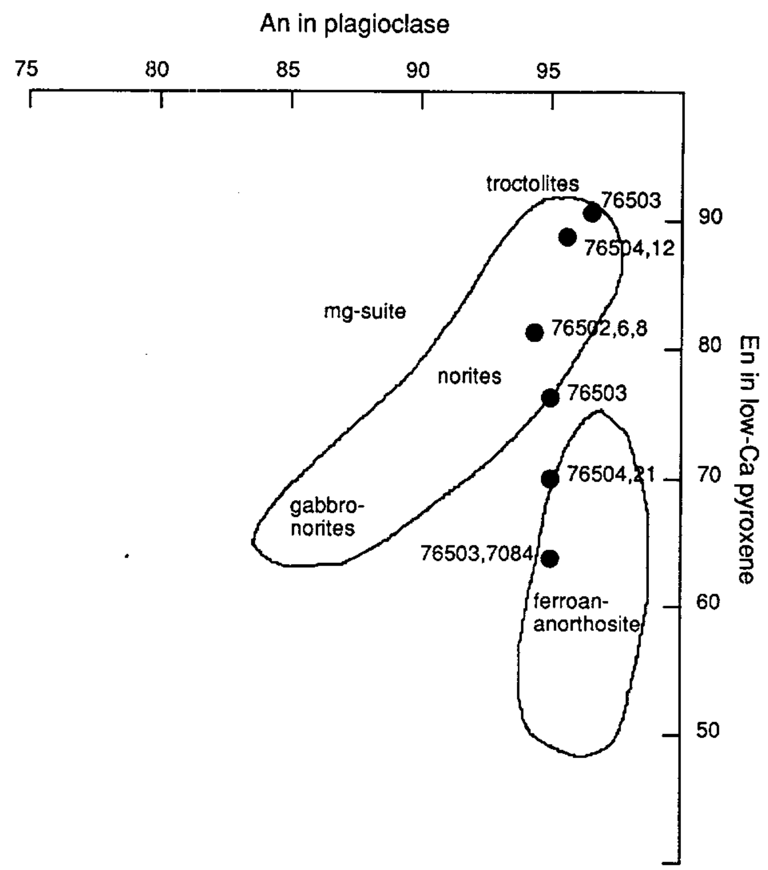


Figure 3: Plagioclase vs. pyroxene composition diagram. Fields are from James and Flohr (1983). Data are from Jolliff et al. (1993).

Table 1: Summary of rake samples from Station 6.

76535	Troctolite
76536	Crushed Troctolite
76537	High-Ti Mare Basalt
76538	High-Ti Mare Basalt
76539	Aphanitic High-Ti Mare Basalt
76545	Dark Matrix Regolith Breccia
76546	Dark Matrix Regolith Breccia
76547	Dark Matrix Regolith Breccia
76548	Dark Matrix Regolith Breccia
76549	Dark Matrix Regolith Breccia
76555	Micropoikilitic Impact Melt Breccia
76556	Micropoikilitic Impact Melt Breccia
76557	Micropoikilitic Impact Melt Breccia
76558	Impact Melt Breccia
76559	Poikilitic Impact Melt Breccia
76565	Dark Matrix Regolith Breccia
76566	Dark Matrix Regolith Breccia
76567	Light Matrix Regolith Breccia
76568	Aphanitic High-Ti Mare Basalt
76569	Aphanitic Impact Melt Breccia
76575	Feldspathic Impact Melt Breccia
76576	Micropoikilitic Impact Melt Breccia
76577	Poikilitic Impact Melt Breccia

76535
Troctolite
155.5 g, ~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 ($Wo_1En_{86}Fs_{13}$), 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 (~10^8 y.) in the temperature range 1100 °C to 600 °C. Stewart termed this "Apollonian" metamorphism.

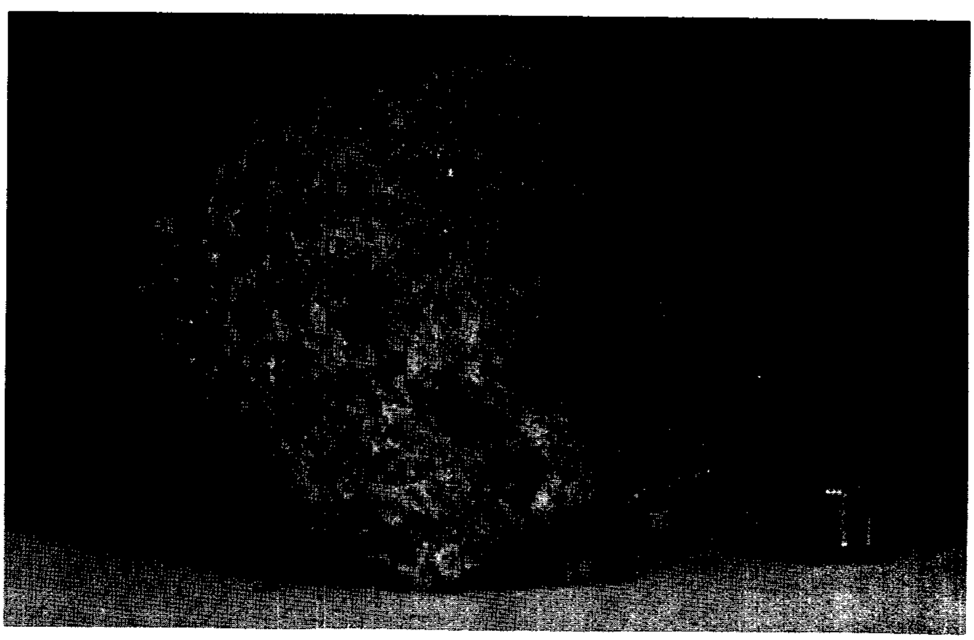


Figure 1: Photograph of lunar troctolite 76535. Cube is 1 cm. S73-19459.

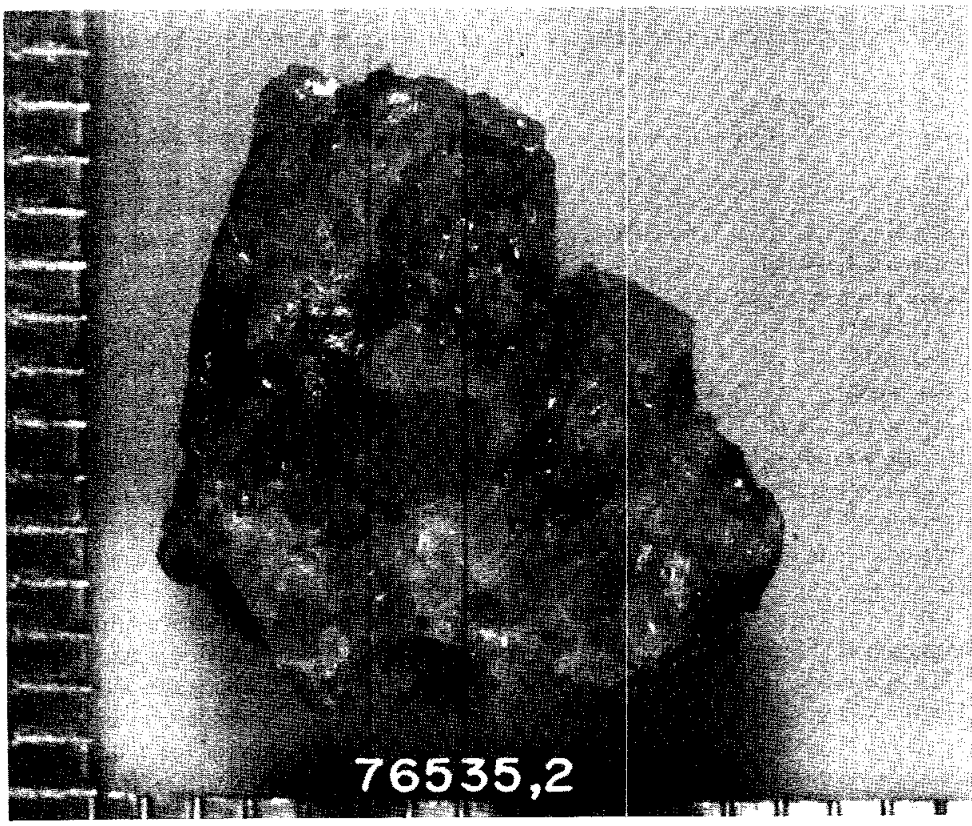


Figure 2: Photograph of lunar troctolite 76535,2. Scale bar is marked in mm. S73-19601.

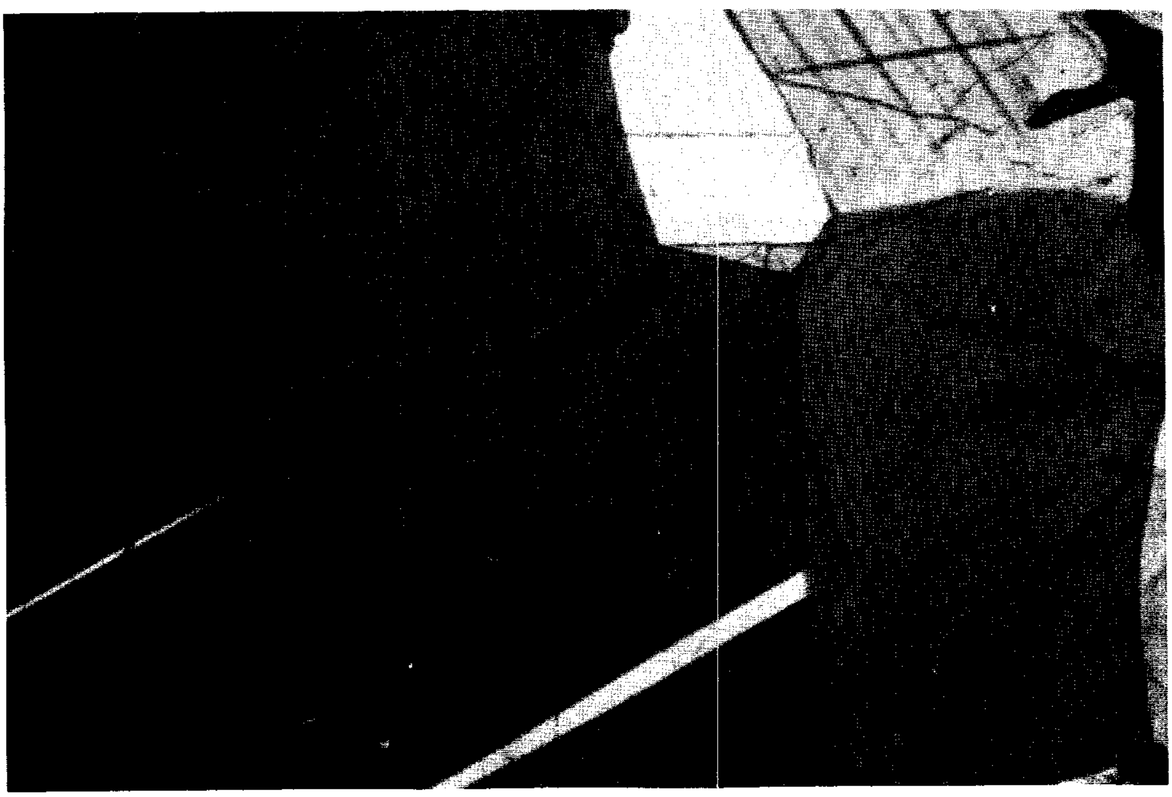


Figure 3: Photomicrograph of thin section 76535 in partially cross-polarized light. Field of view is 2 x 3 mm. S76-20796.

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 inclusions 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

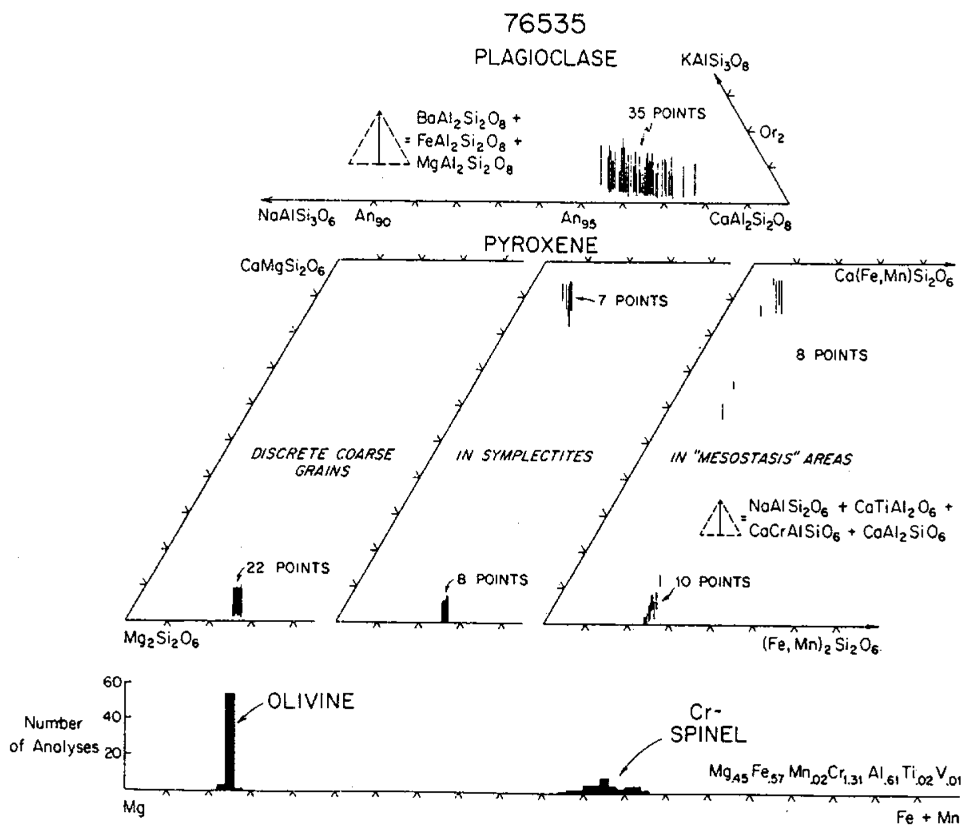


Figure 4: Pyroxene diagrams and mineral compositions of 76535 (from Dymek et al., 1975). Plagioclase and olivine are main minerals.

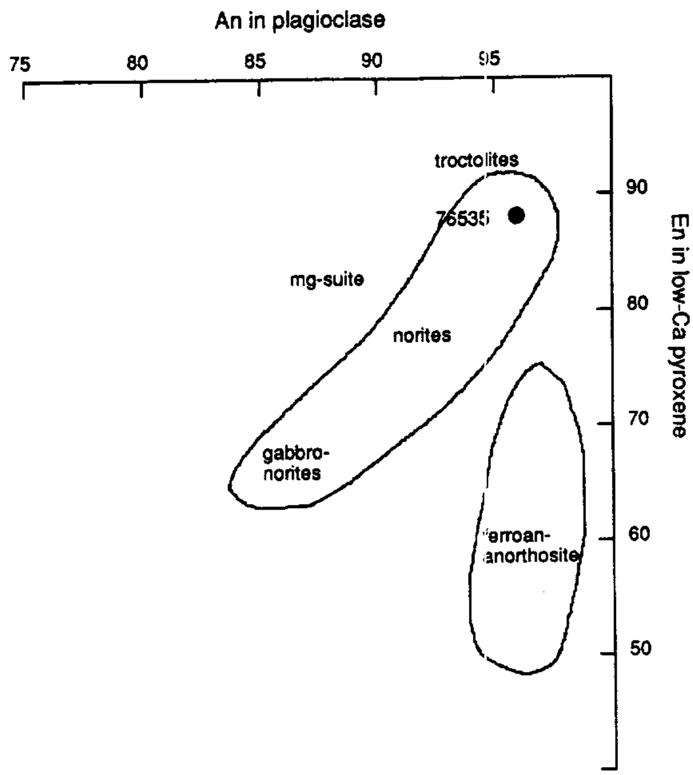


Figure 5: Plagioclase vs. low-Ca pyroxene composition of 76535 troctolite, showing that it is the end-member of the Mg-suite of plutonic lunar rocks. Fields are from James and Flohr (1983).

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 similar 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 1 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 $^{207}Pb/^{206}Pb$,

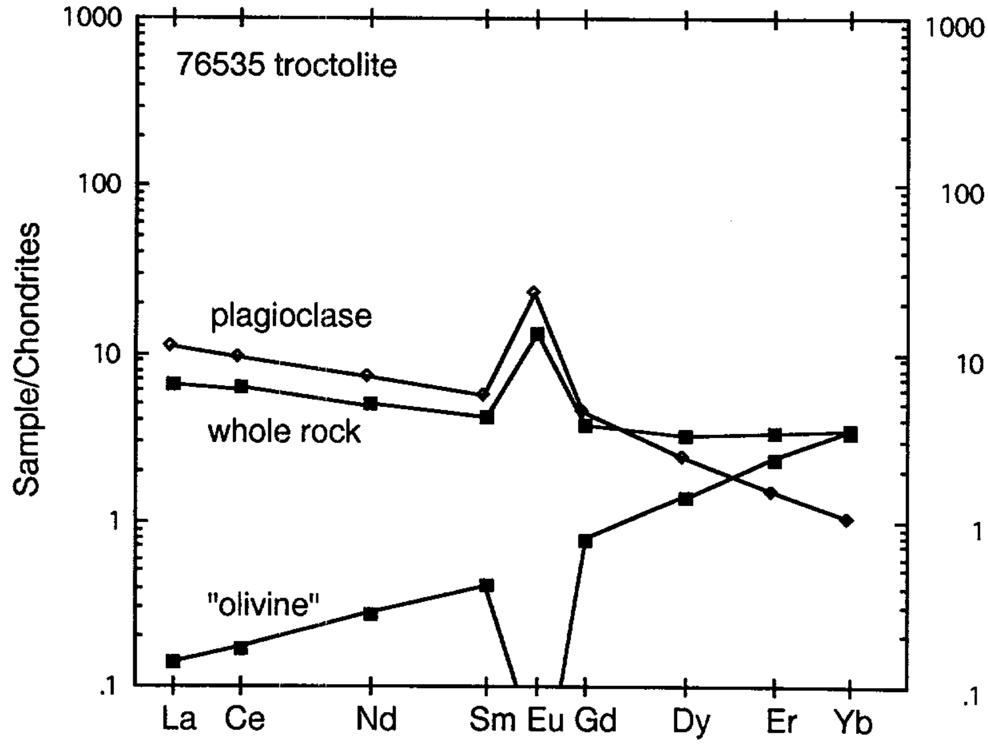


Figure 6: Normalized rare earth element diagram for lunar troctolite 76535. Data are from Haskin et al. (1975.)

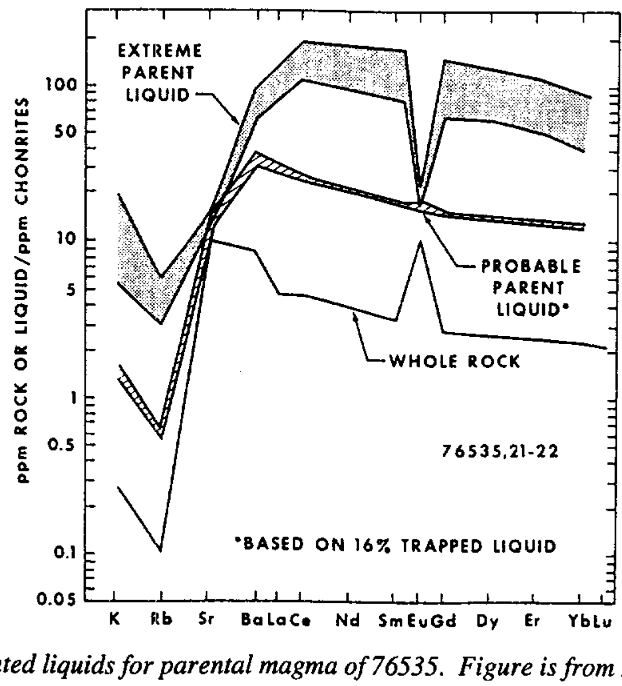


Figure 7: Calculated liquids for parental magma of 76535. Figure is from Haskin et al. (1975).

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 $^{40}Ar/^{39}Ar$ 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 al., 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 $^{40}Ar/^{39}Ar$ 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 m.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 good 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 and 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 troctolite 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 μm 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!

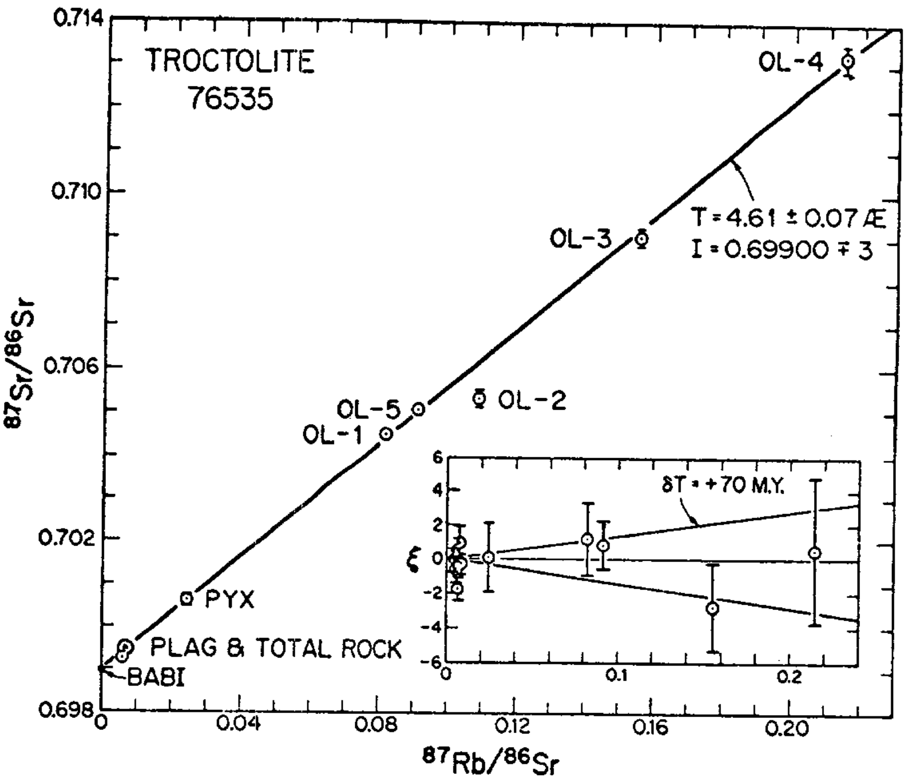


Figure 8: Rb-Sr isochron diagram for lunar troctolite 76535. From Papanastassiou and Wasserburg (1976).

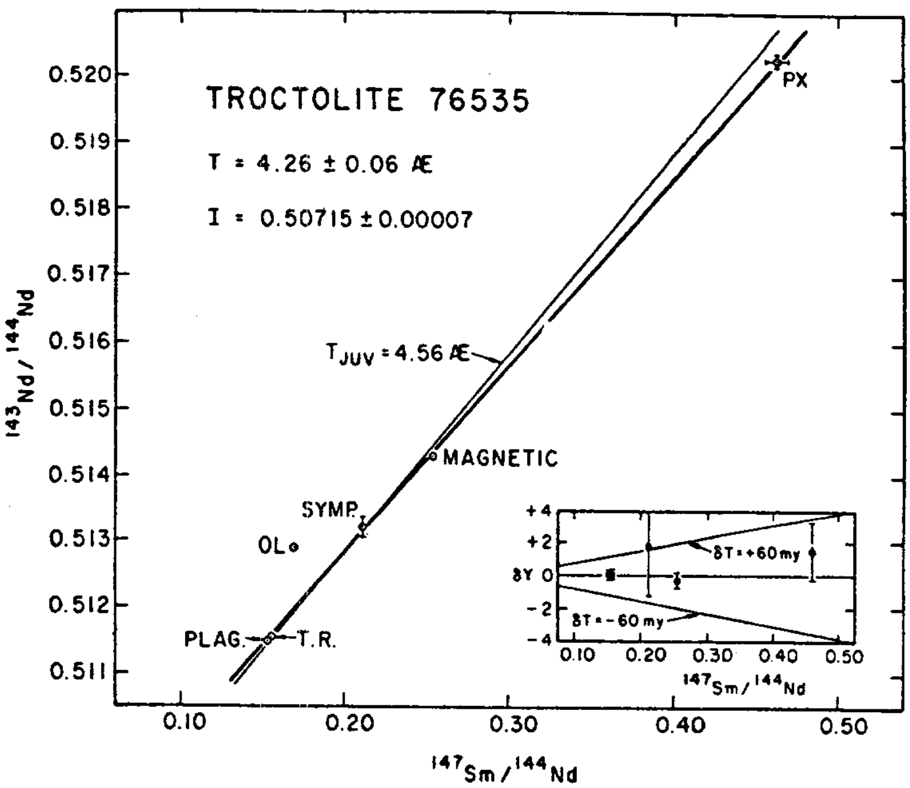


Figure 9: Sm-Nd isochron diagram for 76535. From Lugmair et al. (1976).

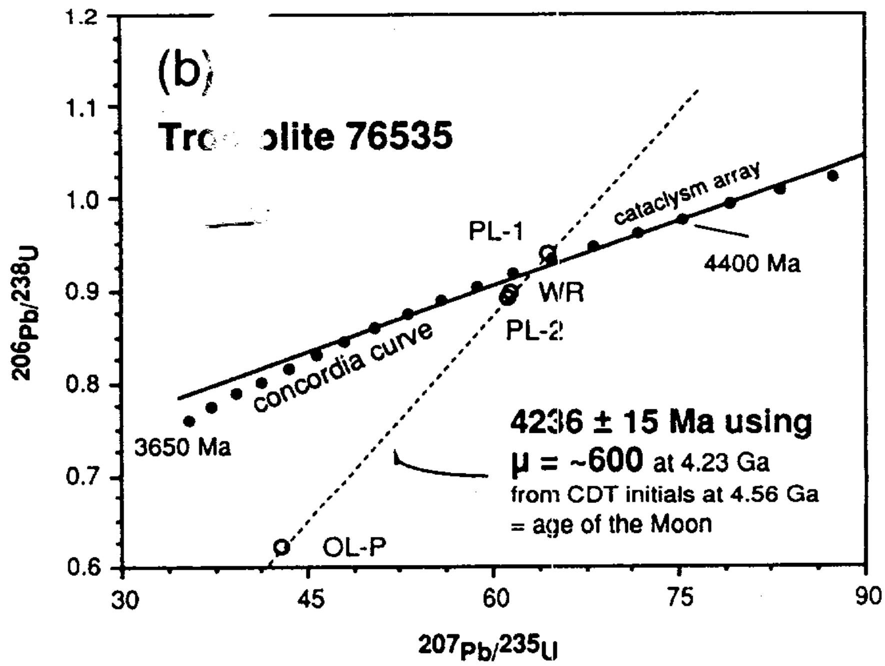


Figure 10: U-Pb concordia diagram for 76535. From Premo and Tatsumoto (1992).

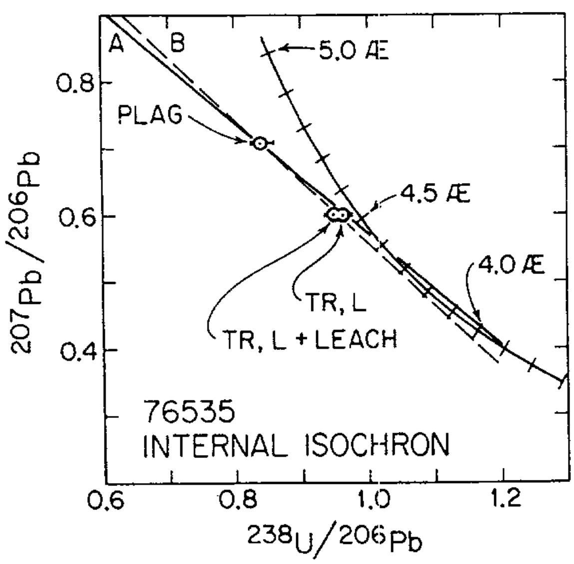


Figure 11: U-Pb concordia diagram for 76535. From Tera and Wasserburg (1974).

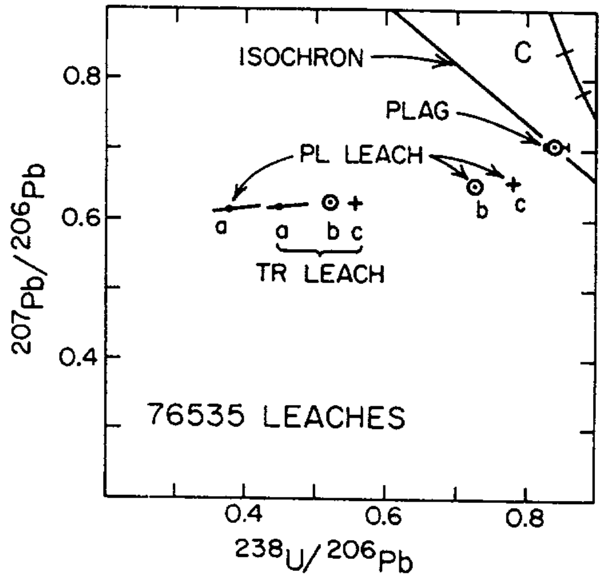


Figure 12: U-Pb concordia diagram showing the Pb data for the leached fractions. From Tera and Wasserburg (1974).

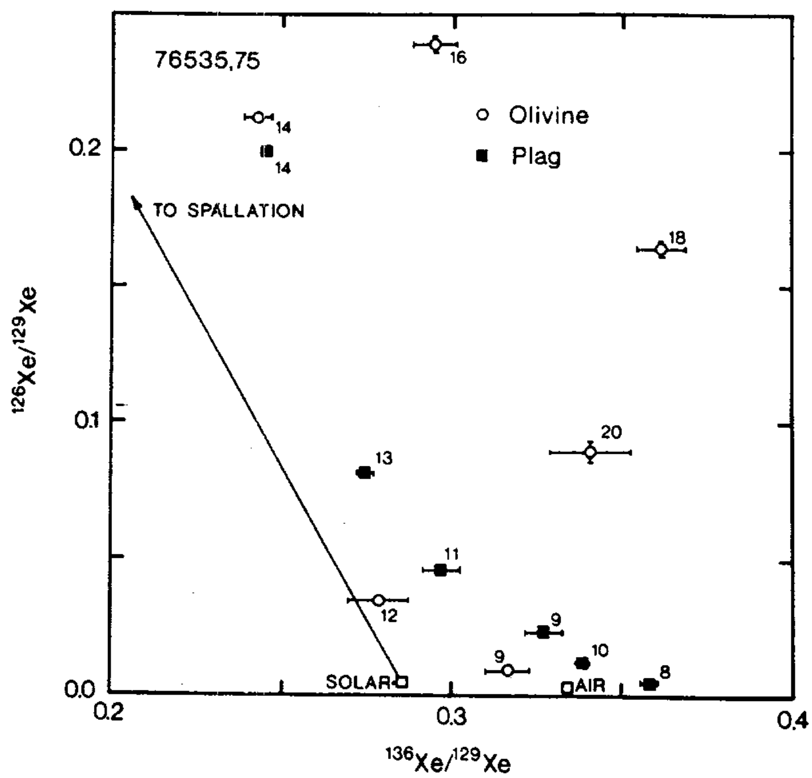


Figure 13: Xe isotope data from olivine and plagioclase in 76535. From Caffee et al. (1981).

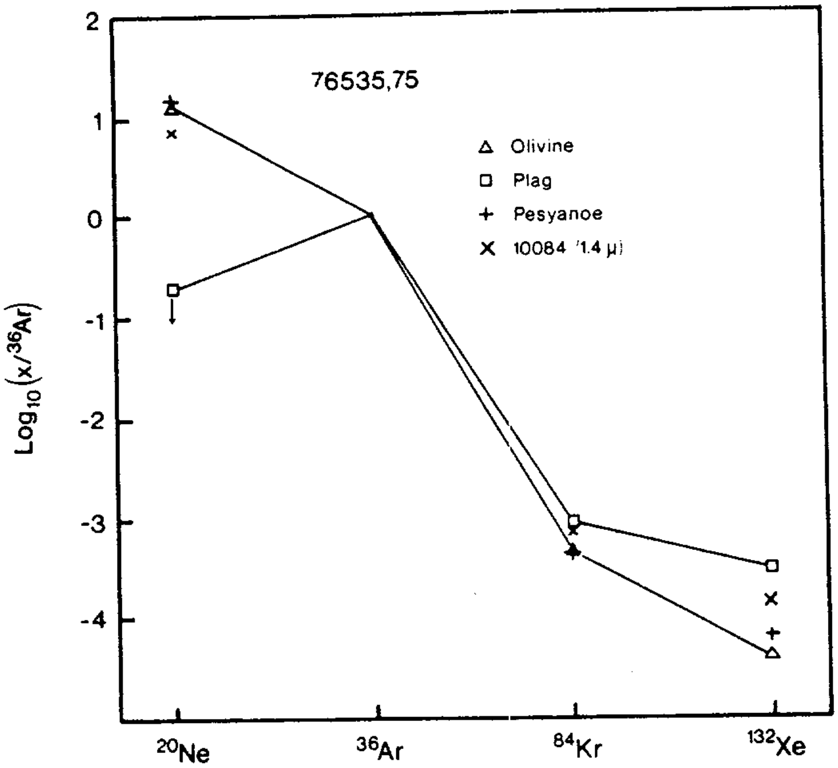


Figure 14: Relative abundances of trapped rare gases in 76535. From Caffee et al. (1981).

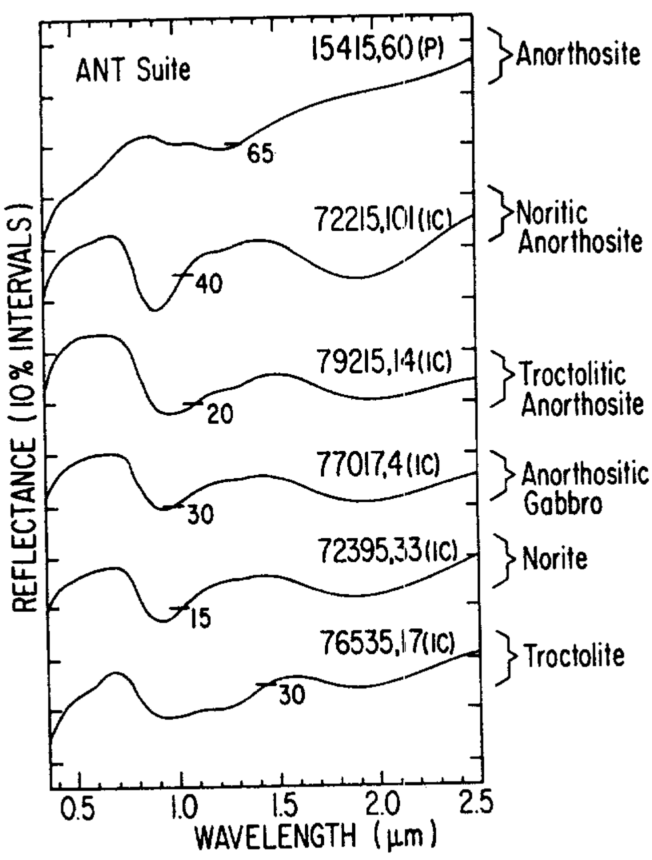


Figure 15: Reflectance spectra of 76535 compared with other lunar samples. From Charette and Adams (1977).

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 76 .
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).

76536
Crushed Troctolite
10.26 g, 3.5 x 1.8 x 1 cm

INTRODUCTION

Lunar sample 76536 is a pristine troctolite that has been shocked and crushed—without contamination by other lunar or meteorite materials. Sample 76536 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974).

PETROGRAPHY

Sample 76535 is white or very light grey with a hackly surface. It has a granulated texture and is relatively coherent (Fig. 1). There are occasional large grains of plagioclase (2 mm) with striations (Fig. 2).

The mineral assemblage in 76536 has been crushed in place. There appear to be about equal amounts of olivine and plagioclase (Fig. 3).

MINERAL CHEMISTRY

Precise mineral compositions for olivine and low-Ca pyroxene are given in Bersch et al. (1991). Both olivine and pyroxene seem to have a slightly lower Mg/Fe ratio in 76536 than in 76535. The composition of plagioclase has not been reported (Warren et al., 1993). Ryder and Norman (1979) observe that 76536 contains symplectite intergrowths that are similar to those reported in 76535.

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) report electron probe analysis of fused glass bead by Roy Brown (unpublished), Ryder and Norman (1979) report a REE analysis by Blanchard (unpublished), and Warren and Wasson (1979) have determined trace elements by RNAA for 76536 (Table 1). The unpublished analysis by Blanchard indicates a higher trace element content than the analysis by Warren and Wasson and is not plotted in Fig. 4. The analysis by Warren and Wasson is in complete agreement with that of 76535, which is plotted as a reference. Ebihara et al. (1992) have reported the trace siderophile and volatile element content of 76536 (Table 2).

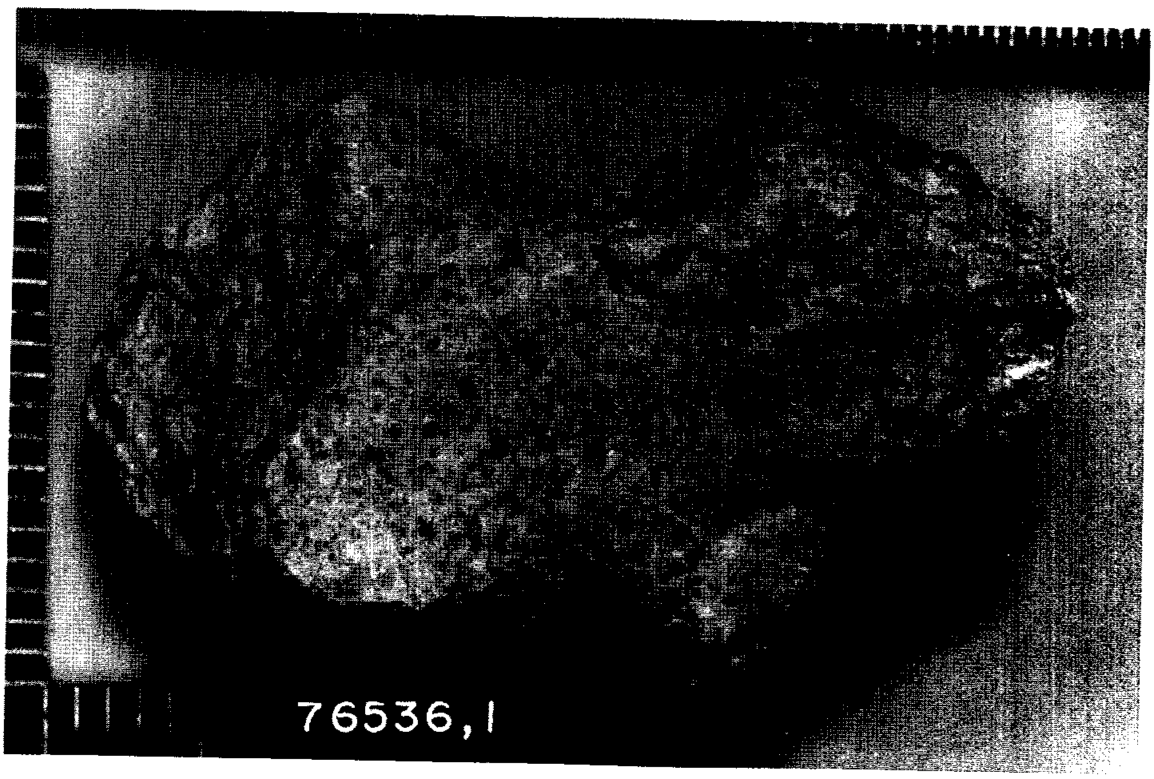


Figure 1: Photograph of 76536,1. Scale bar is marked in mm. S73-19600.

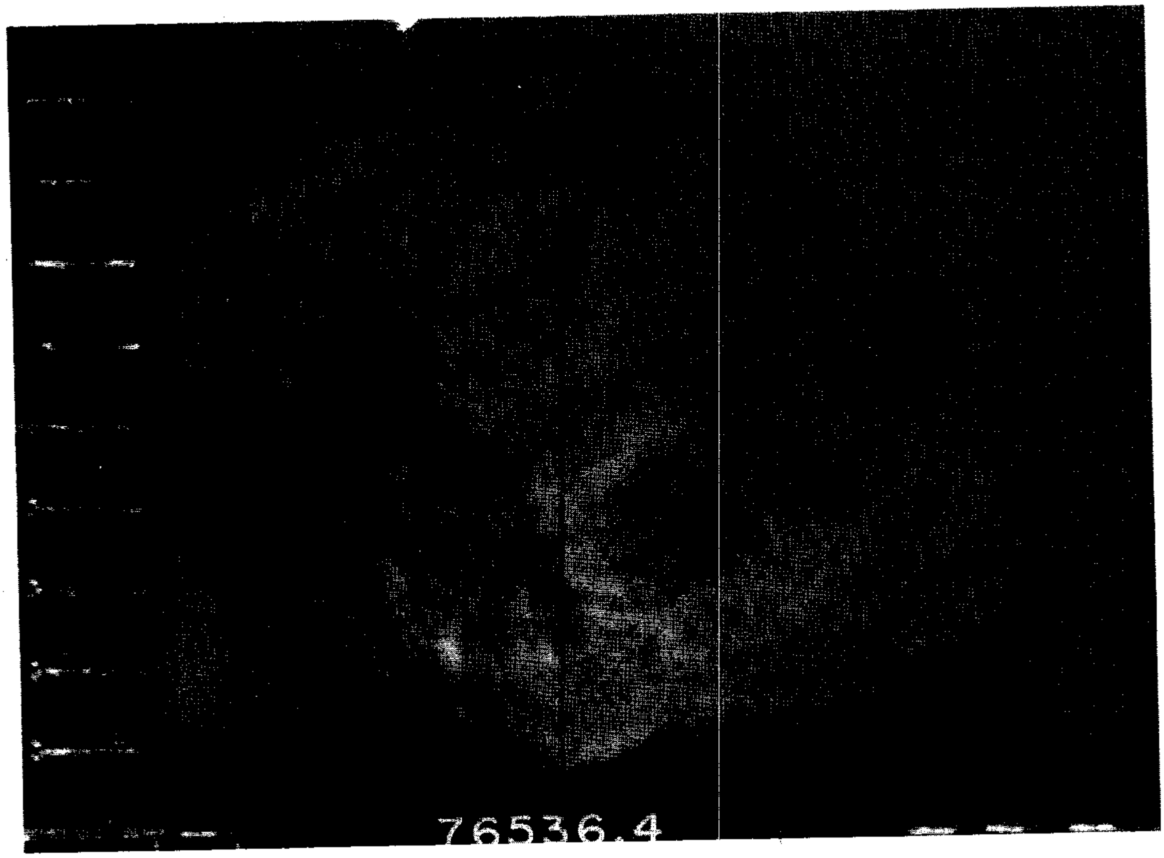


Figure 2: Photograph of 76536,4. Scale bar is marked in mm. S73-19604.

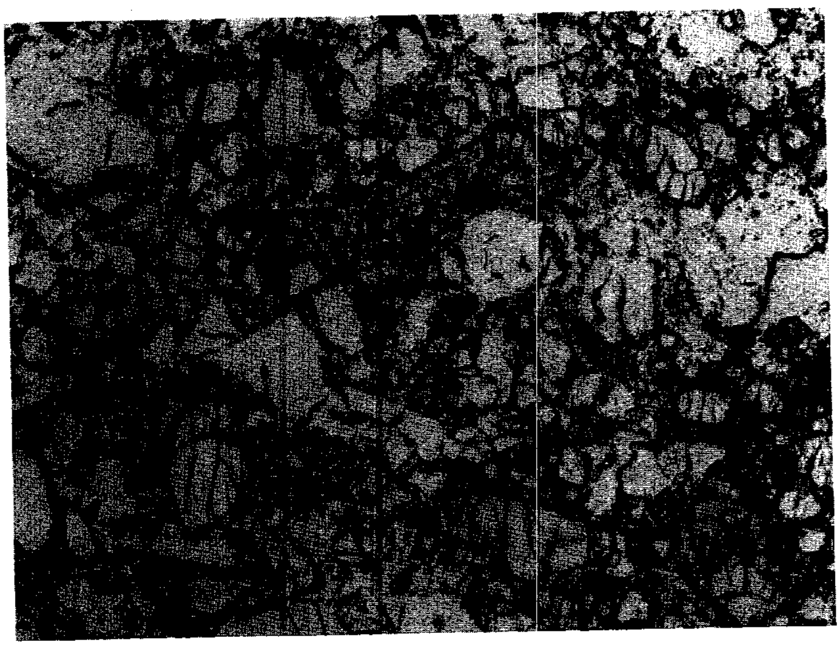


Figure 3: Photomicrograph of thin section 76536,15. There are about equal amounts of olivine and plagioclase. Both minerals are crushed in place. Field of view is 2 x 3 mm.

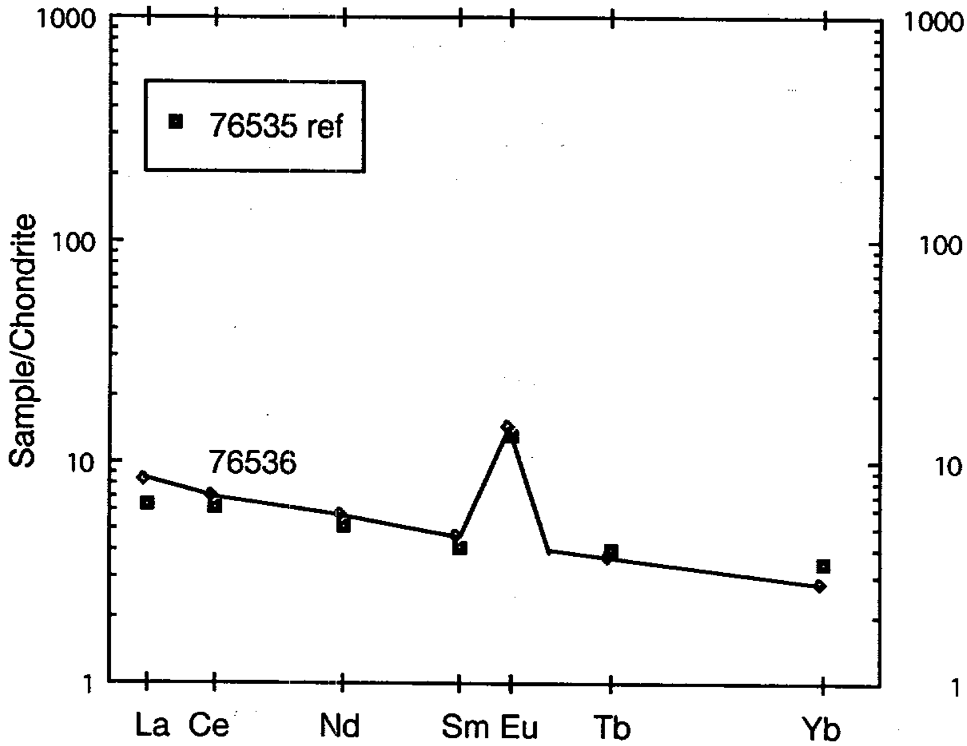


Figure 4: Normalized rare earth element diagram for 76536. Reference data from troctolite 76535 are plotted as squares on the diagram. Data from Warren and Wasson (1979).

Table 1: Whole-rock chemistry of 76536.
a) Simonds and Warner (1981 – unpublished emp analyses by Roy Brown); b) Ryder and Norman (1979 – unpublished REE analysis by Blanchard); c) Warren and Wasson (1979)
**(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)*

Split Technique	,9 (a, b) EMP, *INAA*	,16 (c) INAA
SiO_2 (wt%)	43.54*	42.4
TiO_2	0.07*	–
Al_2O_3	21.01*	26.2
Cr_2O_3	0.12*	0.08
FeO	4.94*	3.6
MnO		0.04
MgO	17.42*	13.6
CaO	11.76*	13.3
Na_2O	0.28*	0.29
K_2O	0.06*	0.04
Nb (ppm)		
Hf	*1.04*	0.36
Ta	*0.13*	0.031
U		–
Th	*4.2*	0.20
Zn	*12*	1.13
Ni	*32*	5
Co	*25.6*	20
Sc	*2.42*	1.8
Ba		49
La	*11.0*	1.9
Ce	*31.9*	4.1
Nd		2.5
Sm	*6.03*	0.65
Eu	*0.745*	0.78
Tb	*1.13*	0.13
Yb	*2.67*	0.44
Lu	*0.341*	0.062
Ge (ppb)		2.4
Ir		0.051
Au		0.02

Table 2: Trace element data for 76536. Concentrations in ppb.
From Ebihara et al. (1992).

	Sample 76536,19
Ir	0.026
Os	<0.19
Re	<0.004
Au	0.011
Pd	<1.9
Ni (ppm)	55.3
Sb	0.37
Ge	2.73
Se	4.56
Te	<0.97
Ag	0.179
Br	
In	1.41
Bi	0.6
Zn (ppm)	0.42
Cd	<3.3
Tl	0.005
Rb (ppm)	0.724
Cs	456
U	52

76537
High-Ti Mare Basalt
26.48 g, 3.2 x 2.7 x 1.5 cm

INTRODUCTION

Sample 76537 is a rake sample from Station 6 (Phinney et al., 1974). It is a typical Apollo 17 high-Ti mare basalt.

PETROGRAPHY

The B1 surface of sample 76537 is covered with micrometeorite pits and patina (Fig. 1). This fine-grained mare basalt has a variolitic texture with olivine phenocrysts and long needles of ilmenite (Fig. 2). Brown pyroxene is intergrown with plagioclase in radial clusters.

WHOLE-ROCK CHEMISTRY

This basalt has 13% TiO_2. It has been analyzed for major elements by Rhodes et al. (1976a) and for REE by Wiesmann and Hubbard (1975) (Table 1). It is typical of Apollo 17 high Ti basalts (Fig. 3). Nyquist et al. (1975) have reported isotopic data (Table 2).

Figure 1: Photograph of cratered surface of 76537. S73-19735.

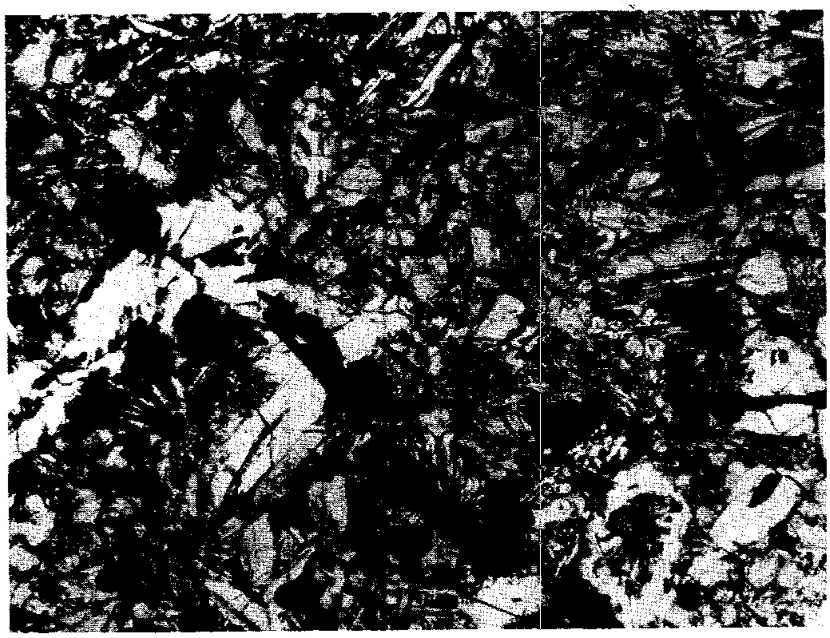


Figure 2: Photomicrograph of texture of 76537. Field of view is 2 x 3 mm.

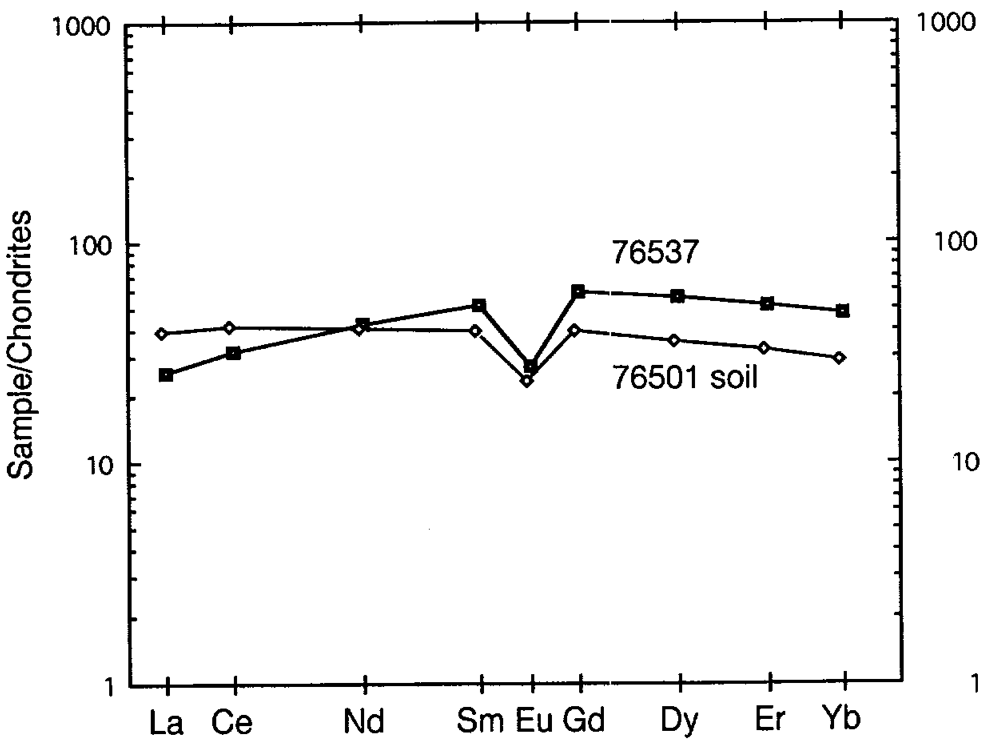


Figure 3: Normalized rare earth element diagram for mare basalt sample 76537. Data from Wiesmann and Hubbard (1975).

Table 1: Whole-rock chemistry of 76537.
From Rhodes et al. (1976a); Wiesmann and Hubbard (1975).

Split Technique	,1 XRF, IDMS	Split Technique	,1 XRF, IDMS
SiO_2 (wt%)	38.25	Th	0.45
TiO_2	13.05	Sr	131
Al_2O_3	8.69	Rb	0.41
Cr_2O_3	0.37	Li	8.4
FeO	19.60	Ba	66.5
MnO	0.29	La	6.01
MgO	8.01	Ce	19.4
CaO	10.67	Nd	18.9
Na_2O	0.40	Sm	7.51
K_2O	0.05	Eu	1.51
P_2O_5	0.11	Gd	11.5
S	0.15	Dy	13.6
Nb (ppm)		Er	8.21
Zr	201	Yb	7.61
U	0.13		

Table 2: Rb-Sr composition of 76537.
Data from Nyquist et al. (1975).

Sample	76537,1
wt (mg)	47
Rb (ppm)	0.410
Sr (ppm)	131
$^{87}Rb/^{86}Sr$	0.0091 ± 4
$^{87}Sr/^{86}Sr$	0.69973 ± 7
T_B	4.8 ± 0.8
T_L	5.3 ± 0.8

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

76538
High-Ti Mare Basalt
5.87 g, 1.4 x 2.0 x 1.5 cm

INTRODUCTION

Sample 76538 is a small, coarse-grained, high-Ti mare basalt collected as part of the rake sample taken at Station 6 (Phinney et al., 1974).

PETROGRAPHY

Mare basalt fragment 76538 has a fresh, hackly surface (Fig. 1). It has a few relict zap pits on all surfaces. Thin section 76538,8 (Fig. 2) shows that it has an equigranular-to-subophitic texture with intergrown ilmenite, plagioclase, and pyroxene.

WHOLE-ROCK CHEMISTRY

The preliminary fused bead electron probe analysis of 76538 (Table 1) shows that it has a high TiO_2 content (~14%). This analysis indicates that this fragment is typical of mare basalts from Apollo 17.

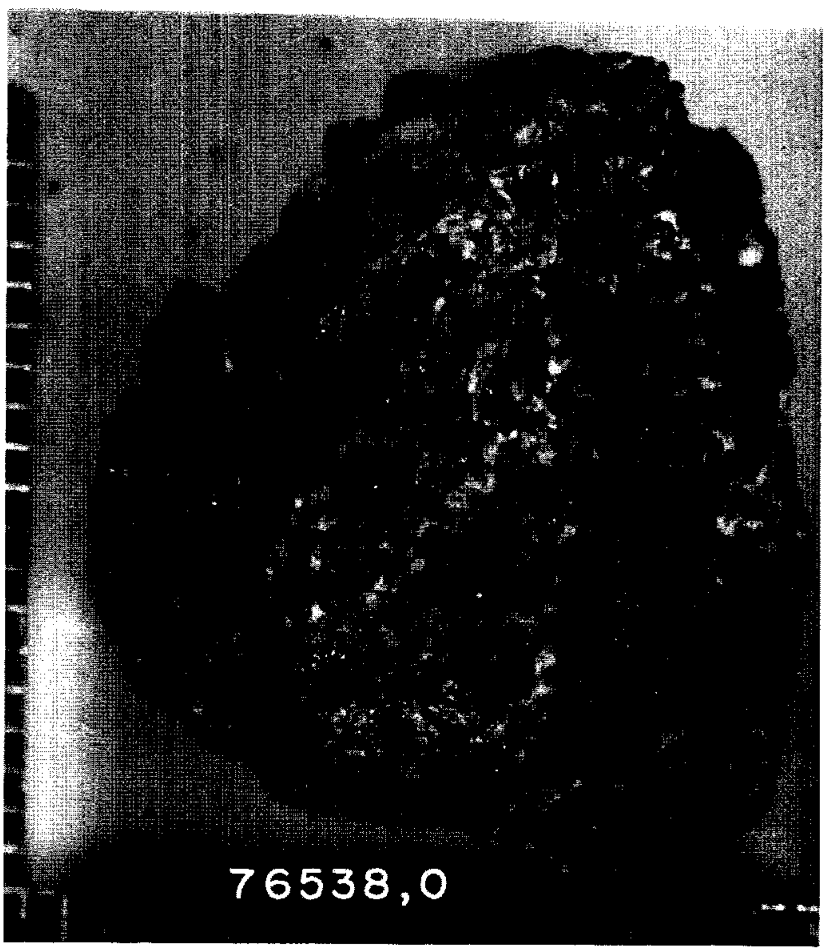


Figure 1: Photograph of 76538. Scale bar is marked in mm. S73-19609.

Figure 2: Photomicrograph of thin section 76538,8. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76538.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split Technique	,4 EMP
SiO_2 (wt%)	36.79
TiO_2	13.87
Al_2O_3	9.70
Cr_2O_3	0.50
FeO	18.58
MnO	
MgO	8.37
CaO	9.63
Na_2O	0.54
K_2O	0.08

76539

Aphanitic High-Ti Mare Basalt
14.8 g, 3 x 2 x 1 cm

INTRODUCTION

Phinney et al. (1974) and Simonds and Warner (1981) find that 76539 is a typical Apollo 17 mare basalt sample.

PETROGRAPHY

Sample 76539 is an aphanitic mare basalt (Fig. 1). This basalt sample has about 15% skeletal olivine (Fig. 2) and ~10% skeletal ilmenite (Fig. 3), in quenched basaltic glass. It has no zap pits on the surface and only a few small vugs.

WHOLE-ROCK CHEMISTRY

Rhodes et al. (1976a) and Wiesmann and Hubbard (1975) have determined the composition of 76539 (Table 1). It is typical of other high-Ti mare basalts from Apollo 17 (Fig. 4).

RADIOGENIC ISOTOPES

Nyquist et al. (1975) have reported whole-rock isotopic data for 76539 (Table 2).

Figure 1: Photograph of 76539. Scale bar is marked in mm. S73-19606.

Figure 2: Photomicrograph of thin section 76539,10, showing transparent skeletal olivine and opaque matrix. Field of view is 2 x 3 mm.

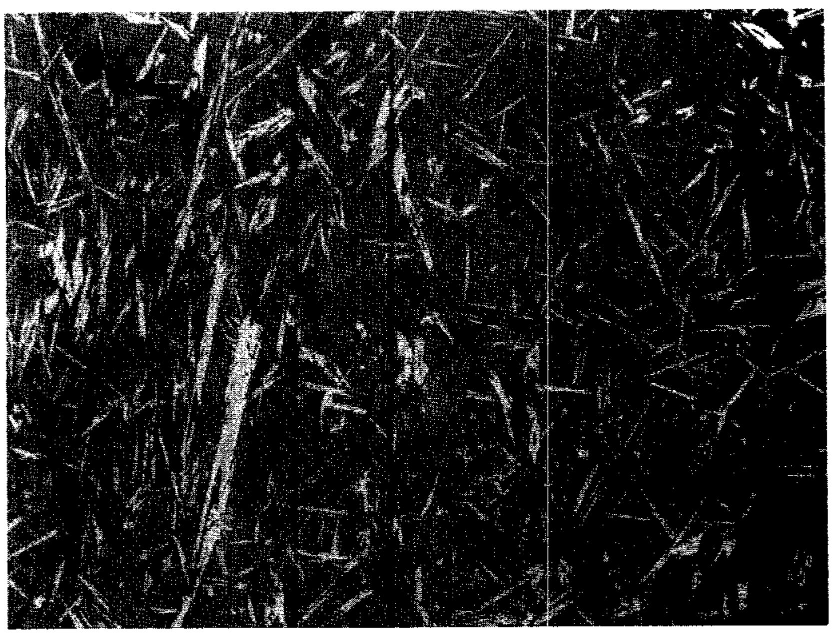


Figure 3: Reflected light photomicrograph of same area as Fig. 2, showing abundant skeletal ilmenite. Field of view is 2 x 3 mm.

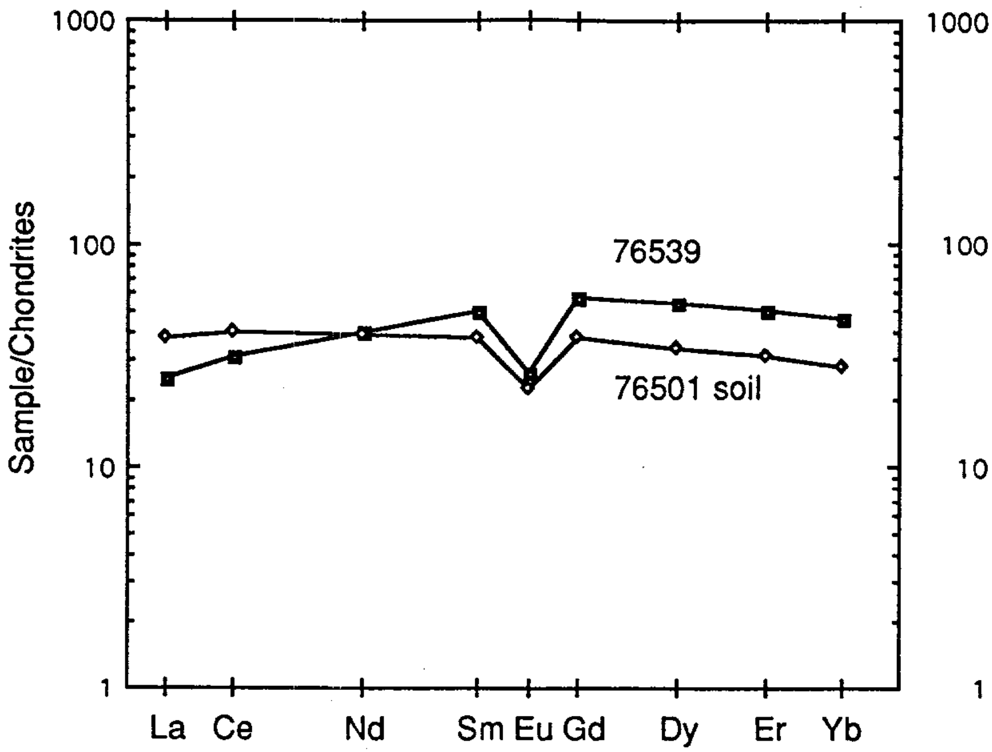


Figure 4: Normalized rare earth element diagram from 76539, showing pattern typical of high-Ti Apollo 17 mare basalts.

Table 1: Whole-rock chemistry of 76539.
From Rhodes et al. (1976a); Wiesmann and Hubbard (1975).

Split Technique	,3 XRF, IDMS	Split Technique	,3 XRF, IDMS
SiO_2 (wt%)	38.21	Sr	130
TiO_2	12.65	Rb	0.383
Al_2O_3	8.80	Li	–
Cr_2O_3	0.34	Ba	64.8
FeO	19.42	La	5.88
MnO	0.29	Ce	18.6
MgO	7.87	Nd	18.3
CaO	10.91	Sm	7.32
Na_2O	0.39	Eu	1.48
K_2O	0.06	Gd	11.3
P_2O_5	0.10	Dy	13.3
S	0.16	Er	8.02
Nb (ppm)		Yb	7.40
Zr	196	Lu	1.05

Table 2: Rb-Sr composition of 76539.
Data from Nyquist et al. (1975).

Sample	76539,3
wt (mg)	57
Rb (ppm)	0.383
Sr (ppm)	130
$^{87}Rb/^{86}Sr$	0.0085 ± 3
$^{87}Sr/^{86}Sr$	0.69967 ± 6
T_B	4.7 ± 0.7
T_L	5.2 ± 0.7

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

76545
Dark Matrix Regolith Breccia
51.21 g; 76545 = 7.676 g, 76546 = 24.31 g, 76547 = 10.05 g, 76549 = 9.175 g (4 pieces)

INTRODUCTION

Phinney et al. (1974) mated these fragments into a common group on the basis of their common appearance (Figs. 1-4).

PETROGRAPHY

Sample 76545 is a dark matrix regolith breccia with seriate distribution of mineral clasts (Fig. 5). The matrix has a high proportion of brown glass, and the fragments are veined and splattered with black agglutinated glass.

Phinney et al. (1976) have studied 76545 by SEM petrography. The pieces of this sample are described as vitric matrix breccias by Simonds et al. (1975), who noted the occurrence of orange glass in the matrix. Phinney et al. suggest that the origin of these breccias is by hot glass quenched by cold clastic debris in an impact (Simonds, 1974).

76545,14 contains "radial-arcuate lapillar structures that are compressed and deformed" and are interpreted by Nagle (1982) as being "ejecta that was modified by subcrater processes." This interesting alternative model is more consistent with the fact that these fragments have the exact same composition as the soil (76501).

WHOLE-ROCK CHEMISTRY

A piece of sample 76545 has been analyzed by XRF and isotope dilution mass spectroscopy (Table 1) (Wiesmann and Hubbard, 1975). It has exactly the same composition as the 76501 soil from which it was collected (Fig. 6).

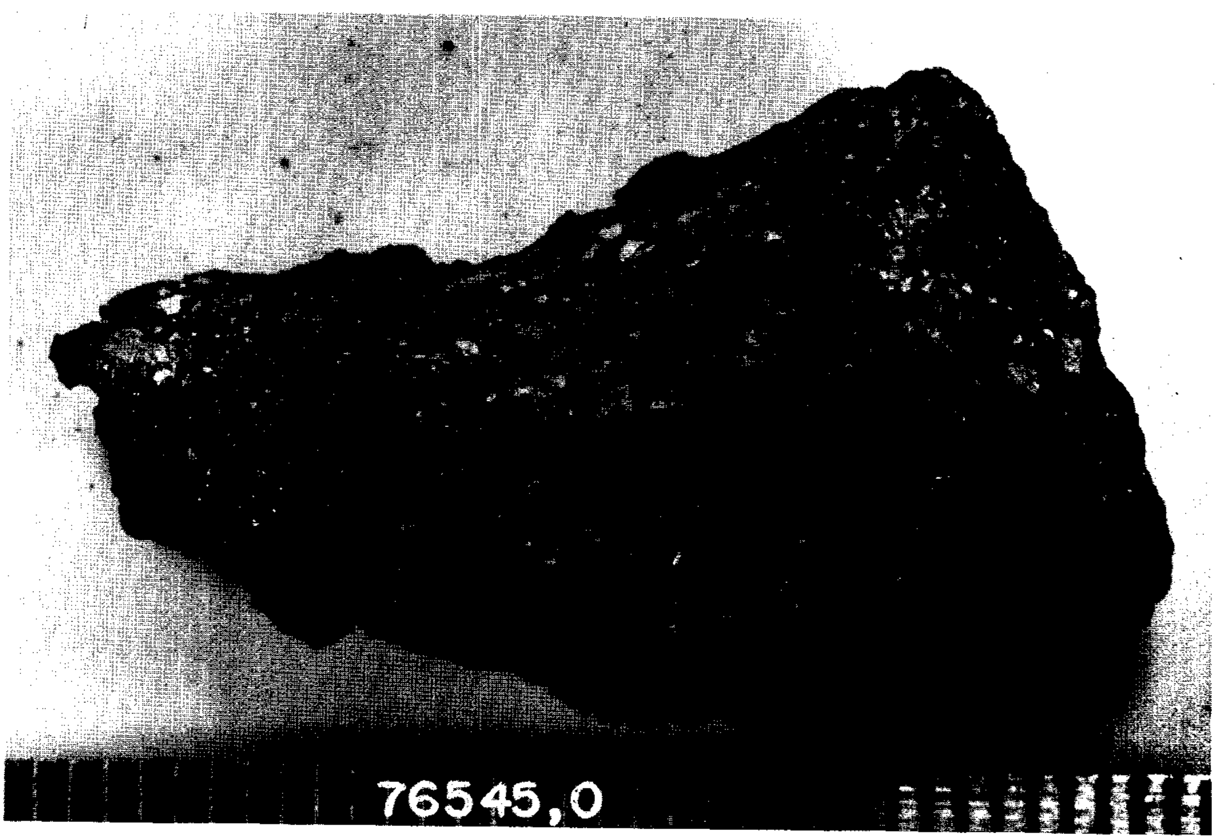


Figure 1: Photograph of 76545. Scale bar is marked in mm. S73-19611.

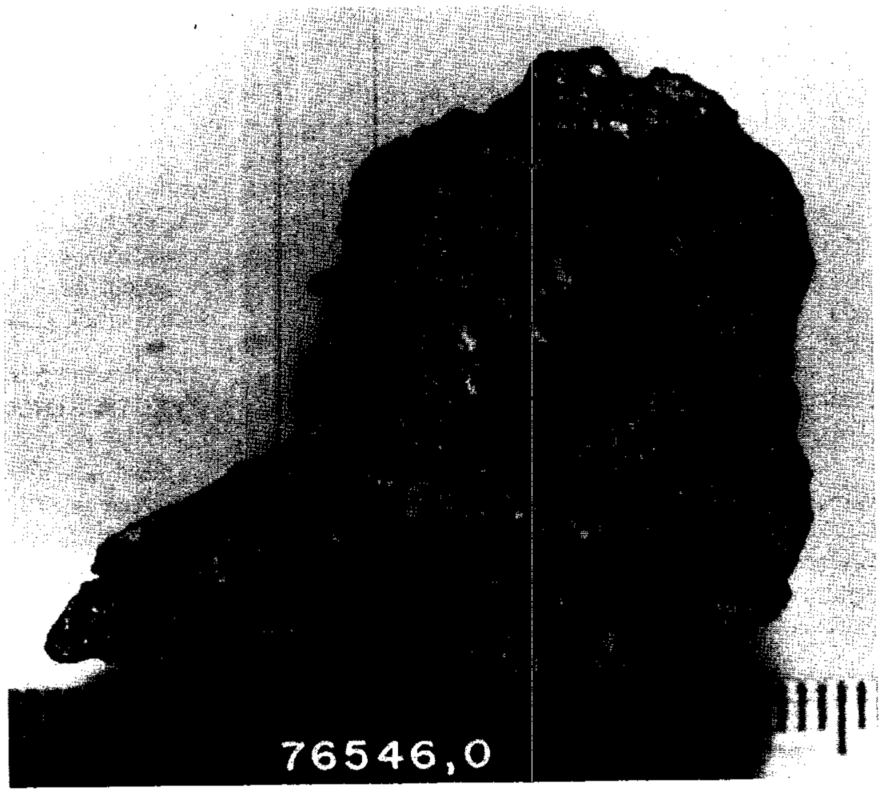


Figure 2: Photograph of 76546. Scale bar is marked in mm. S73-19621.

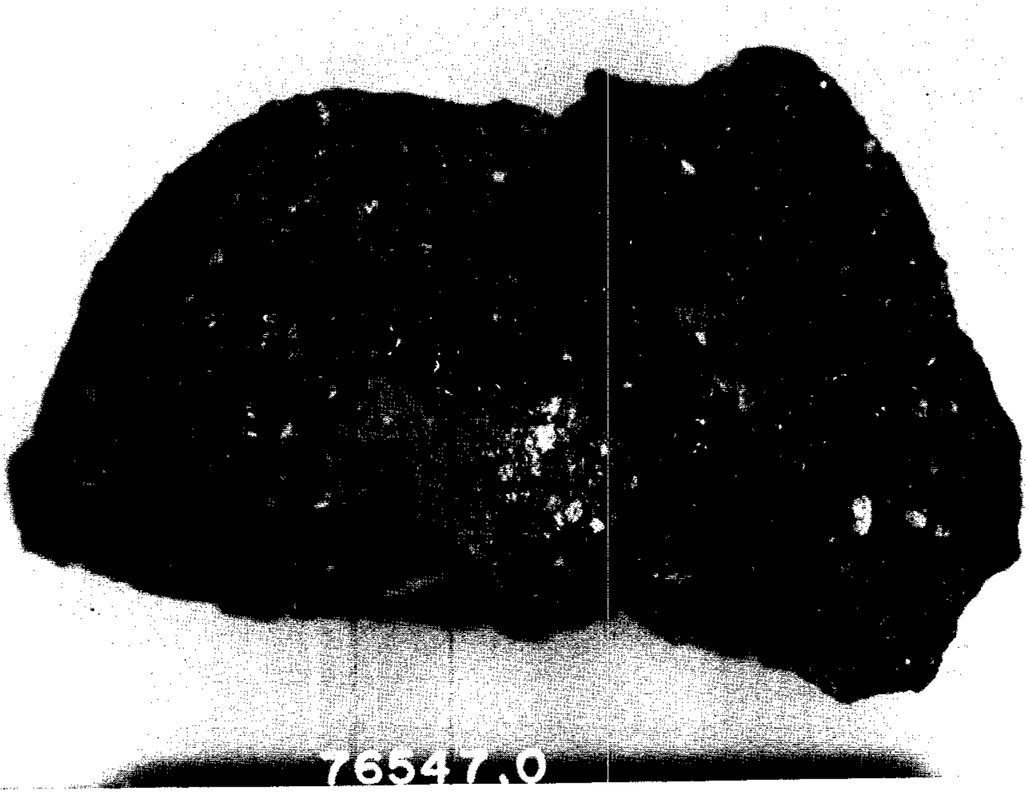


Figure 3: Photograph of 76547. Scale bar is marked in mm. S73-19616.

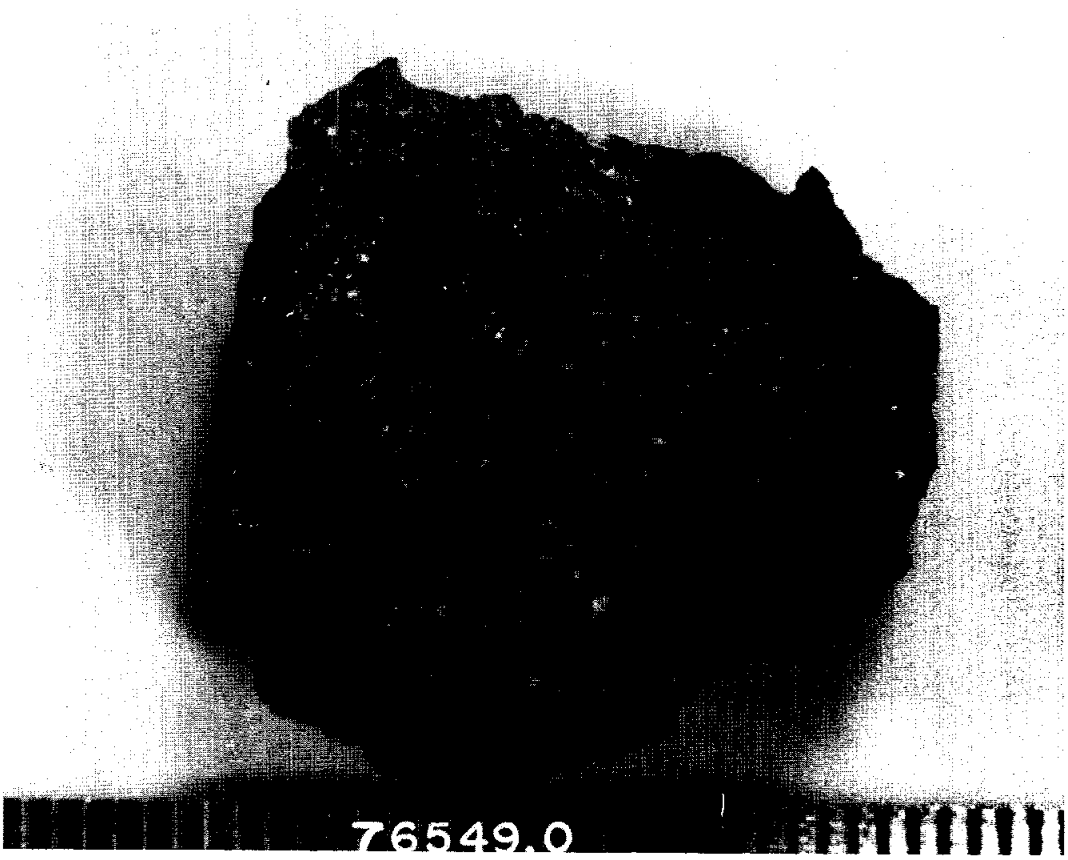


Figure 4: Phqtograph of 76549. Scale bar is marked in mm. S73-19623.

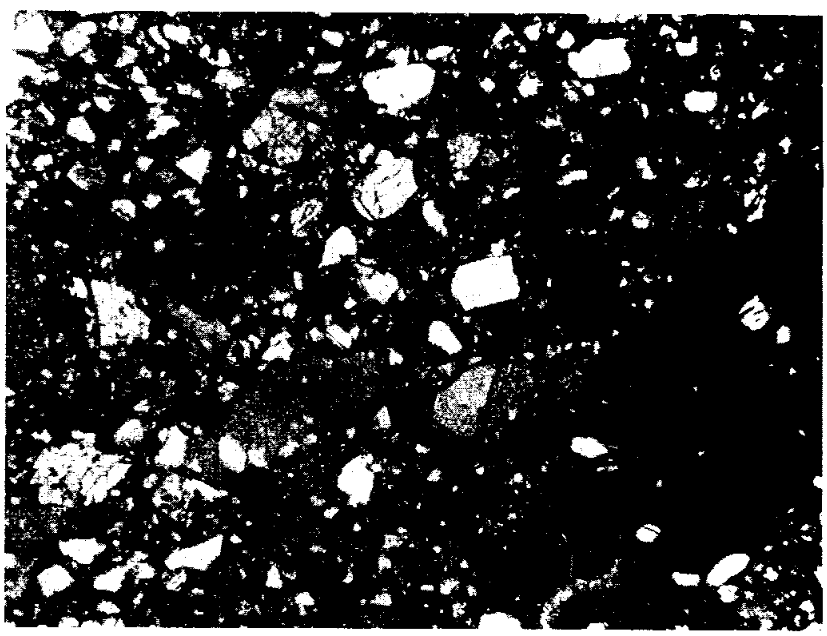


Figure 5: Photomicrograph of thin section 76545,14. Field of view is 2 x 3 mm.

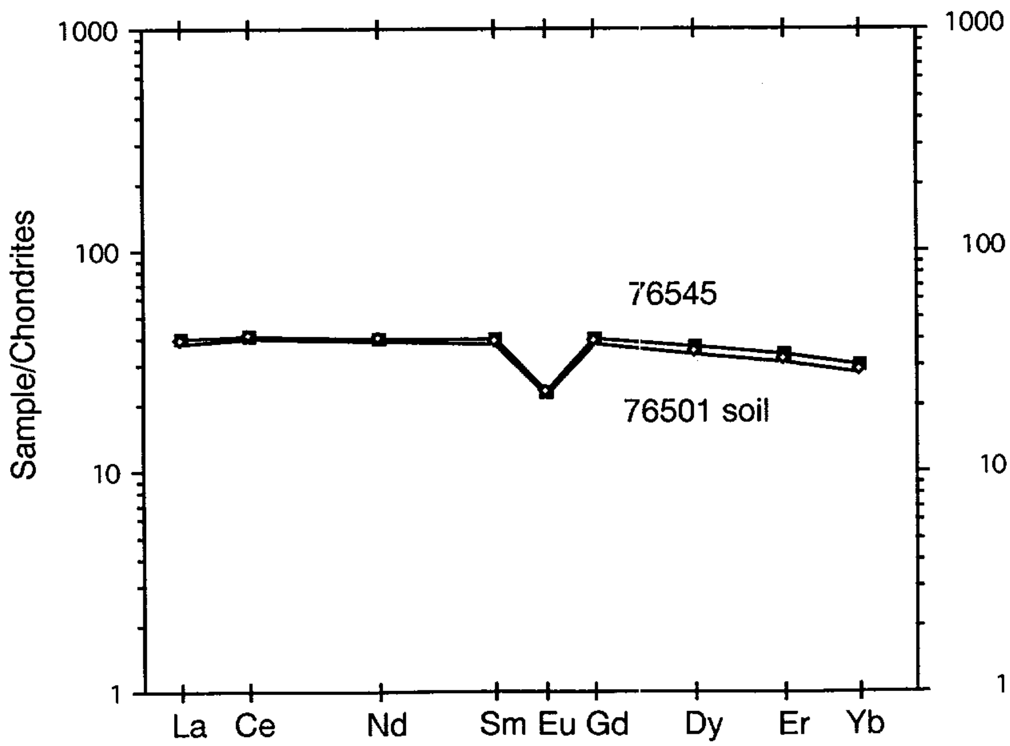


Figure 6: Normalized rare earth element diagram comparing composition of 76545 with 76501 reference soil. Data from Wiesmann and Hubbard (1975).

Table 1: Whole-rock chemistry of 76545.
From Simonds and Warner (1981); Wiesmann and Hubbard (1975).

Split Technique	,3 ,5 XRF, IDMS
SiO_2 (wt%)	43.45
TiO_2	3.69
Al_2O_3	17.89
Cr_2O_3	0.26
FeO	10.94
MnO	0.15
MgO	10.51
CaO	12.21
Na_2O	0.40
K_2O	0.13
P_2O_5	0.09
S	0.07
Nb (ppm)	
Zr	191
U	0.43
Th	1.56
Sr	–
Rb	2.43
Li	8.9
Ba	114
La	9.36
Ce	25
Nd	17.9
Sm	5.87
Eu	1.29
Gd	7.96
Dy	8.89
Er	5.33
Yb	4.88

76548

Dark Matrix Regolith Breccia
2.527 g, 1 x 1 x 1 cm

INTRODUCTION

This sample of regolith breccia is similar to 76545 except that it has about 20% black agglutinated glass welding it together (Fig. 1).

PETROGRAPHY

Phinney et al. (1976) have studied 76548 by SEM petrography. They found that it was a coherent vitric matrix breccia with seriate distribution of mineral clasts welded together by matrix glass. The origin of matrix glass is uncertain. Clasts of mare basalt and orange glass beads are also included (Fig. 2), and this particle is probably derived from nearby mare soil.

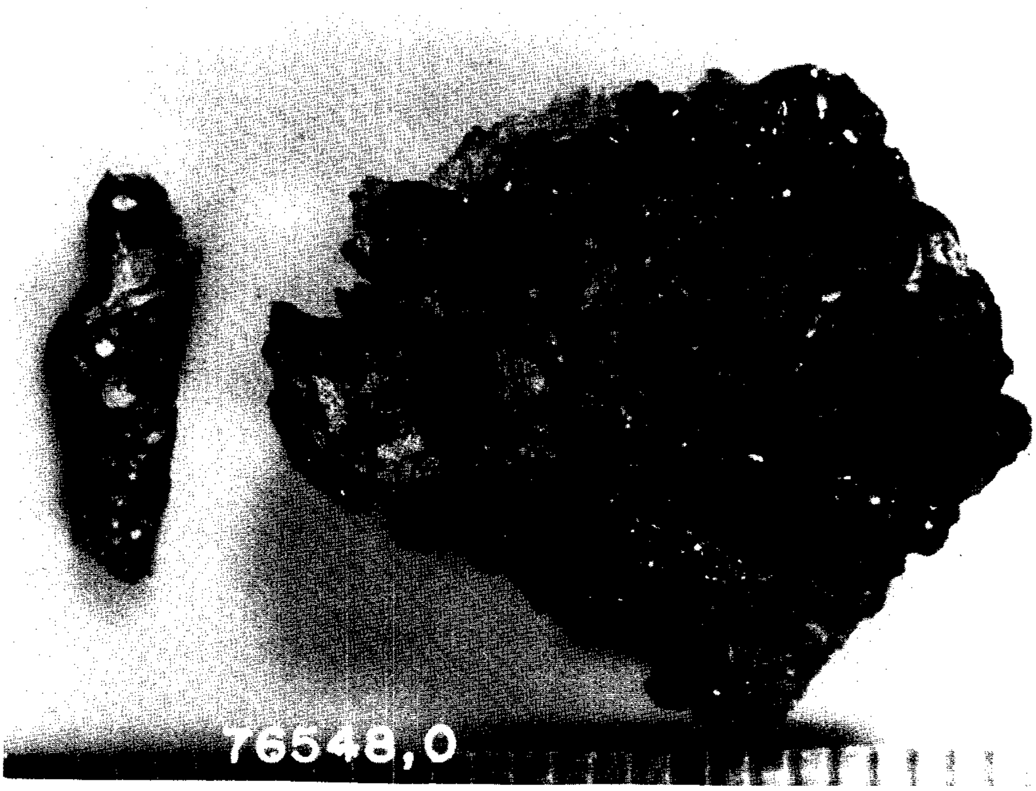


Figure 1: Photograph of 76548. Scale bar is marked in mm. S73-19620.

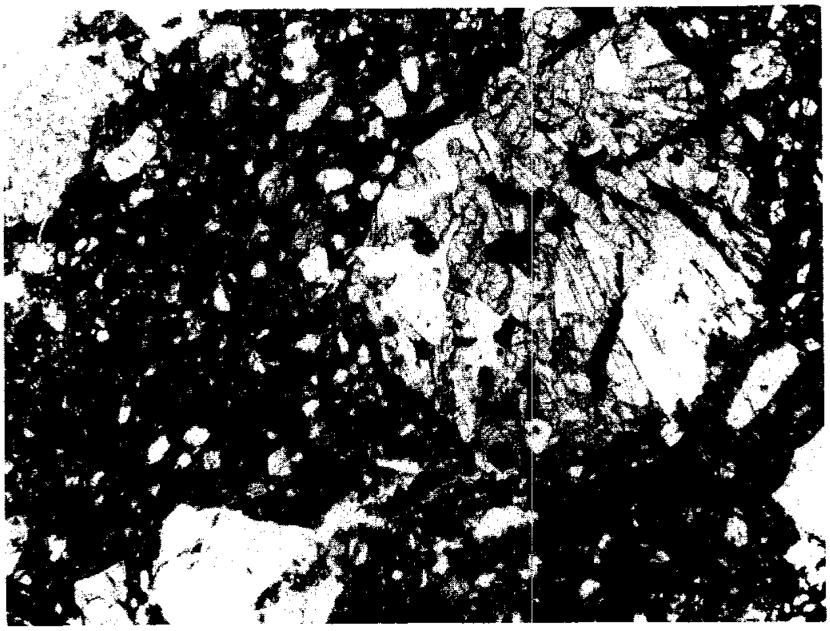


Figure 2: Photomicrograph of thin section 76548,5, showing clastic texture with brown glass matrix and a small (1 mm) mare basalt clast. Field of view is 2 x 3 mm.

76555

Micropoikilitic Impact Melt Breccia
8.435 g, 2.5 x 2 x 1 cm

INTRODUCTION

Sample 76555 is a light grey impact melt rock that was collected as a rake sample from Station 6 (Phinney et al., 1974).

PETROGRAPHY

The thin sections of 76555 show that it has a clastic texture with a fine-grained, annealed, micropoikilitic matrix (Fig. 2).

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) point out that this poikilitic impact melt breccia has less Fe and more Mg than the boulder at Station 6 (Table 1), and is similar to sample 76055.

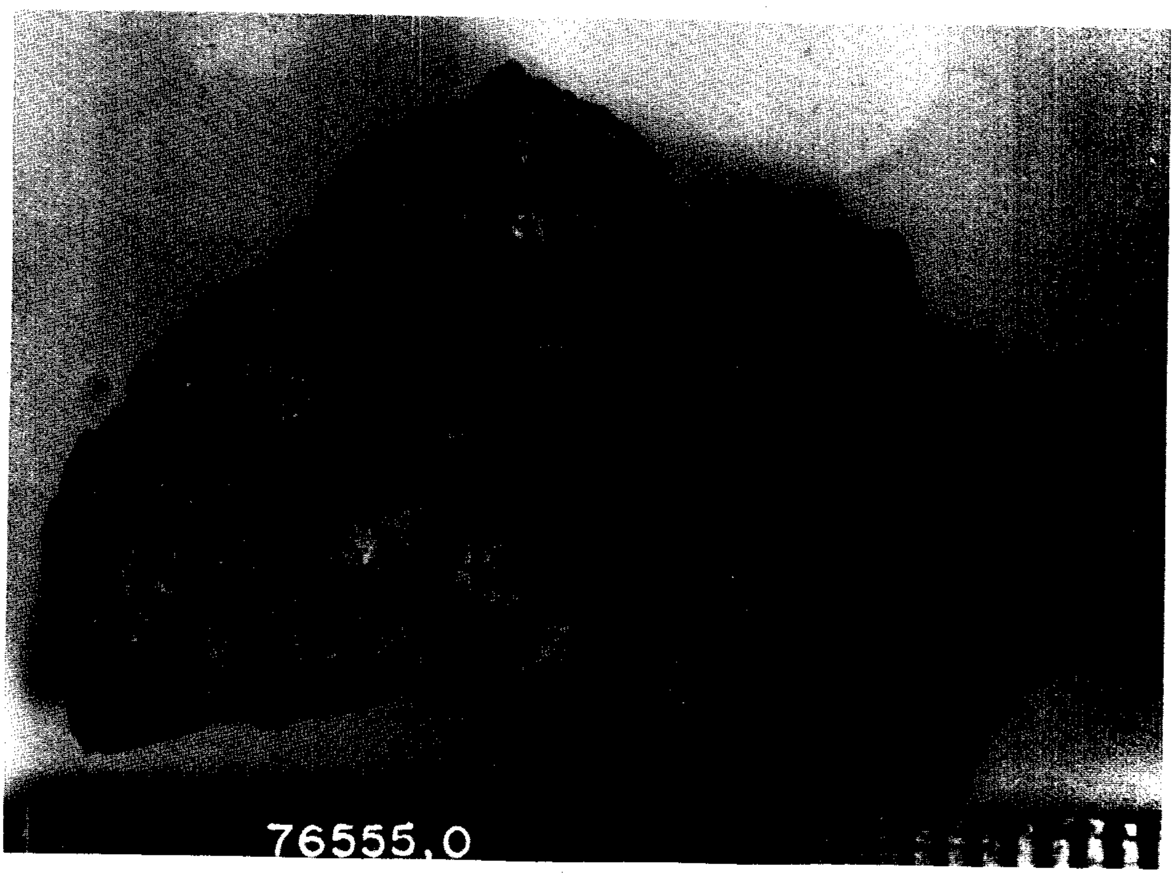


Figure 1: Photograph of 76555. Scale bar is in mm. S73-19618.

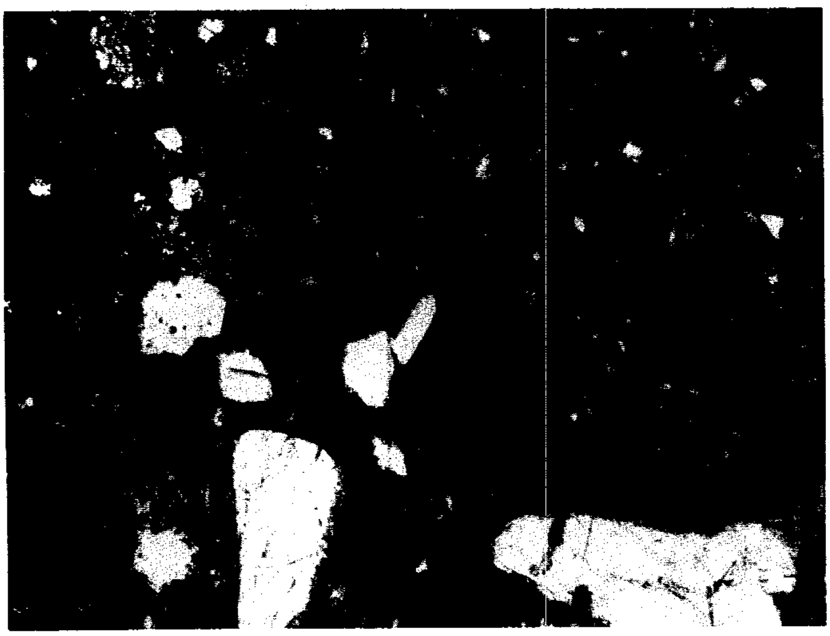


Figure 2: Photomicrograph of thin section 76555,7. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76555.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split Technique	,2 EMP
SiO_2 (wt%)	46.36
TiO_2	1.49
Al_2O_3	18.04
Cr_2O_3	0.18
FeO	8.32
MnO	
MgO	12.23
CaO	10.96
Na_2O	0.8
K_2O	0.29

76556

Micropoikilitic Impact Melt Breccia
7.396 g, 2.5 x 2 x 2 cm

INTRODUCTION

Sample 76556 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974).

PETROGRAPHY

76556 is a light grey, microcrystalline impact melt rock (Fig. 1). Thin sections of 76556 indicate a clastic origin. The matrix has a micropoikilitic texture (Fig. 2).

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) point out that this micropoikilitic impact melt breccia has less Fe and more Mg than the boulder at Station 6 (Table 1). They speculate that it may be similar to the large sample 76055.

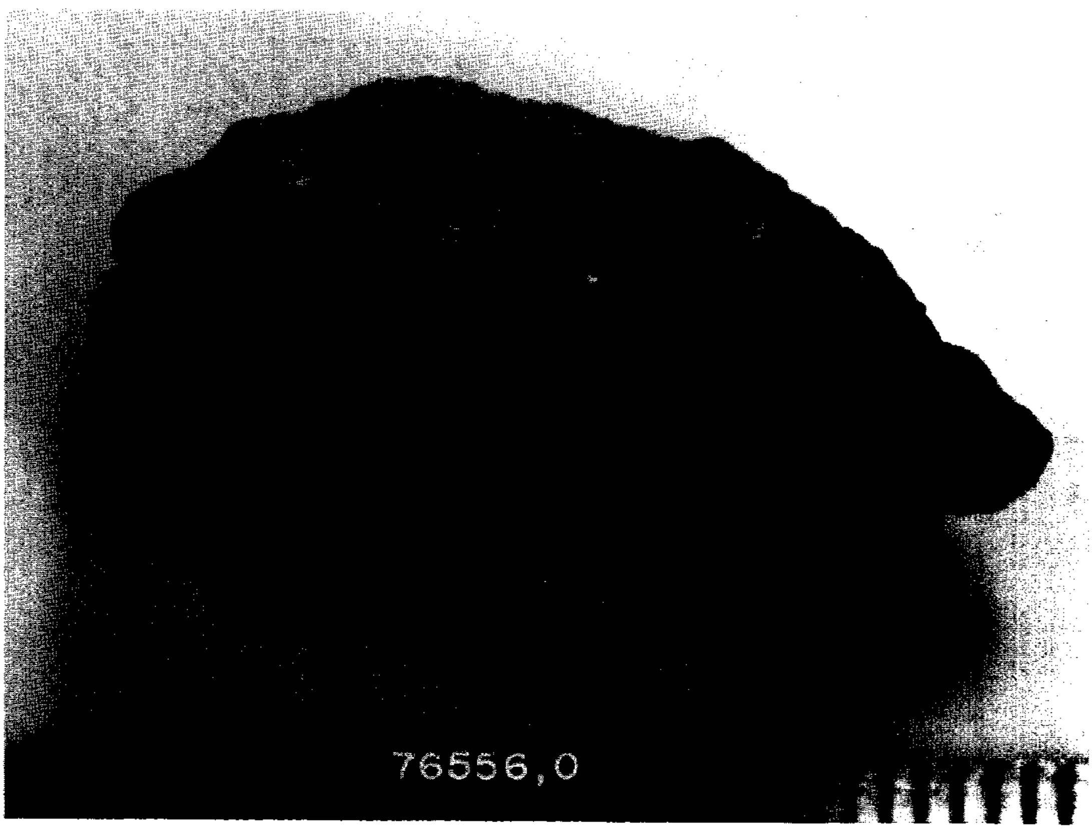


Figure 1: Photograph of 76556. Scale bar is marked in mm. S73-19597.

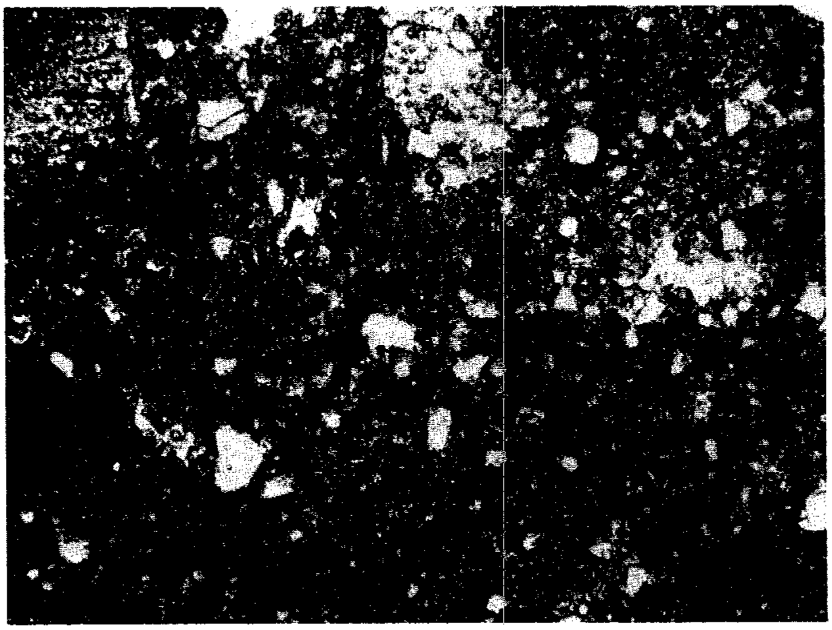


Figure 2: Photomicrograph of thin section 76556,7. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76556.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split **Technique**	**,3** **EMP**
SiO_2 (wt%)	46.55
TiO_2	1.47
Al_2O_3	18.73
Cr_2O_3	0.18
FeO	7.40
MnO	
MgO	11.73
CaO	11.47
Na_2O	0.75
K_2O	0.24

76557

Micropoikilitic Impact Melt Breccia
5.592 g, 2 x 1.5 x 1 cm

INTRODUCTION

Breccia 76557 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974).

PETROGRAPHY

Sample 76557 has a clastic texture with micropoikilitic matrix. Fig. 1 shows that it has small flattened cavities that define a foliation. Fig. 2 shows the clastic texture and annealed, poikilitic matrix. A clast of exsolved pyroxene is incorporated in the crystallized melt.

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) point out that this micropoikilitic breccia has less Fe and more Mg than the boulder at Station 6 (Table 1). They speculate that it may be similar to the large sample 76055.

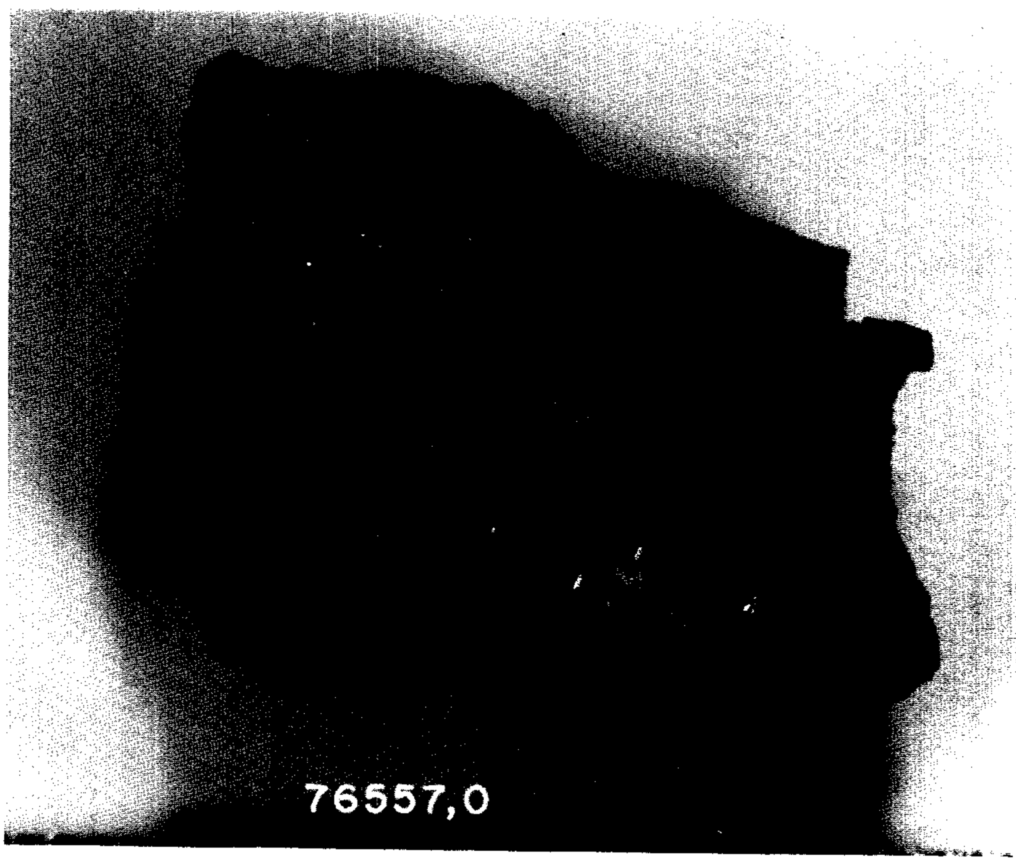


Figure 1: Photograph of 76557. Scale bar is in mm. S73-19599.

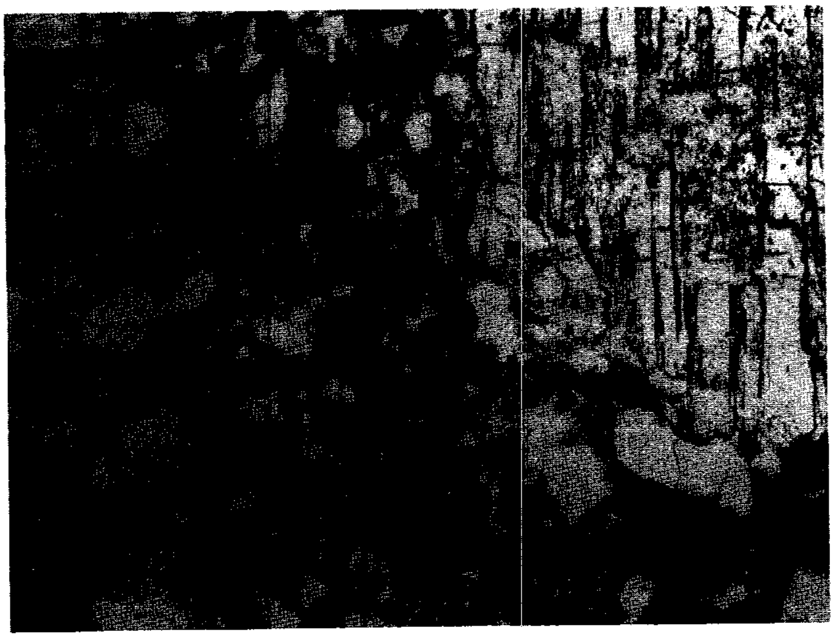


Figure 2: Photomicrograph of section 76557,7, showing exsolved pyroxene clast incorporated in poikilitic matrix. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76557.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split **Technique**	**,1** **EMP**
SiO_2 (wt%)	46.26
TiO_2	1.21
Al_2O_3	18.05
Cr_2O_3	0.17
FeO	7.64
MnO	
MgO	13.79
CaO	10.46
Na_2O	0.8
K_2O	0.39

76558
Impact Melt Breccia
0.683 g, 1.5 x 0.8 x 0.5 cm

INTRODUCTION

Sample 76558 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974).

PETROGRAPHY

This small fragment of light grey impact melt breccia (with some dark matrix regolith attached) is held together by black glass (Fig. 1). The appearance of 76558 is very similar to 76559.

WHOLE-ROCK CHEMISTRY

The composition of 76558 has not been determined.

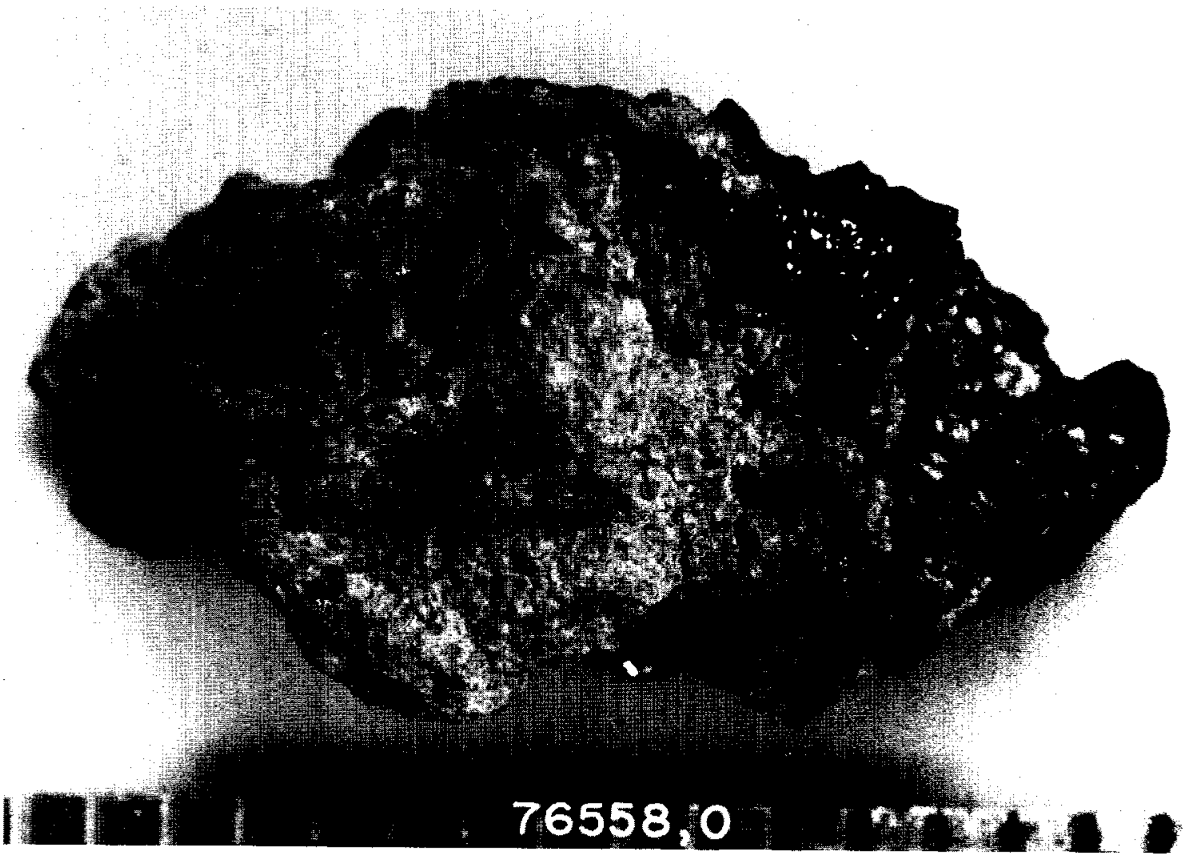


Figure 1: Photograph of 76558. Scale bar is marked in mm. S73-19631.

76559

Poikilitic Impact Melt Breccia
0.747 g, 1 x 1 x 0.75 cm

INTRODUCTION

Sample 76559 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974). There is a black glass splash and some soil breccia attached (Fig. 1).

PETROGRAPHY

Sample 76559 is light grey impact melt rock with a poikilitic matrix. Pyroxene and ilmenite oikocrysts enclose anorthite grains (Fig. 2). The sample is completely crystalline.

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) point out that this poikilitic breccia has less Fe and more Mg than the boulder at Station 6 (Table 1). They speculate that it may be similar to the large breccia sample 76055.

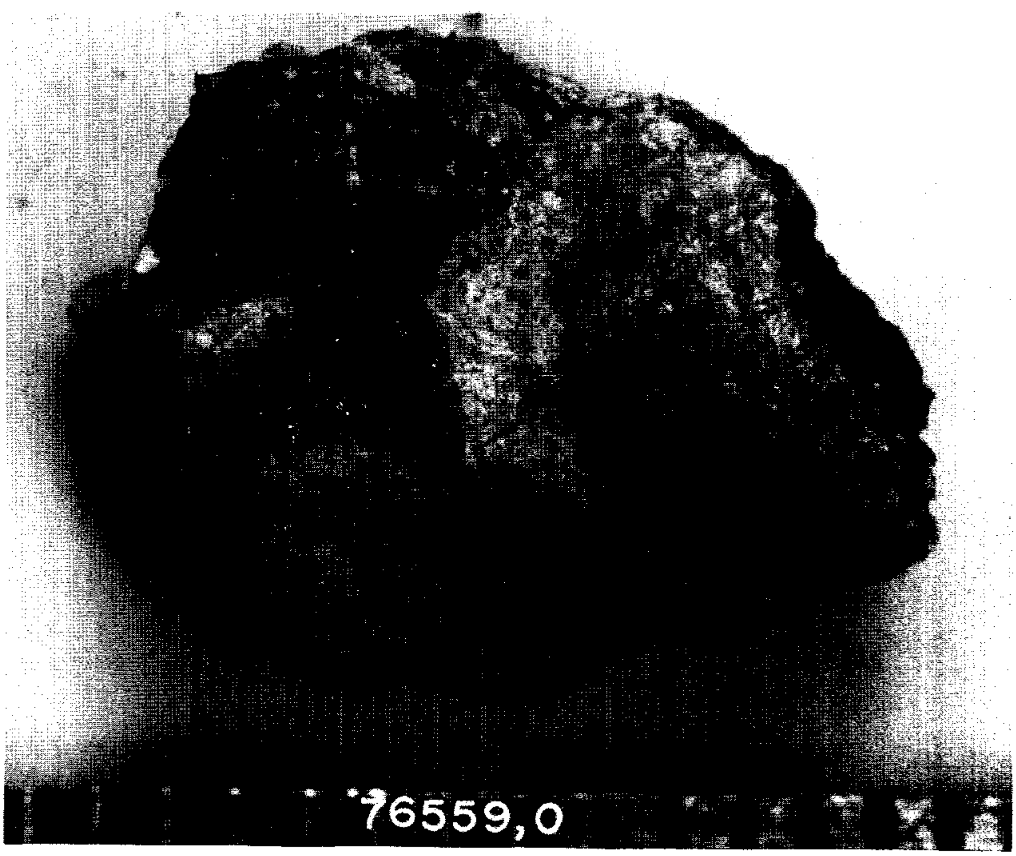


Figure 1: Photograph of 76559. Scale bar is marked in mm. S73-19629.

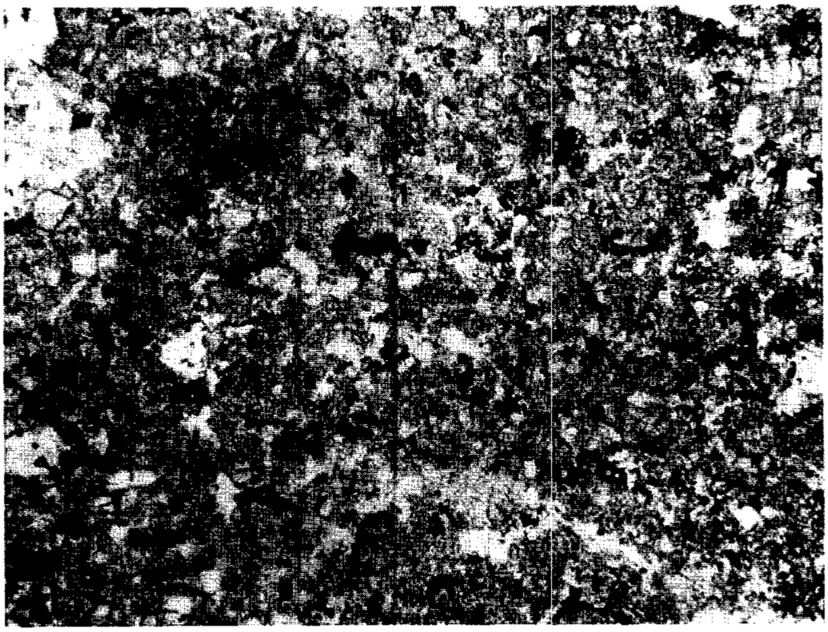


Figure 2: Photomicrograph of thin section 76559,7, showing well-developed poikilitic matrix. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76559.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split **Technique**	**,2** **EMP**
SiO_2 (wt%)	46.47
TiO_2	1.49
Al_2O_3	17.53
Cr_2O_3	0.18
FeO	8.36
MnO	
MgO	12.98
CaO	10.78
Na_2O	0.64
K_2O	0.27

76565
Dark Matrix Regolith Breccia
11.6 g, 2.5 x 2.5 x 2 cm

INTRODUCTION

Fruland (1983) included 76565 in the suite of soil breccias to be studied by the Regolith Initiative, and it has been studied in detail by Simon et al. (1990). Warren et al. (1983) found the small white clast to be nonpristine.

PETROGRAPHY

Sample 76565 is a dark matrix regolith breccia (Fig. 1) with a high percentage of mineral fragments (Simon et al., 1990) (Table 1). It has a brown glass matrix (Fig. 2) and has been termed a "vitric matrix breccia" by Simonds et al. (1975). It contains orange glass beads and mare basalt fragments. It also contains fragments of feldspathic materials from the highlands (Figs. 1 and 2).

WHOLE-ROCK CHEMISTRY

The rare earth element composition of the dark matrix part of 76565 is identical to the Station 6 soil, 76501 (Fig. 3). The composition has been reported by Simonds and Warner (1981) and by Simon et al. (1990) (Table 2). It has a relatively high Ti content for talus from the North Massif, indicating lateral transport for the adjacent mare surface. Simonds et al. (1975) speculate that the vitric matrix breccias from the Station 6 soil may have come from small (less than 1 km across) craters that are within the Apollo 17 valley (e.g., SWP, Cochise, and Shorty).

SIGNIFICANT CLASTS

Warren et al. (1983) have studied the small white clast seen in Fig. 1 (estimated mass is ~150 mg). They

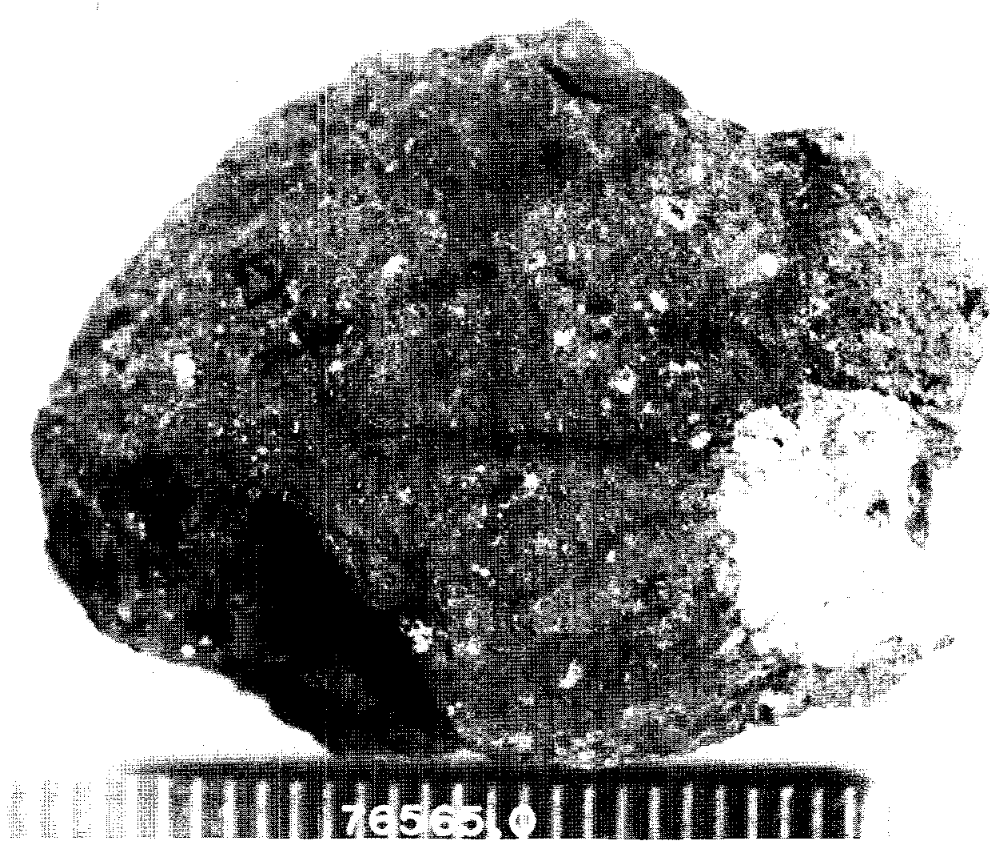


Figure 1: Sample 76565, showing a white clast studied by Warren. Scale bar is 1 mm. S73-19644.

conclude that it is a nonpristine "anorthositic, polymict, granulitic breccia." The relatively high Ir (20 ppb) and the Ni and Co content of the metal indicate meteoritic contamination. It is about 70% plagioclase ($An_{92.6-97.3}$), with olivine ($Fo_{71.9-74.1}$), and with both high-Ca and low-Ca pyroxene (Fig. 4).

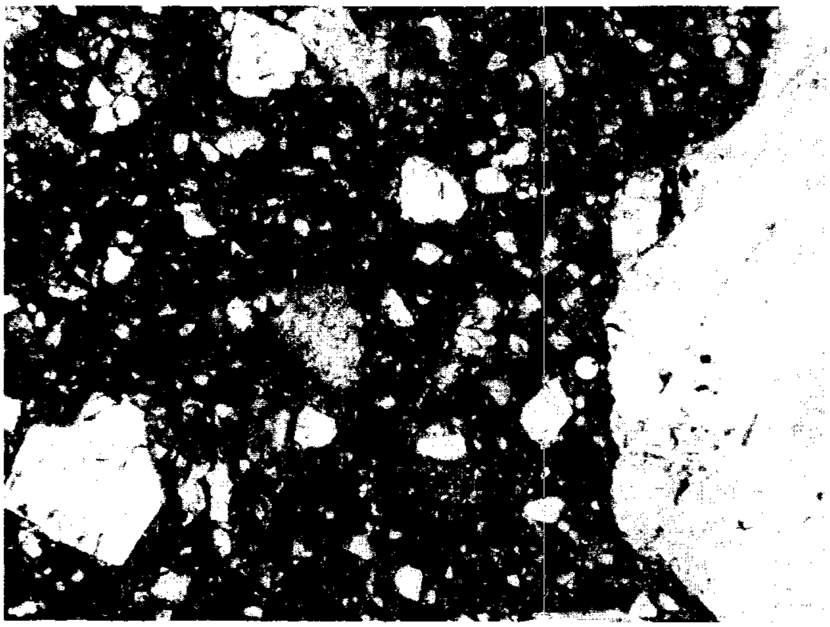


Figure 2: Photomicrograph of 76565,7, showing brown glass matrix and part of a clast of feldspathic highlands material. Field of view is 2 x 3 mm.

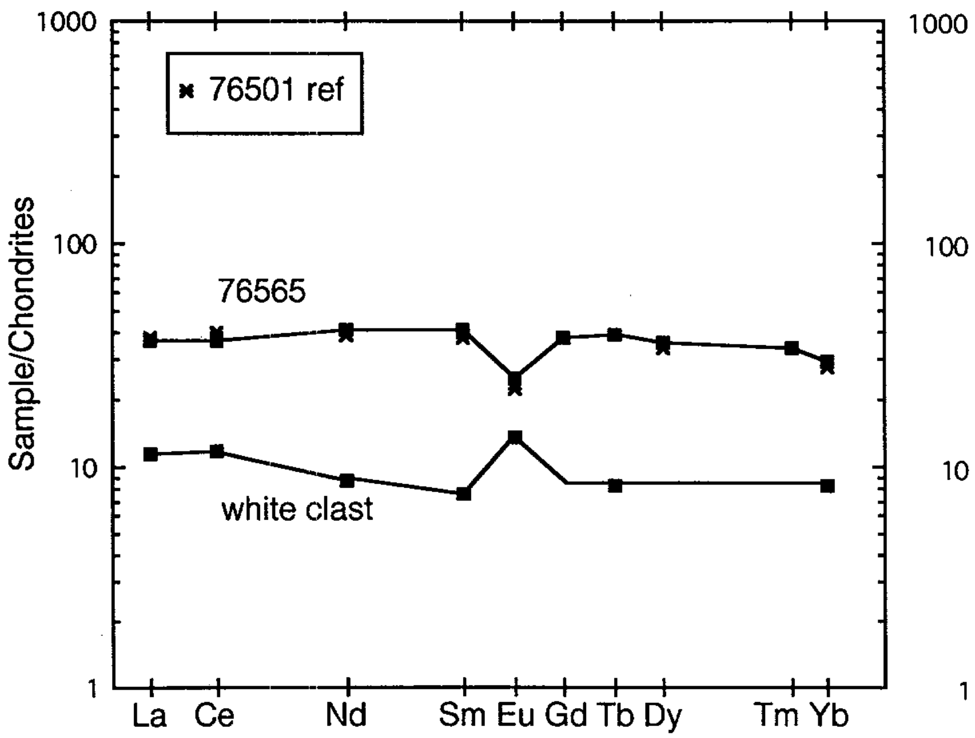


Figure 3: Normalized rare earth element diagram for 76565 and white clast in Fig. 1. The brown glass matrix has the same composition as 76501 soil.

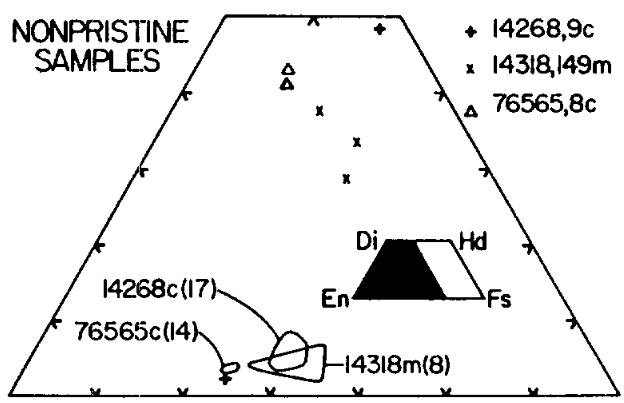


Figure 4: Pyroxene composition of 76565 white clast. From Warren et al. (1983).

Table 1: Mineralogical mode of brown glass matrix of 76565. From Simon et al. (1990).

	76565		78546		79035		79135		79175	
	S	L	S	L	S	L	S	L	S	L
Lithic Fragments										
Mare Component										
Mare Basalt	0.4	2.2	0.1	3.7	1.1	5.0	0.4	1.9	0.5	3.3
Highland Component										
Plutonic	0.5	2.5	0.1	1.8	0.1	0.1	0.1	0.6	0.3	3.0
Feld. Frag. Breccia	0.1	–	–	0.1	–	0.1	–	0.5	–	0.2
Feld. Basalt	–	–	–	0.1	–	–	0.1	–	–	–
Granulite/Poik.	0.5	1.9	0.2	0.5	–	–	0.2	0.6	0.1	0.2
Impact Melt	0.5	0.4	0.5	1.5	0.7	1.2	0.5	1.5	0.4	1.2
Fused Soil Component										
Regolith Brecc.	0.1	1.5	0.1	2.7	0.3	0.3	0.2	0.8	0.1	2.0
Agglutinate	1.6	1.5	0.7	3.5	5.0	8.6	0.9	5.0	0.6	4.0
Mineral Fragments										
Pyroxene	3.8	1.6	3.8	1.2	3.8	1.7	3.2	1.7	2.9	1.7
Olivine	2.4	1.0	1.4	0.4	0.8	0.4	0.9	0.5	0.6	0.3
Plagioclase	7.8	5.6	4.2	3.4	2.2	0.8	3.4	1.6	1.7	1.4
Opaque	1.5	0.3	0.8	–	1.7	0.2	1.9	0.3	1.5	0.6
Glass Fragments										
Orange/Black	1.1	–	2.5	0.5	1.1	–	2.7	0.7	0.7	0.3
Yellow/Green	0.6	0.6	1.5	0.4	0.8	0.4	1.2	1.1	0.2	0.1
Colorless	1.0	0.1	0.8	–	0.6	1.0	1.3	1.1	0.2	0.3
Brown	0.2	–	0.2	–	0.2	–	0.1	–	0.2	0.1
Miscellaneous										
Devit. Glass	1.7	1.2	3.7	6.8	2.2	1.4	3.0	2.7	2.0	3.1
Other	0.2	0.2	–	0.2	0.1	–	–	0.4	0.1	0.2
Total	24.0	20.6	20.6	26.8	20.7	21.2	20.1	21.0	12.1	22.0
Matrix	55.4		52.6		58.1		58.9		65.9	

Matrix = <20μm; S = small clasts (90 – 20μm); L = large clasts (1000 – 90μm); tr = trace.

Table 2: Whole-rock chemistry of 76565.
a) Simonds and Warner (1981); b) Simon et al. (1990); c) Warren et al. (1983)
**(Cautionary note: Some of these preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)*

Split Technique	,2 (a) EMP matrix	,13 (b) INAA matrix	,10 (c) INAA clast
SiO_2 (wt%)	43.94*	–	45.37
TiO_2	3.24*	4.57	0.25
Al_2O_3	18.59*	16.1	26.08
Cr_2O_3	0.27*	0.32	0.16
FeO	9.57*	12.4	5.66
MnO		0.16	0.08
MgO	10.22*	10.3	8.13
CaO	12.15*	12.0	14.56
Na_2O	0.49*	0.41	0.35
K_2O	0.12*	0.09	0.10
Nb (ppm)			
Zr		120	–
Hf		5.00	1.08
Ta		0.86	0.16
U		0.32	0.21
Th		1.12	0.72
Sr		160	
Rb		4.7	
Ba		105	62
Cs		0.14	0.22
Zn		35	9.4
Ni		130	420
Co		30	33.1
Sc		38.7	10.9
La		8.55	2.71
Ce		22.5	7.1
Nd		18.7	3.9
Sm		6.04	1.13
Eu		1.38	0.75
Gd		7.4	
Tb		1.4	0.3
Dy		8.7	1.91

Table 2: (Concluded).

Split **Technique**	**,2 (a)** **EMP** **matrix**	**,13 (b)** **INAA** **matrix**	**,10 (c)** **INAA** **clast**
Tm		0.81	
Yb		4.78	1.32
Lu		0.72	0.21
Ga			3.9
Ge (ppb)			0.15
Ir		4.5	20
Au		2.0	7.2

76566

Dark Matrix Regolith Breccia
2.639 g, 2 x 1.5 x 1 cm

INTRODUCTION

These two fragments of brown glass matrix regolith breccia are very similar to 76545 from the same rake sample.

PETROGRAPHY

Sample 76566 is typical brown glass regolith breccia (Fig.1). It is lithified local soil. No studies have been done and no thin sections exist.

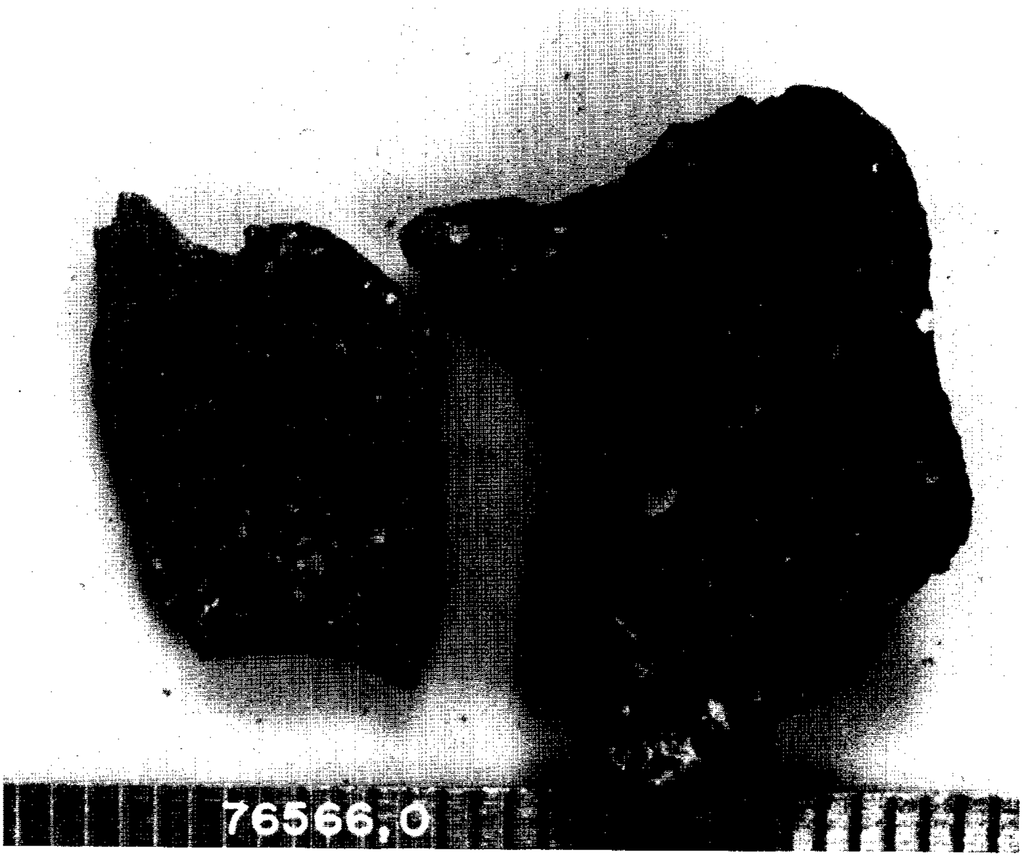


Figure 1: Photograph of 76566. Scale bar is marked in mm. S73-19639.

76567

Light Matrix Regolith Breccia
5.49 g, 2 x 1.5 x 1 cm

INTRODUCTION

Sample 76567 is a vitric matrix breccia that contains fragments of mare, nonmare, and orange glass. It has a light-colored grey matrix with both light and dark clasts. It does not have the brown tint characteristic of the mare regolith breccias.

PETROGRAPHY

Phinney et al. (1976) have studied 76567 by SEM petrography. They term it a moderately coherent vitric matrix breccia with only ~20% glass in matrix.

The surface of 76537 has zap pits galore (Fig. 1). The thin section shows that the matrix is transparent (Fig. 2). A clast of a feldspathic highlands rock is attached.

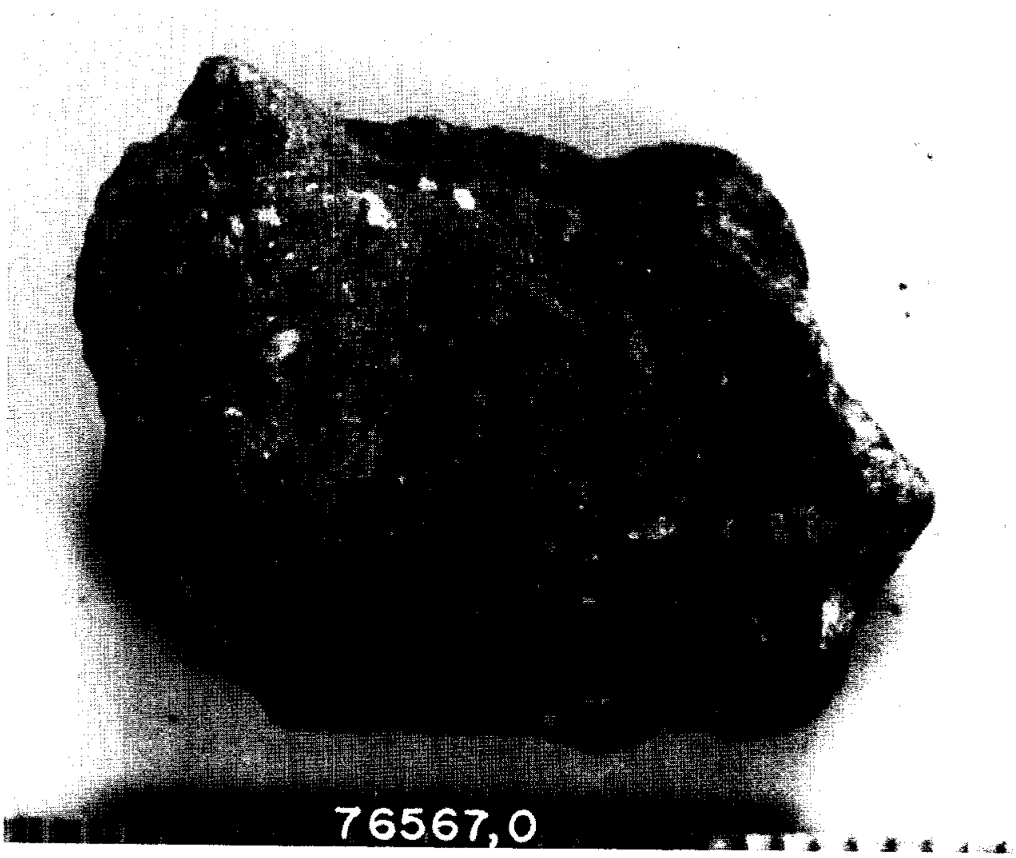


Figure 1: Photograph of light grey breccia 76567. Scale bar is marked in 1 mm. S73-19641.

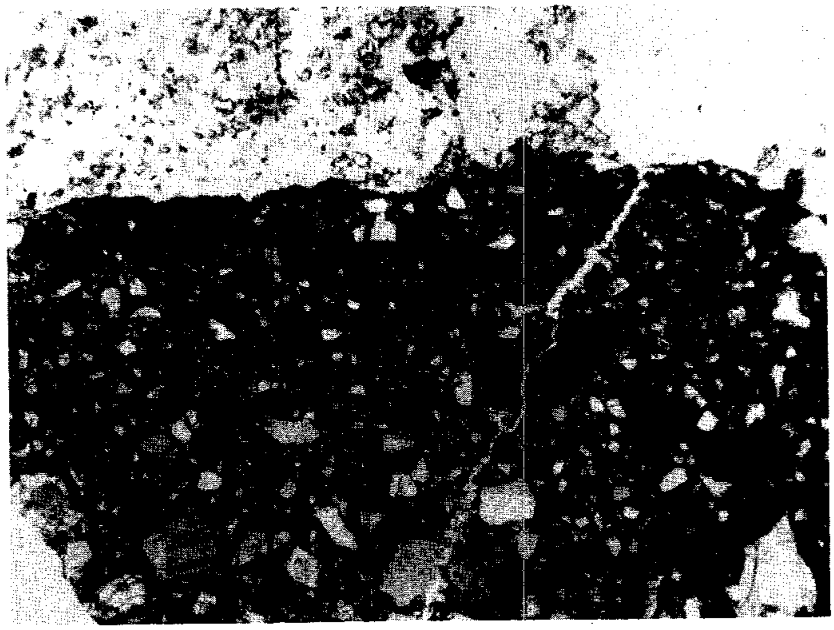


Figure 2: Photomicrograph of 76567,7, showing matrix attached to clast of highlands material. Field of view is 2 x 3 mm.

76568

Aphanitic High-Ti Mare Basalt
9.477 g, 2.5 x 2 x 2 cm

INTRODUCTION

Sample 76568 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974).

PETROGRAPHY

Sample 76568 is an aphanitic mare basalt with variolitic texture (Fig. 1). The thin section of 76568,7 shows that it is ilmenite rich (Fig. 2). The chemical composition of this fragment has been determined by Roy Brown (unpublished, in Simonds and Warner, 1981). The high TiO_2 content (~11%) is consistent with the ilmenite abundance in the thin section.

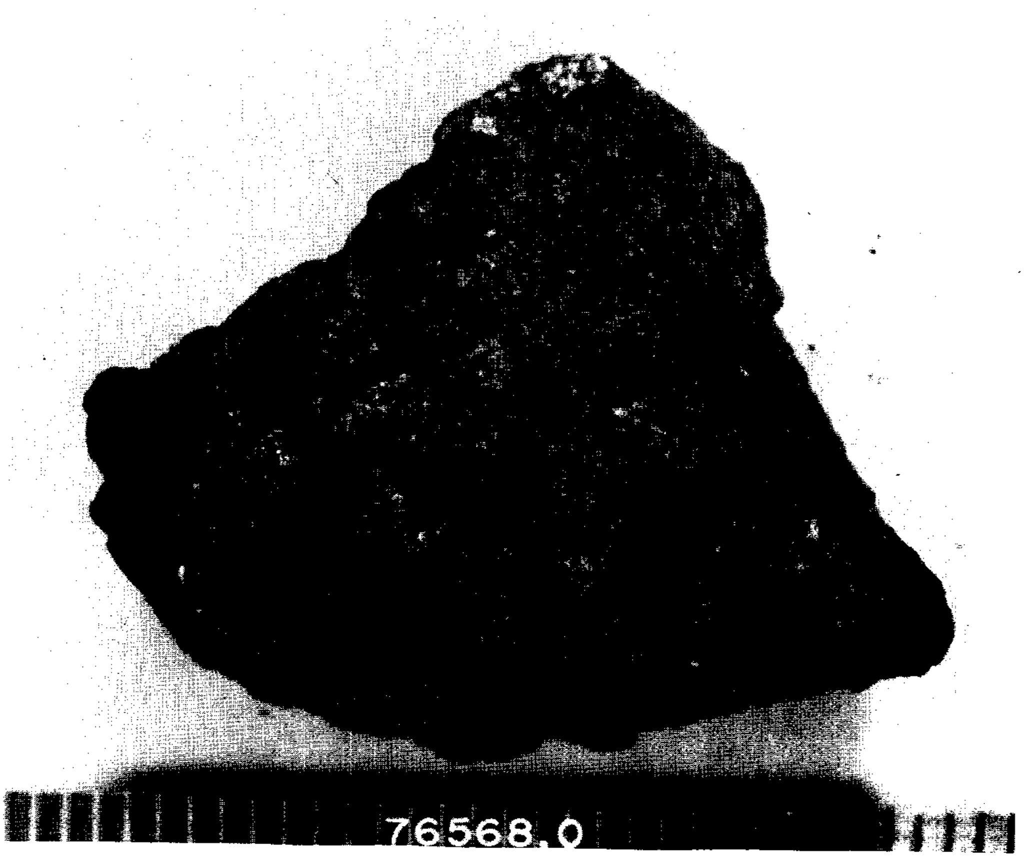


Figure 1: Photograph of 76568. Scale bar is in mm. S73-19642.

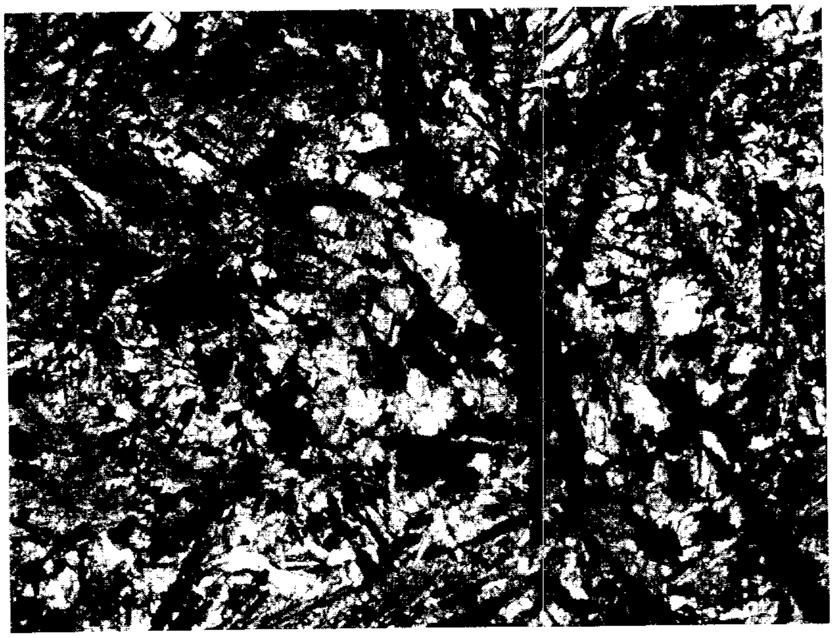


Figure 2: Photomicrograph of 76568,7. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76568.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split Technique	,2 EMP
SiO_2 (wt%)	39.50
TiO_2	11.12
Al_2O_3	9.16
Cr_2O_3	0.46
FeO	17.79
MnO	
MgO	8.70
CaO	10.65
Na_2O	0.53
K_2O	0.10

76569
Aphanitic Impact Melt Breccia
4.207 g, 2 x 1.5 x 1 cm

INTRODUCTION

Sample 76569 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974).

PETROGRAPHY

Sample 76569 is a coherent, dark grey impact melt rock. It has zap pits on all surfaces (Fig. 1). The matrix of this sample is crystalline, but very fine grained, so that the sample is aphanitic. Mineral and lithic clasts in the matrix are rounded (Fig. 2).

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) report a preliminary analysis of 76569 (Table 1).

Figure 1: Photograph of 76569. Scale bar is marked in mm. S73-19635.

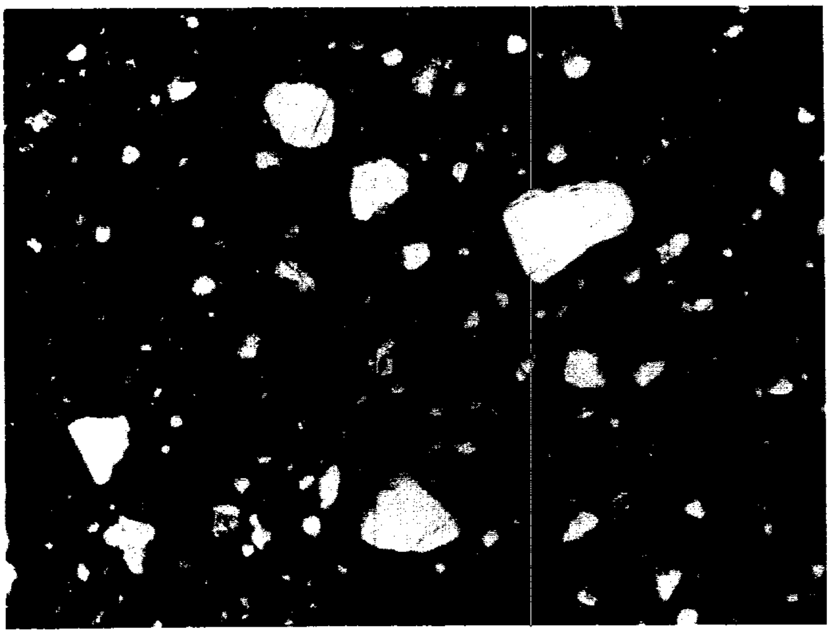


Figure 2: Photomicrograph of thin section 76569,8. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76569.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split Technique	,2 EMP
SiO_2 (wt%)	47.79
TiO_2	1.23
Al_2O_3	17.34
Cr_2O_3	0.23
FeO	8.66
MnO	
MgO	11.42
CaO	10.73
Na_2O	0.68
K_2O	0.36

76575

Feldspathic Impact Melt Breccia
16.25 g, 3 x 2 x 2 cm

INTRODUCTION

Sample 76575 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974). The surface of this rounded fragment is covered with glass splashes, patina, and micrometeorite pits (Fig. 1).

PETROGRAPHY

This unique fragment has clasts of aphanitic breccia included within a fragmental matrix of mostly feldspar (Fig. 2).

WHOLE-ROCK CHEMISTRY

This sample has been analyzed by XRF and isotopic dilution mass spectroscopy (Table 1). It has a high Al_2O_3 content (~ 26%) and low trace element content (Fig. 3).

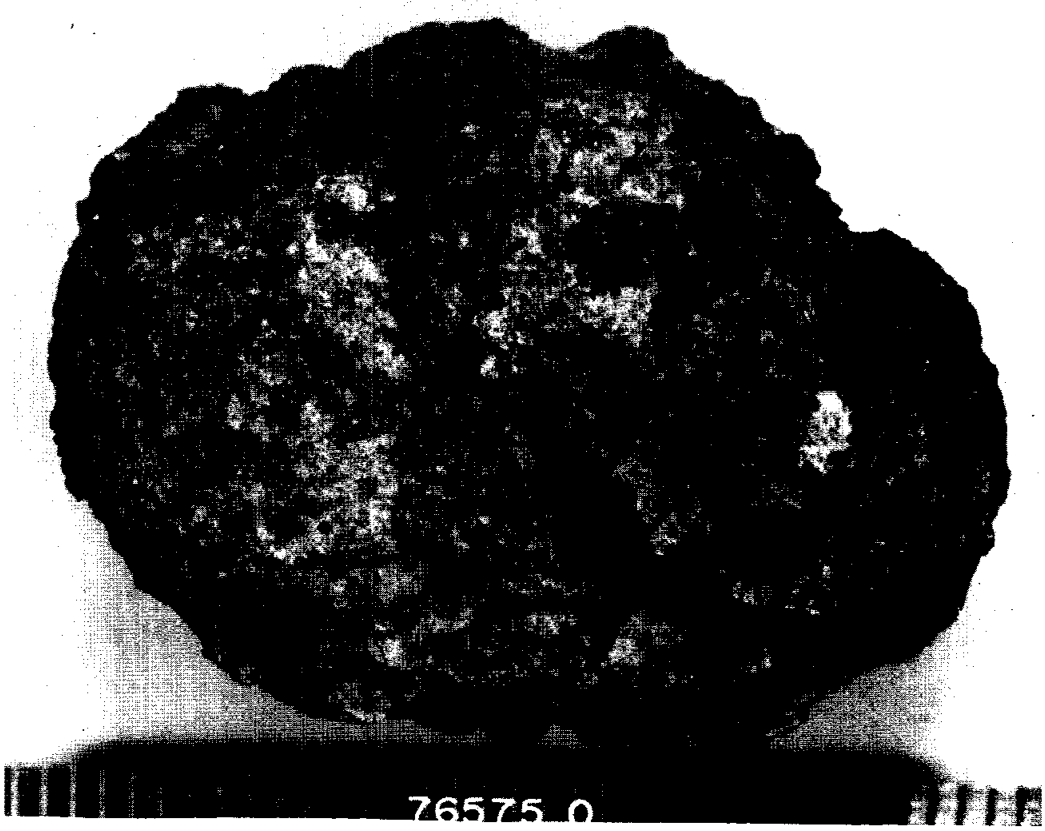


Figure 1: Photograph of 76575. Scale bar is marked in mm. S73-19633.

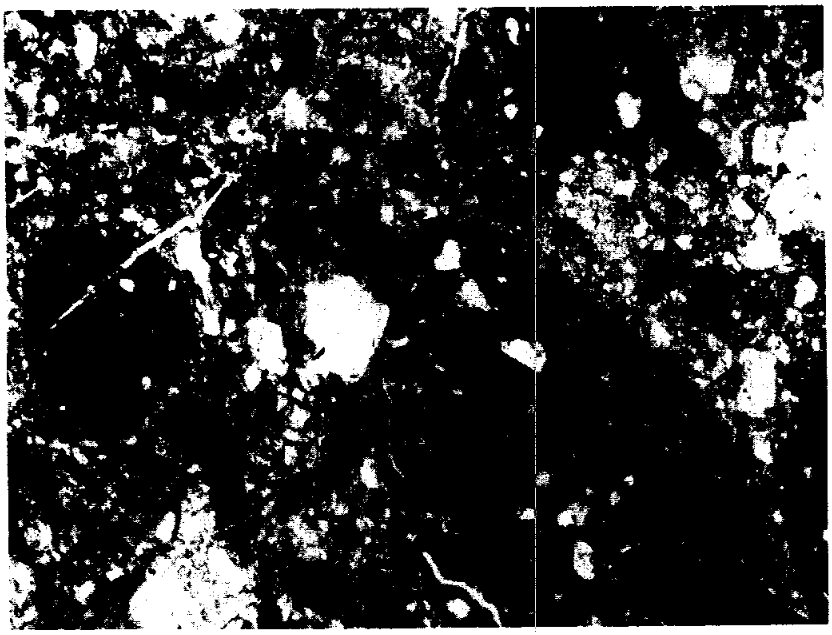


Figure 2: Photomicrograph of thin section 76575,10 showing suevite texture. Field of view is 2 x 3 mm.

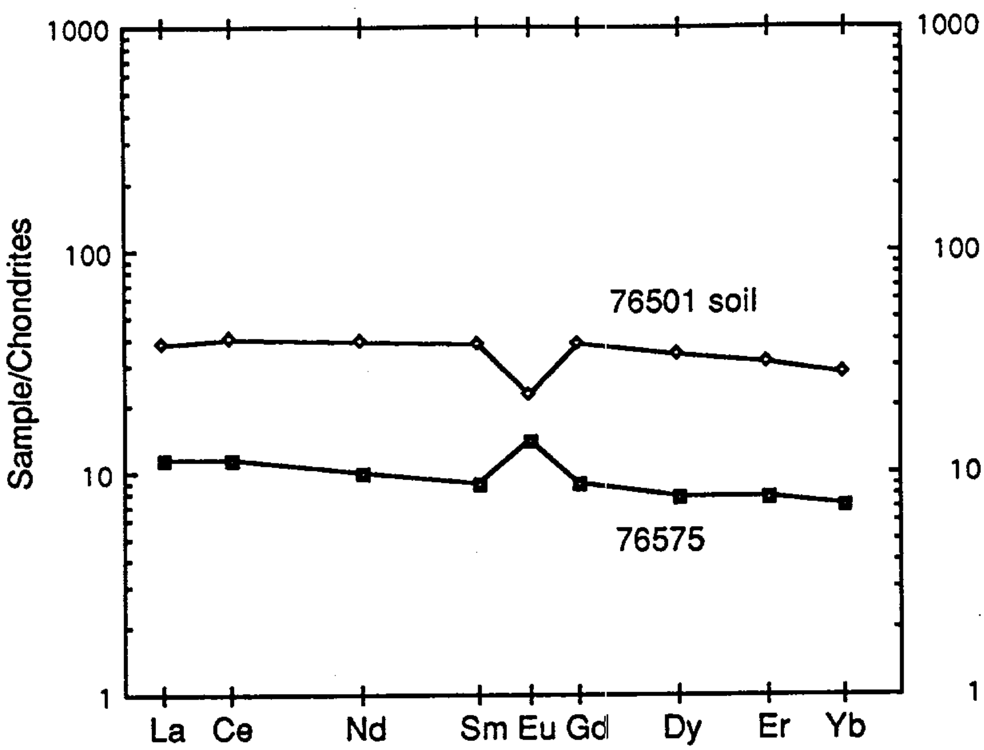


Figure 3: Normalized rare earth element diagram comparing 76575 with the Station 6 soil (76501).

Table 1: Whole-rock chemistry of 76575.
From Simonds and Warner (1981); Wiesmann and Hubbard (1975).

Split Technique	,3 XRF, IDMS
SiO_2 (wt%)	44.83
TiO_2	0.34
Al_2O_3	25.77
Cr_2O_3	0.11
FeO	5.61
MnO	0.08
MgO	7.45
CaO	15.23
Na_2O	0.35
K_2O	0.03
P_2O_5	0.04
S	0.04
Nb (ppm)	
Zr	47
U	0.13
Th	0.48
Sr	–
Rb	0.697
Li	3.7
Ba	36.7
La	2.67
Ce	7.02
Nd	4.49
Sm	1.31
Eu	0.775
Gd	1.75
Dy	1.90
Er	1.23
Yb	1.16
Lu	0.169

76576
Micropoikilitic Impact Melt Breccia
5.327 g, 2.5 x 1.5 x 1.5 cm

INTRODUCTION

This light grey fragment has lots of small micrometeorite pits on its surface (Fig. 1). This unique highlands sample is a nonpristine impact melt breccia with a micropoikilitic breccia texture.

PETROGRAPHY

Sample 76567 has an annealed cataclastic breccia texture that is different from the boulders at Station 6 and may be from a different part of the highlands crust. It has many small mineral fragments set in an aphanitic matrix (Fig. 2). Pyroxene oikocrysts are just beginning to form. It has about 65% plagioclase, 20% olivine, and 10% low-Ca pyroxene and ~5% high-Ca pyroxene.

WHOLE-ROCK CHEMISTRY

According to Simonds and Warner (1981), sample 76576 has "a K_2O-poor unique composition and an annealed texture which is totally different from the boulder matrices." However, there is the possibility that it could have been a clast in the melt sheet. This sample has also been analyzed by Warren and Wasson (1978) (Table 1). It is nonpristine and has a uniquely low and flat rare earth element pattern (Fig. 3).

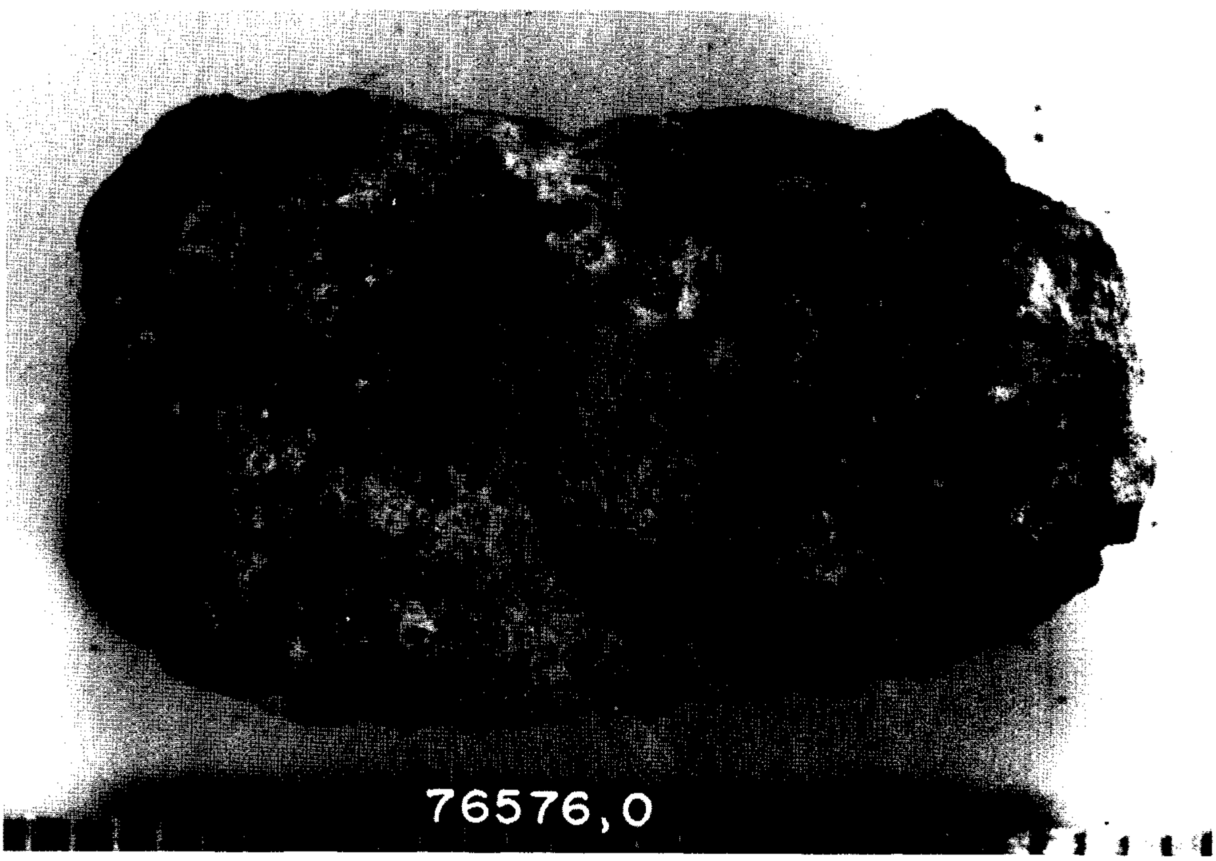


Figure 1: Photograph of rake sample 76576. Scale bar is marked in 1 mm. S73-19637.

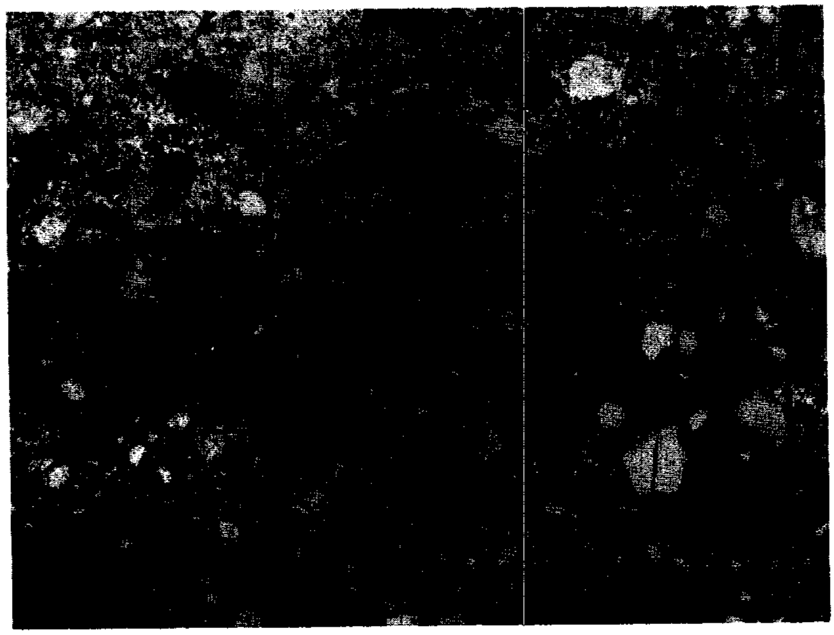


Figure 2: Photomicrograph of thin section 76576,7. Field of view is 2 x 3 mm.

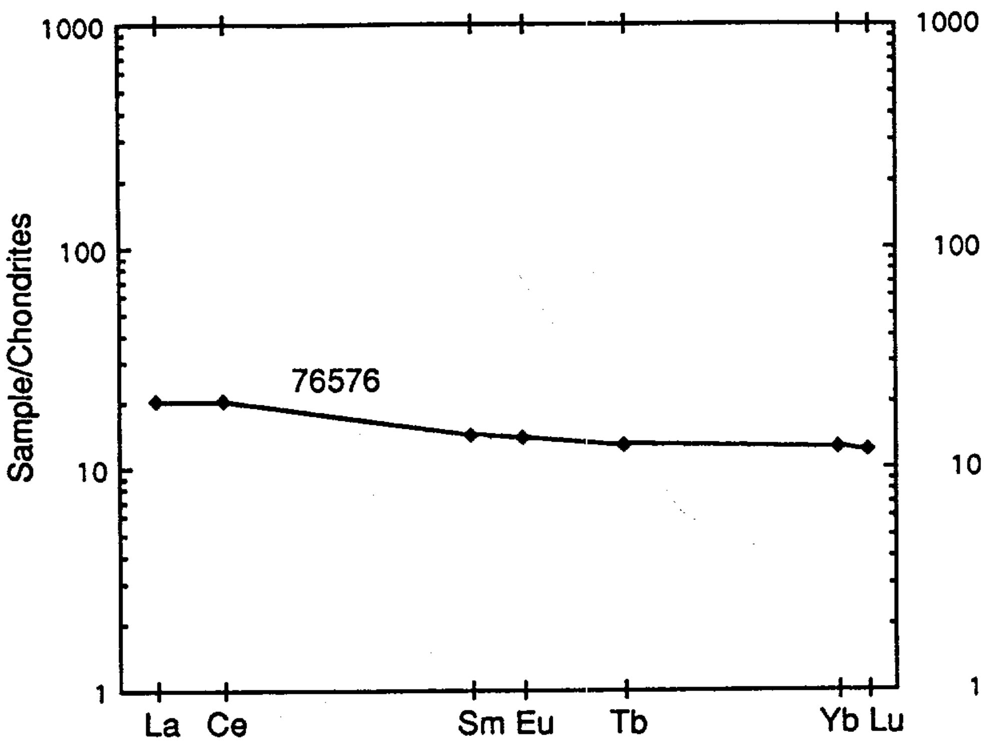


Figure 3: Normalized rare earth element diagram for highlands sample 76576.

Table 1: Whole-rock chemistry of 76576.
a) Simonds and Warner (1981); b) Warren and Wasson (1978)
**(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)*

Split technique	,2 (a) EMP	,3 (b) INAA
SiO_2 (wt%)	43.34*	45.15
TiO_2	0.29*	0.20
Al_2O_3	19.95*	23.06
Cr_2O_3	0.19*	
FeO	10.53*	8.23
MgO	12.95*	9.88
CaO	11.62*	13.86
Na_2O	0.34*	0.30
K_2O	0.08*	0.10
Nb (ppm)		
Cr		1230
Mn		780
Zr		–
Hf		1.7
Ta		0.28
U		0.31
Th		1.2
Ba		90
Zn		1.4
Ni		111
Co		28.4
Sc		12.1
La		4.7
Ce		12
Nd		–
Sm		2.03
Eu		0.75
Tb		0.45
Yb		2
Lu		0.29
Ga		3.22
Ge (ppb)		20
Re		0.51
Ir		6.3
Au		2.18

76577
Poikilitic Impact Melt Breccia
13.54 g, 2.5 x 2 x 2 cm

INTRODUCTION

Sample 76577 was collected as a rake sample from the soil at Station 6 (Phinney et al., 1974) (Fig. 1).

PETROGRAPHY

Sample 76577 has a nicely developed poikilitic texture (Fig. 2) with orthopyroxene and ilmenite oikocrysts surrounding relict angular clasts of anorthite plagioclase. It has small rounded vesicles (1 mm).

WHOLE-ROCK CHEMISTRY

Simonds and Warner (1981) point out that this poikilitic breccia has less FeO and more MgO than the boulder at Station 6. They speculate that it may be similar to the lithology represented by large sample 76055.

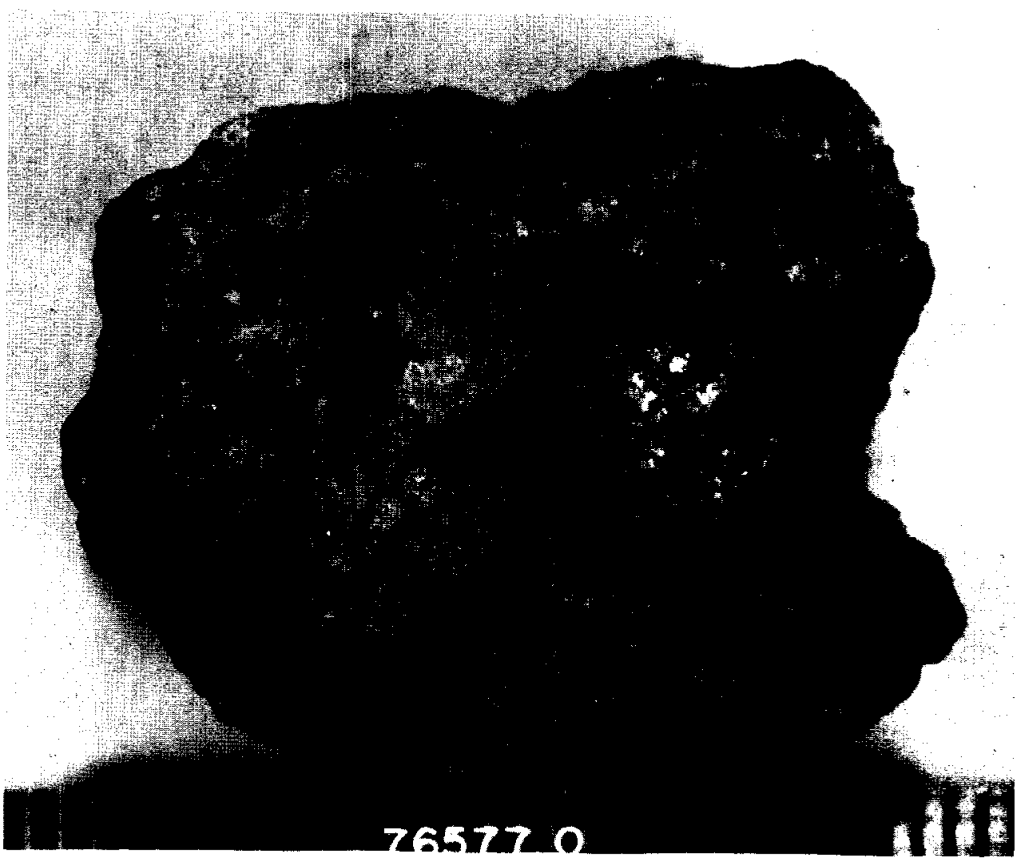


Figure 1: Photograph of 76577. Scale bar is marked in mm. S73-19645.

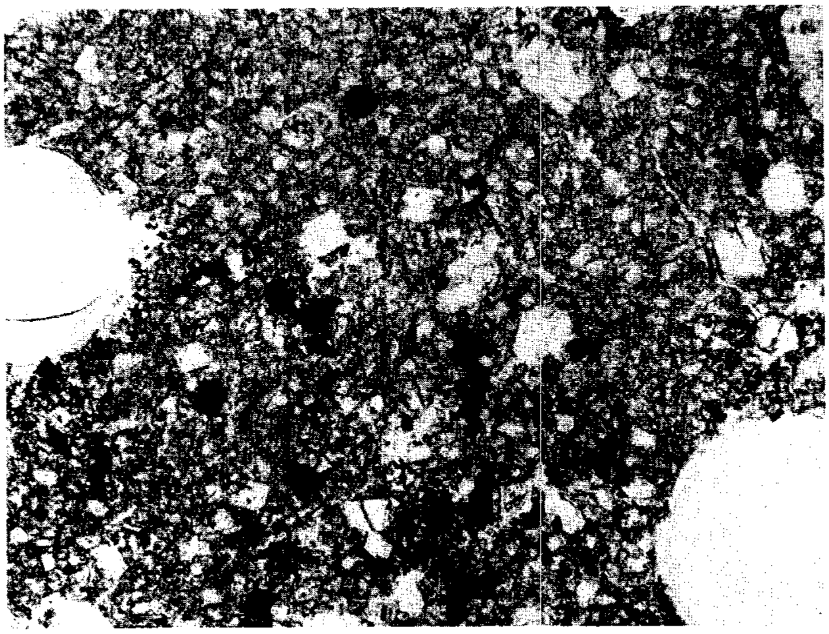


Figure 2: Photomicrograph of thin section 76577,7, showing mm-sized vesicles and poikilitic matrix texture. Field of view is 2 x 3 mm.

Table 1: Whole-rock chemistry of 76577.
From Simonds and Warner (1981).
(Cautionary note: These preliminary analyses were made by fused bead electron microprobe analyses, R. Brown, analyst.)

Split **Technique**	**,2** **EMP**
SiO_2 (wt%)	46.34
TiO_2	1.49
Al_2O_3	18.07
Cr_2O_3	0.17
FeO	8.02
MnO	
MgO	11.94
CaO	11.09
Na_2O	0.8
K_2O	0.33

77017
Poikilitic Anorthositic Gabbro
1730 g, 17 x 12.5 x 9 cm

INTRODUCTION

Sample 77017 is a large, annealed, feldspathic breccia set in a frothy black glass matrix (Fig. 1). A photograph of a slab through this rock reveals how the anorthositic portion has been incorporated in the black glass matrix (Fig. 2). The feldspathic portions all appear to be the same, with uniform chemistry and mineral composition. The anorthositic portion has high siderophiles with an age of about 4 b.y., while the glassy matrix is basaltic with a fusion age of about 1.5 b.y. (see below). The petrogenetic history of this rock was well-described by Helz and Appleman (1974).

Various names have been given to the feldspathic portion of this rock:

Crushed anorthositic gabbro – Butler (1973), Helz and Appleman (1974)

Poikilitic anorthositic gabbro – McCallum et al. (1974)

Feldspathic granulitic impactite – Warner et al. (1977)

Olivine gabbro breccia – Wolfe and others (1981)

Poikilitic anorthositic norite – Lindstrom and Lindstrom (1986).

PETROGRAPHY

The feldspathic portion of Apollo 17 sample 77017 is an olivine-bearing, anorthositic gabbro with a relatively coarse-grained poikilitic texture (McCallum et al., 1974; Helz and Appleman, 1974; and Ashwal, 1975). The mineral composition of 77017 is ~75% plagioclase (An_{94-97}), ~5% olivine (Fo_{60-65}), ~10% augite ($Wo_{37}En_{46}Fs_{17}$), and ~10% pigeonite ($Wo_8En_{62}Fs_{30}$). It contains relict lithic clasts of annealed troctolitic anorthosite and anorthosite. Mineral clasts of plagioclase, olivine, pink spinel, and opaque minerals are enclosed within

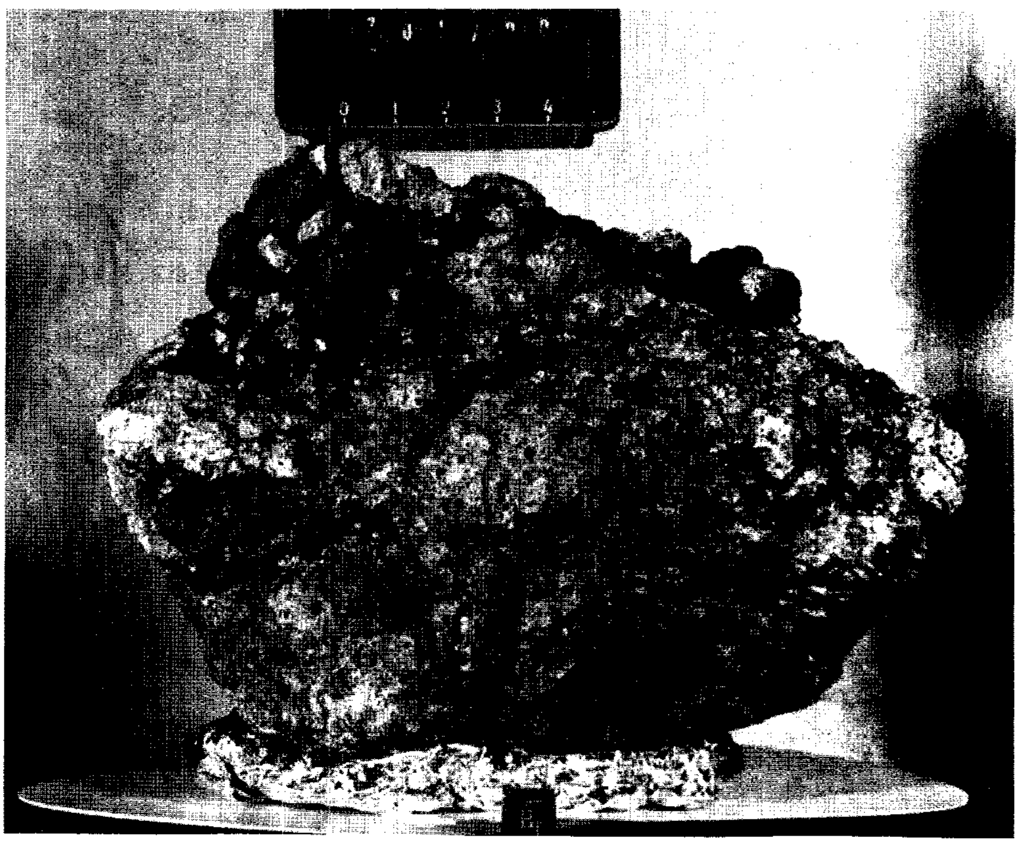


Figure 1: Photograph of lunar sample 77017. Cube is 1 cm. S73-17772.

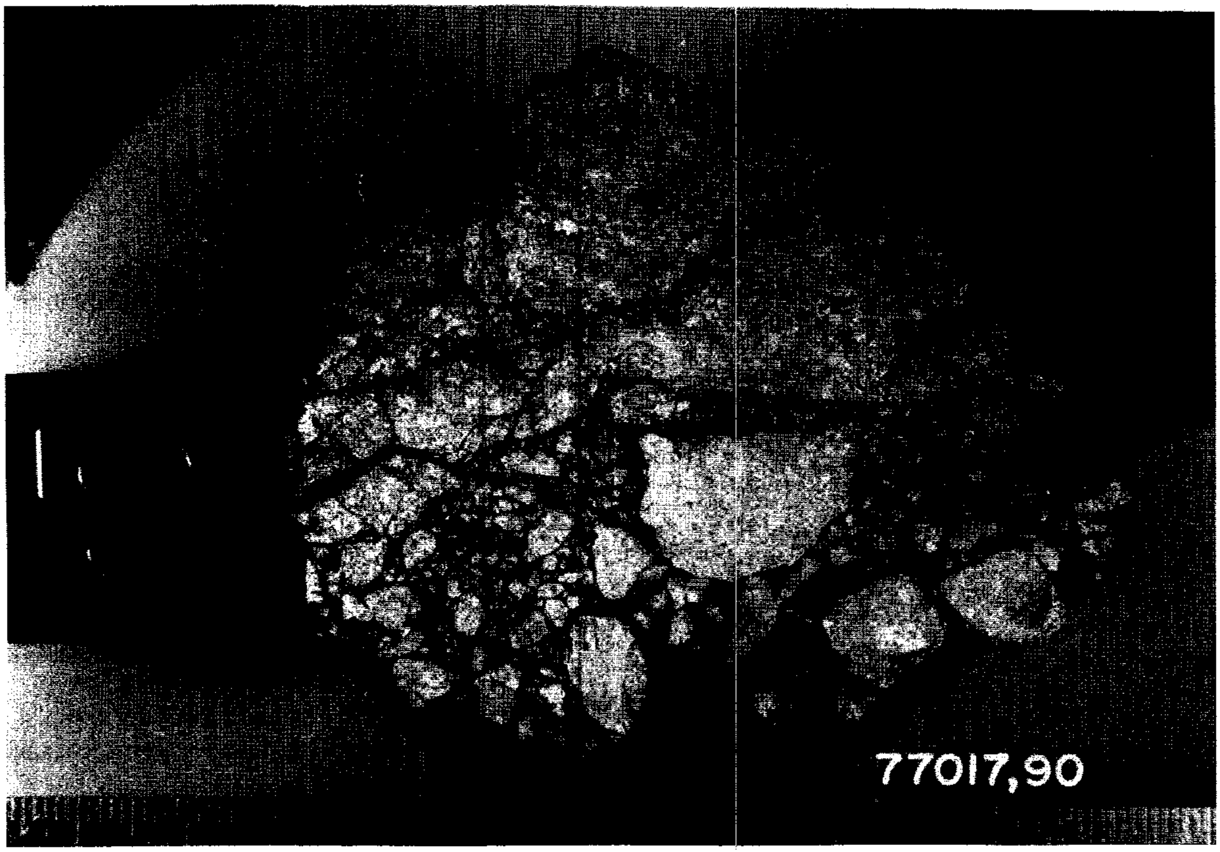


Figure 2: Slab surface of 77017. Cube is 1 inch. S75-34250.

pigeonite and augite oikocrysts. All minerals show a restricted compositional range.

A late shock event has caused partial granulation, producing a fine-grained cataclastic matrix. The proportions and compositions of minerals in the crushed areas are the same as in the uncrushed, indicating that the cataclasis was not accompanied by any significant transfer of material. Shock features are common: undulose extinction, shock-induced twinning, mosaicism, and partial to complete vitrification of plagioclase. Minor amounts of clear glass in the interior of the rock were produced by this late shock.

The plagioclase in the relict anorthosite and troctolitic anorthosite lithic clasts has well-developed polygonal grain boundaries indicative of extensive subsolidus annealing. Pyroxene oikocrysts (up to 1 mm) occur as both pigeonite and augite; sometimes found epitaxially intergrown (McCallum et al., 1974). Both pyroxenes show well-developed exsolution lamellae up to 2 µm wide. The pyroxenes are homogeneous in composition and show a well-defined compositional gap (Fig. 5). Anhedral olivine grains occur in the troctolitic anorthosite and are included in the pyroxene oikocrysts. Ilmenite oikocrysts enclose plagioclase and mafic minerals.

Temperatures calculated from the pyroxene pairs indicate a temperature of equilibration between 1050 and 1100 °C, which is estimated to be about 100 °C below the solidus for a rock of this composition (McCallum et al. 1974). One interpretation could be that this represents the Apollonian metamorphism proposed by Stewart (1975). However, the abundant amount of trace siderophiles leads one to consider the impact model of Simonds et al. (1975). Warner et al. (1977) propose that 77017 formed in the period after the consolidation of the lunar crust but before the final bombardment when "still hot impactite sheets could have been buried by layers of younger ejecta that were themselves hot." Helz and Appleman (1974) and Lindstrom and Lindstrom (1986) interpret the clasts in 77017 to represent a plutonic anorthositic norite lithology that was brecciated and metamorphosed to produce the poikiloblastic texture. Cushing et al. (1993) and James (1993) have recently discussed the relationship of 77017 to the "granulitic suite."

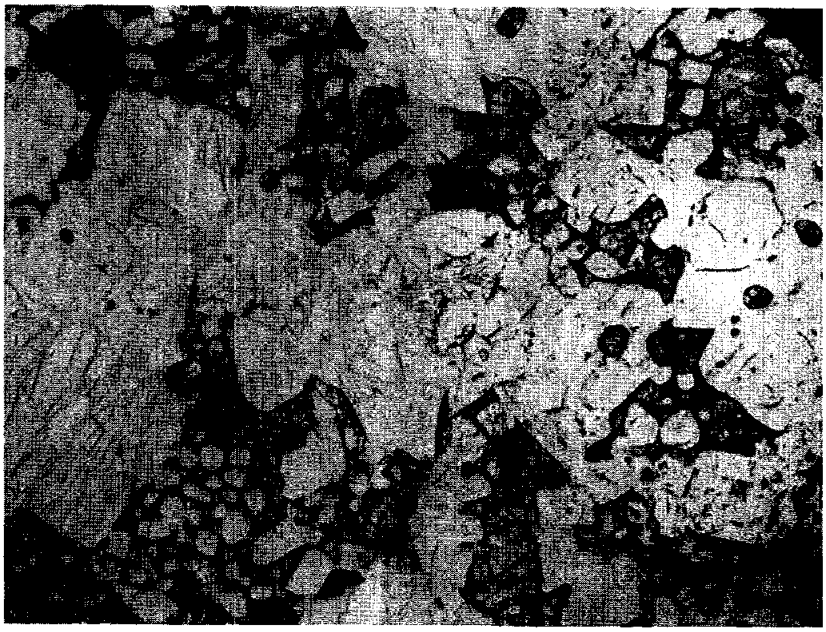


Figure 3: Photomicrograph of a thin section of the feldspathic portion of thin section 77017,65, showing coarse poikilitic texture. Field of view is 3 x 5 mm.

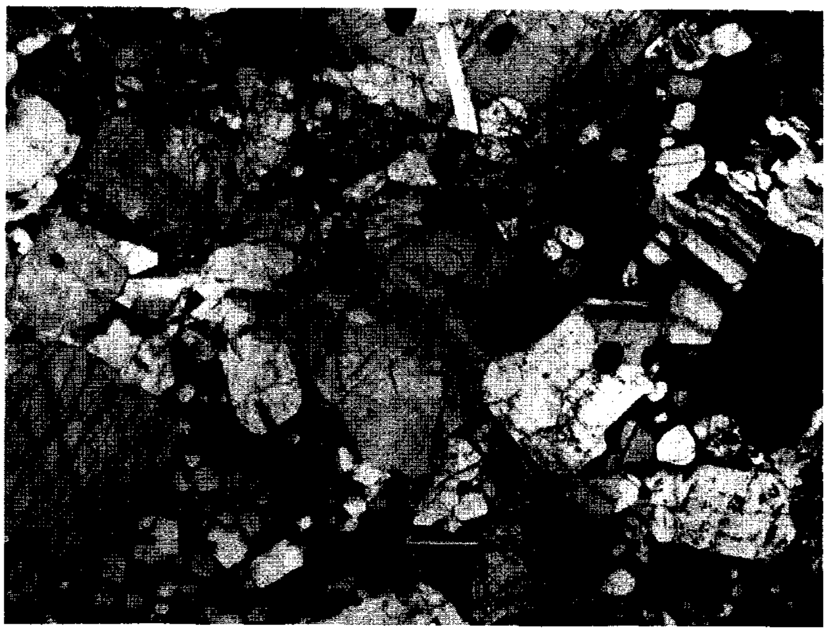


Figure 4: Photomicrograph of the same feldspathic portion of 77017,65 using partially crossed polarizers to show the granulitic texture on the plagioclase grains with 120 deg triple junctions. Field of view is 3 x 5 mm.

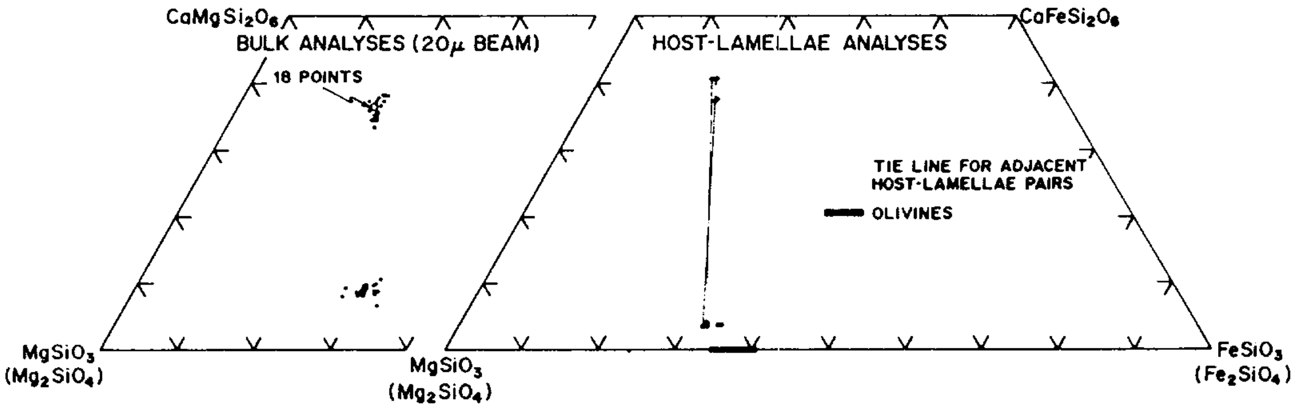


Figure 5: Pyroxene and olivine compositions in 77017. Data from McCallum et al. (1974).

Finally, the anorthositic portion of this rock was caught up in the black matrix, which has a high mare component. This is best seen in the saw cut of the slab (Fig. 2).

Bence et al. (1974) have studied a small fragment 78503,7,1, which they claim is the equivalent of 77017.

MINERAL CHEMISTRY

The composition of olivine, plagioclase, and pyroxene is relatively homogeneous in the feldspathic portion of 77017 (Helz and Appleman, 1974 and McCallum et al., 1974). Fig. 6 shows that 77017 falls in the field of ferroan anorthosite even though the minerals have "equilibrated" composition. This indicates that the precursor of 77017 may have been a ferroan anorthosite.

Taylor and Williams (1974) and Hewins and Goldstein (1975) have studied the compositions and phases of the metallic particles (Figs. 7 and 8). Metal grains in the poikilitic facies of 77017 are chemically homogeneous, containing 15 to 20% Ni, while grains in the shocked portion of 77017 show exsolution.

McCallum et al. (1974) present x-ray diffraction data for pyroxenes.

WHOLE-ROCK CHEMISTRY

Hubbard et al. (1974), Laul et al. (1974), and Lindstrom and Lindstrom (1986) have determined the rare earth element contents of 77017 (Table 1). The feldspathic portion of the rock is very low in trace elements (Fig. 9). The incorporation of abundant siderophiles without the addition of a significant amount of rare earth elements by mixing with KREEP-rich rocks is thought to be an important constraint to when KREEP was present on the lunar surface (Warner et al., 1977).

Morgan et al. (1974) have determined the siderophile and volatile element composition of 77017 (Table 2). They found extremely high Ir, Re, and Au (Fig. 10). The data by Lindstrom and Lindstrom (1986) also confirm the extremely high siderophile content of this rock. Hertogen et al. (1977) and James (1994) have reviewed the siderophile and volatile element data.

SIGNIFICANT CLASTS

Helz and Appleman (1974) and McCallum et al. (1974) describe relict feldspathic clasts with apparent cumulate texture. Lindstrom and Lindstrom (1986) attempted to analyze several relict clasts, but found that their samples all had basically the same composition (Fig. 11). However, the feldspathic portion of this large rock has not been fully explored.

STABLE ISOTOPES

Mayeda et al. (1975) have studied the oxygen isotope fractionation of 77017. Two olivine separates have different isotopic compositions, and the plagioclase-olivine fractionation is larger than for other lunar rocks. Muller et al. (1976) attempted to determine the nitrogen in 77017.

RADIOGENIC ISOTOPES

Phinney et al. (1975) dated 77017 as 3.97 ± 0.02 b.y. by the Ar-Ar plateau technique (Fig. 12). Kirsten and Horn (1974) determined 4.05 ± 0.05 b.y. for the white mineral fraction of their sample and 1.5 ± 0.3 b.y. for the black glass vein within it (Fig. 13) using the Ar-Ar technique.

Nunes et al. (1974) and (1975) have studied the U-Th-Pb systematics of 77017 (Table 3), but could not determine an internal isochron or an age for this rock. Nyquist et al. (1974) obtained Rb-Sr data for 77017 (Table 4).

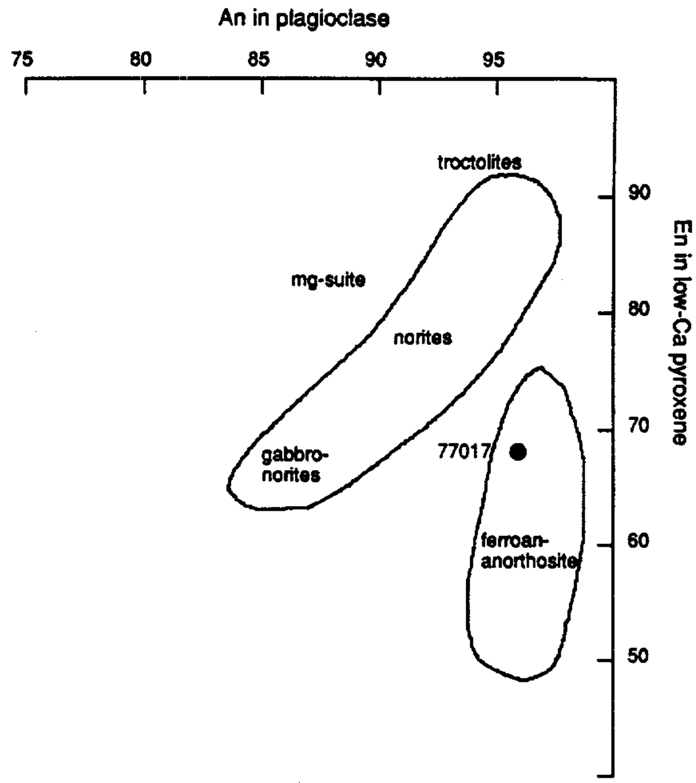


Figure 6: 77017 falls in the field of "ferroan anorthosite" even though the minerals have a metamorphic origin. Boundaries of rock types from James and Flohr (1983).

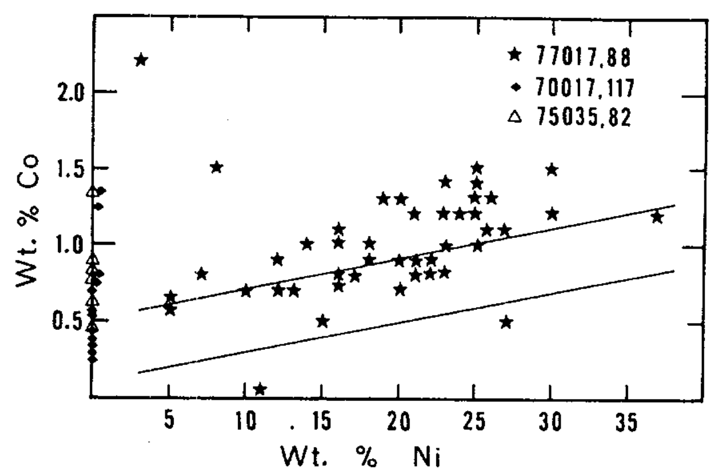


Figure 7: Composition of metal grains in 77017. From Taylor and Williams (1974).

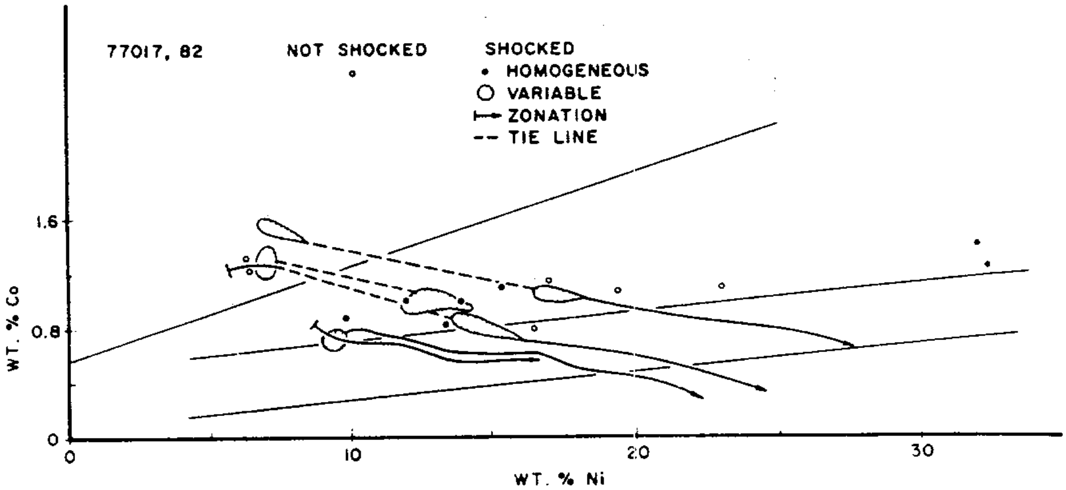


Figure 8: Composition of metal grains in 77017. From Hewins and Goldstein (1975).

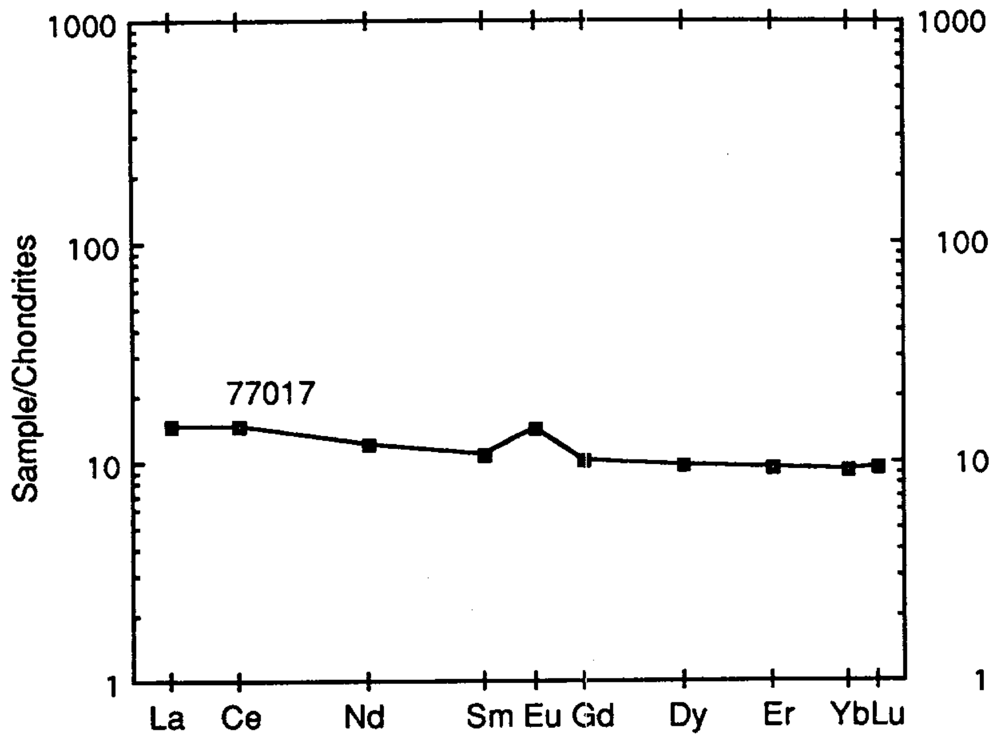


Figure 9: Normalized rare earth element diagram for 77017. Data from Hubbard et al. (1974).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Phinney et al. (1975) determined an exposure age of 224 ± 20 m.y., while Kirsten and Horn (1974) determined one of 80 ± 10 m.y.

MAGNETIC STUDIES

Brecher et al. (1974), Nagata et al. (1974 and 1975), Pierce et al. (1974), and Cisowski et al. (1983) have studied the remanent magnetization of 77017. Huffnan et al. (1974) and Brecher et al. (1975) studied the distribution of Fe by Mössbauer spectroscopy (Fig. 14).

Mizutani and Osako (1974) have studied the elastic wave velocity, thermal diffusivity, and thermal conductivity of 77017 (Fig. 15). According to Horai and Winkler (1976), the thermal diffusivity of 77017 is the lowest among the solid rock samples (Fig. 16).

SURFACE STUDIES

Adams and Charette (1975) and Charette and Adams (1977) determined the spectral reflectance of 77017 and compared it with other anorthositic gabbros (Fig. 17).

PROCESSING

Sample 77017 has 32 thin sections. The largest piece is 1053 g.

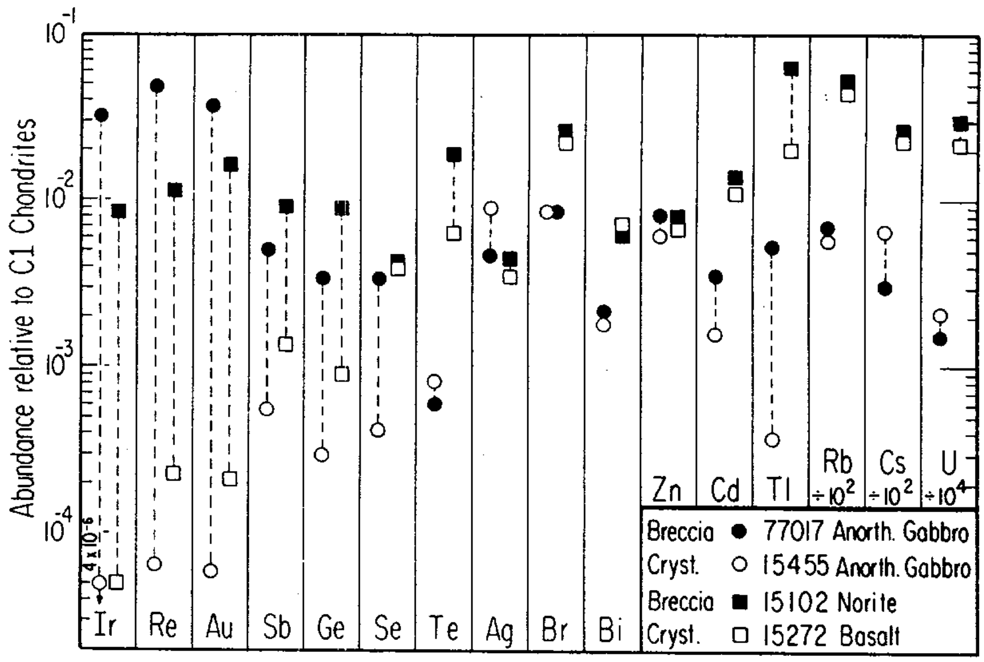


Figure 10: Trace element data for 77017 compared with other rocks. Sample 77017 has elevated siderophiles. From Morgan et al. (1974).

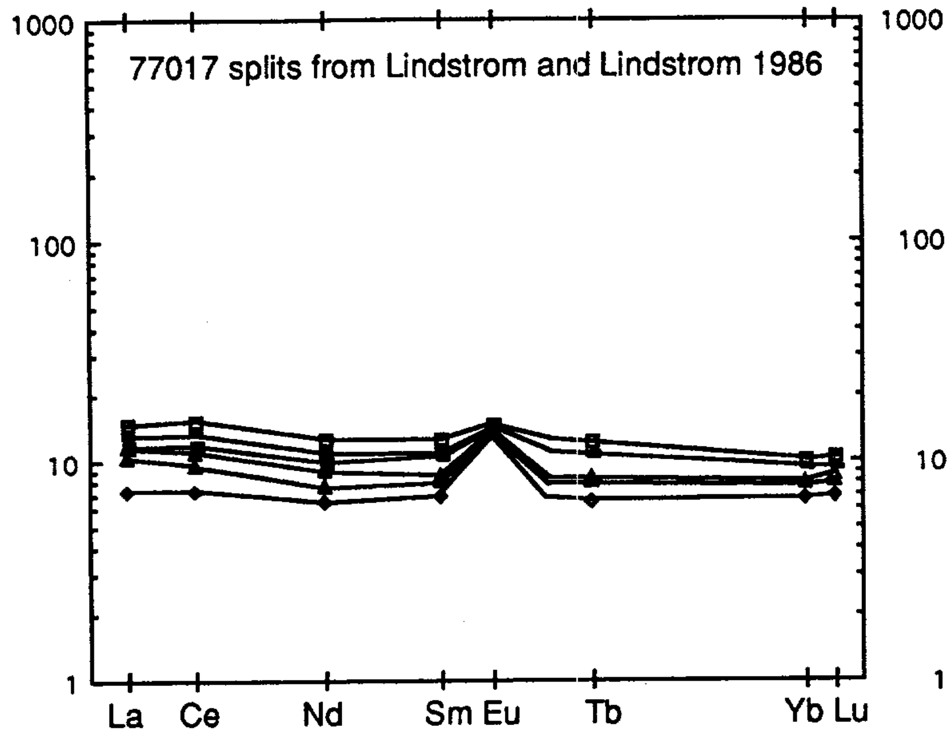


Figure 11: Normalized rare earth element diagram for multiple splits of 77017. Data from Lindstrom and Lindstrom (1986).

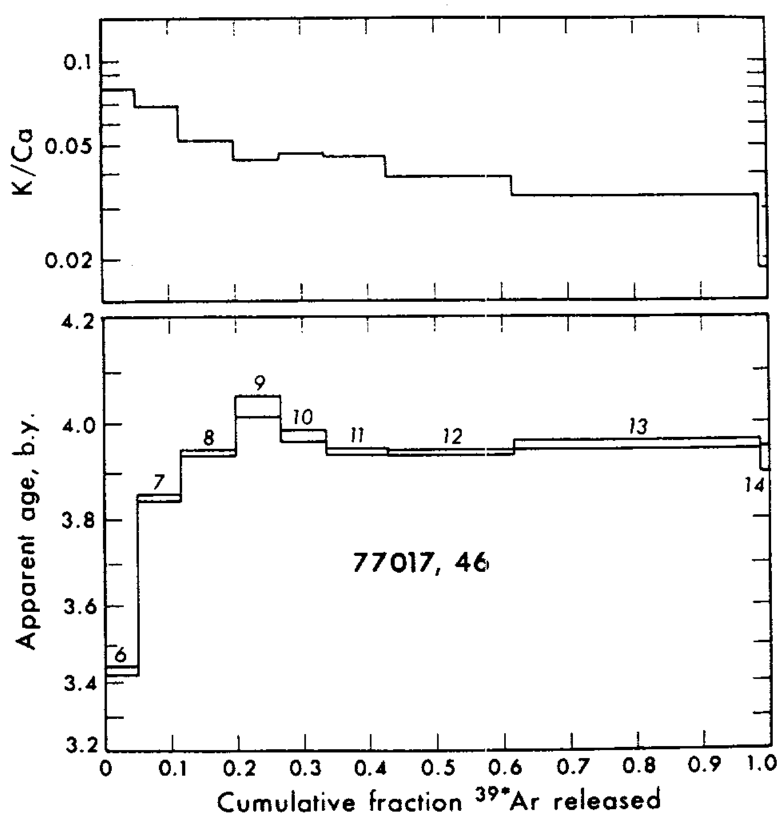


Figure 12: ^{39}Ar-^{40}Ar release patterns and apparent K/Ca ratios for anorthositic breccia 77017,46. From Phinney et al. (1975).

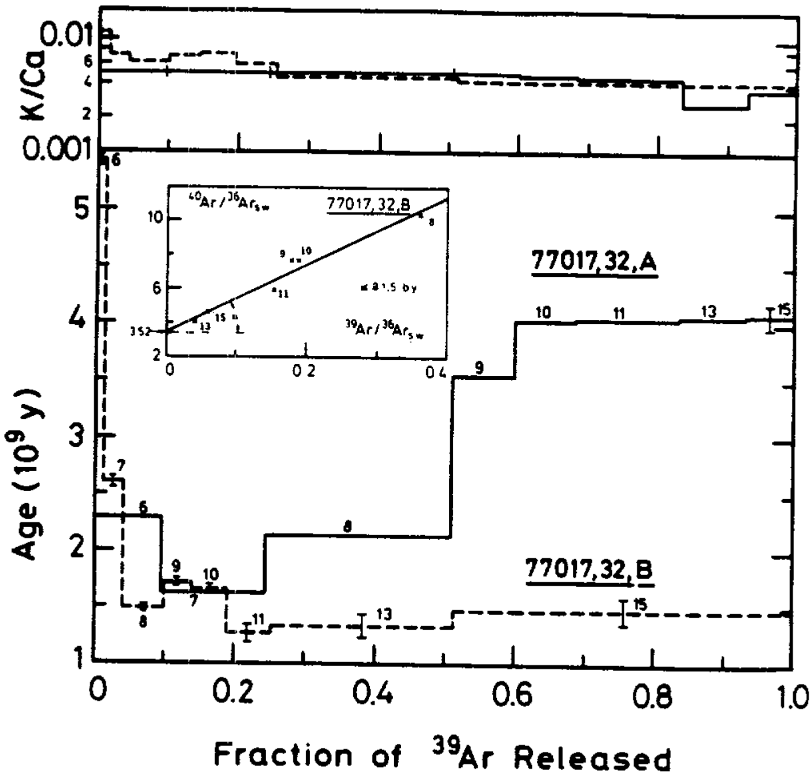


Figure 13: ^{39}Ar-^{40}Ar release patterns and apparent K/Ca ratios for anorthositic breccia 77017,32A and for a black glass vein penetrating the breccia 77017,32B. From Kirsten and Horn (1974).

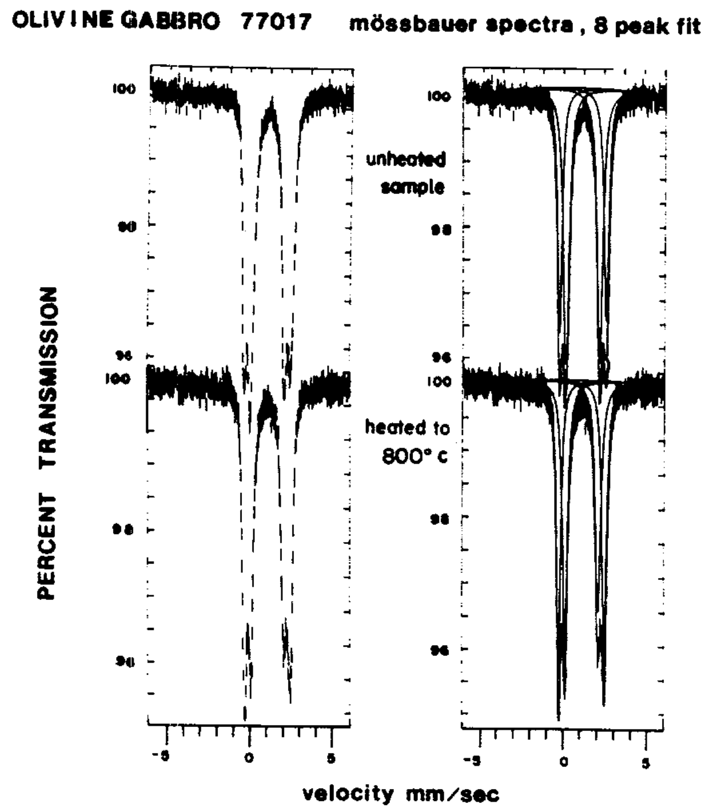


Figure 14: Mössbauer spectra of 77017. From Brecher et al. (1975).

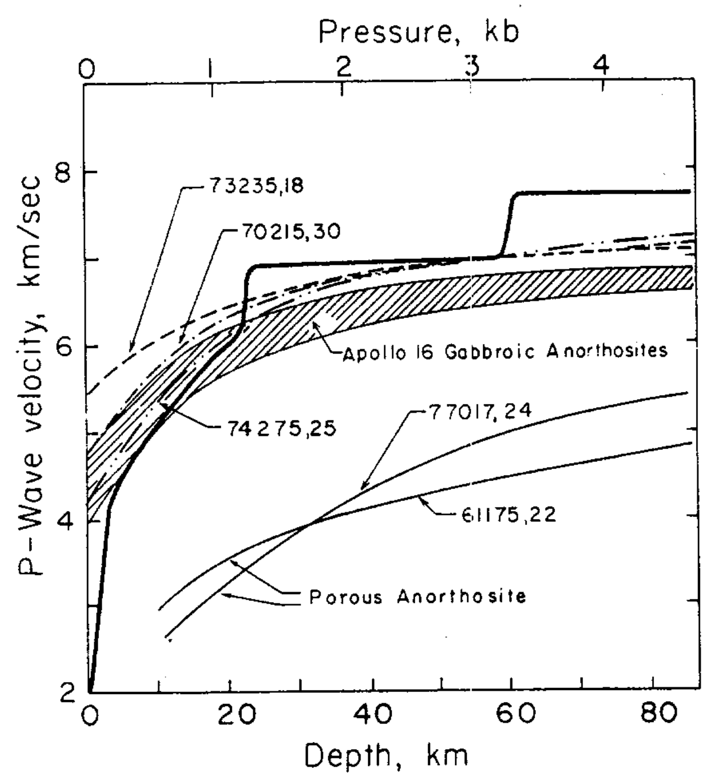


Figure 15: Elastic wave velocity as function of pressure. From Mizutani and Osako (1974).

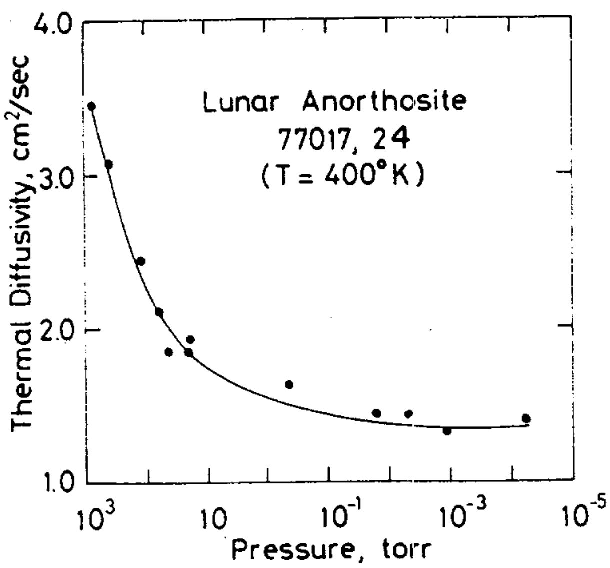


Figure 16: Thermal diffusivity of 77017. From Mizutani and Osako (1974).

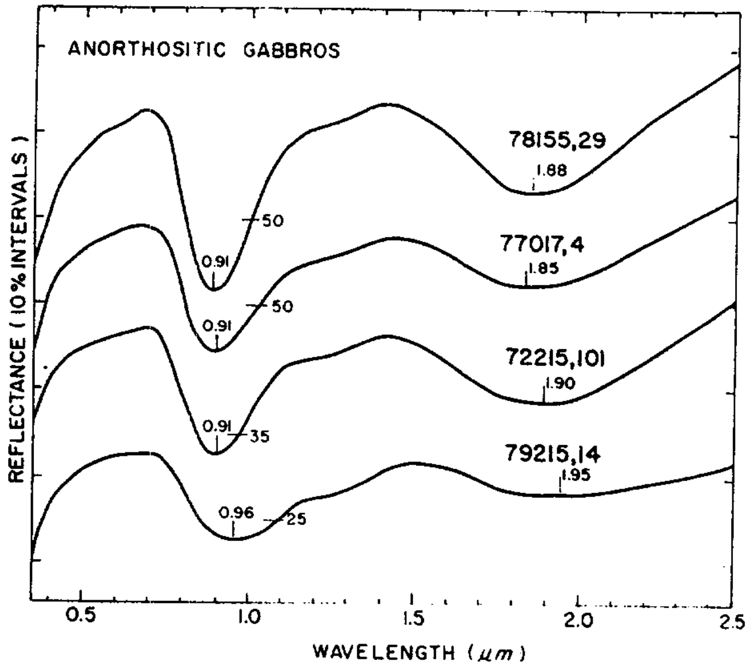


Figure 17: Reflectance spectra of 77017 compared with other anorthositic gabbros. From Adams and Charette (1975).

Table 1: Whole-rock chemistry of 77017.
a) LSPET; b) Hubbard et al. (1974); c) Wiesmann and Hubbard (1975); d) Laul et al. (1974)

Split Technique	,2 (a, b, c) XRF, ID	,57 (d) INAA	matrix (d) INAA	grey fragment (d) INAA
SiO_2 (wt%)	44.09			
TiO_2	0.41	0.75	5.3	0.35
Al_2O_3	26.59	26.0	18.9	27.1
Cr_2O_3	0.13	0.14	0.29	0.126
FeO	6.19	6.2	12.1	5.7
MnO	0.08	0.085	0.155	0.077
MgO	6.06	6	8	6
CaO	15.43	14.5	11.7	15.7
Na_2O	0.30	0.31	0.39	0.36
K_2O	0.06	0.05	0.10	0.076
P_2O_5	0.03			
S	0.15			
Nb (ppm)	4.1			
Zr	59		200	
Hf	1.6	1.5	4.9	1.0
Ta		0.22	0.85	0.14
U	0.22	–	–	–
Th	–	0.4	0.6	–
Y	14			
Sr	142			
Rb	1.31			
Li	4.4			
Ba	49	30	70	40
Zn	4			
Ni	95	290	290	300
V		40	70	40
Co		24	27	23
Sc		12	36	9.8
La	3.48	3.3	6.4	3.6
Ce	8.9	9	22	10
Nd	5.56	5	18	5
Sm	1.6	1.5	5.9	1.7
Eu	0.794	0.78	1.42	0.81
Gd	2.01			
Tb		0.3	1.3	0.3
Dy	2.34	2.4	9	2.4
Er	1.50			

Table 1: (Continued).

Split Technique	,2 (a, b, c) XRF, ID	,57 (d) INAA	matrix (d) INAA	grey fragment (d) INAA
Yb	1.50	1.6	5.1	1.4
Lu	0.23	0.21	0.66	0.18
Ge (ppb)				
Ir		10	9	10
Au		3	3	3

Table 1: (Continued).
From Lindstrom and Lindstrom (1986).

Split Technique	,151g INAA	,151 INAA	,152 INAA	,153 INAA	,154 INAA	,155 INAA
SiO_2 (wt%)						
TiO_2	1.17	0.70		0.41		
Al_2O_3	24.9	24.7		24.9		
Cr_2O_3	0.15	0.16	0.12	0.14	0.14	0.12
FeO	6.34	5.99	6.18	6.21	6.02	6.02
MnO						
MgO	6.2	6.5		6.1		
CaO	15.5	14.9	15.3	15.4	14.9	15.0
Na_2O	0.36	0.33	0.34	0.34	0.34	0.33
K_2O						
Nb (ppm)						
Zr	40	30	38	50	32	48
Hf	1.57	0.8	1.10	1.27	0.89	1.16
Ta	0.28	0.103	0.112	0.152	0.128	0.148
U	0.11	0.05	0.18	0.17	0.13	0.06
Th	0.47	0.52	0.52	0.72	0.84	0.71
Sr	165	155	170	147	151	150
Ba	45	34	45	46	47	50
Ni	360	300	312	297	296	290
Co	28.5	24.8	27	25.2	24.9	24.6
Sc	15.2	13.4	12.0	13.1	11.8	11.5
La	2.76	1.68	3.17	3.46	2.69	2.4
Ce	7.1	4.3	8.3	9.2	6.6	5.7
Nd	4.5	2.9	5.0	5.7	4.0	3.4
Sm	1.61	0.984	1.621	1.824	1.258	1.164

Table 1: (Concluded).

Split Technique	,151g INAA	,151 INAA	,152 INAA	,153 INAA	,154 INAA	,155 INAA
Eu	0.835	0.75	0.765	0.762	0.74	0.745
Gd						
Tb	0.41	0.235	0.403	0.44	0.29	0.295
Dy						
Er						
Yb	1.57	1.06	1.60	1.61	1.26	1.28
Lu	0.237	0.163	0.24	0.248	0.193	0.203
Ge (ppb)						
Ir	15	14	13	13	13	13
Au	6.2	4.1	4.8	3.5	7.9	3.5

Table 2: Trace element data for 77017. Concentrations in ppb.
From Morgan et al. (1974).

	Sample 77017,48
Ir	17
Os	
Re	1.7
Au	5.65
Pd	
Ni (ppm)	443
Sb	0.72
Ge	110
Se	68
Te	1.9
Ag	0.87
Br	35
In	
Bi	0.22
Zn (ppm)	2.5
Cd	9
Tl	0.77
Rb (ppm)	1.34
Cs	61
U	137

Table 3: U-Th-Pb for 77017.
From Nunes et al. (1974).

wt (mg)	94.7	79.8
U (ppm)	0.2699	0.4147
Th (ppm)	1.025	1.489
Pb (ppm)	0.5733	0.8663
$^{232}Th/^{238}U$	3.92	3.71
$^{238}U/^{204}Pb$	643.0	863.0

Table 4: Rb-Sr composition of 77017.
Data from Nyquist et al. (1974).

	Sample 77017,2
wt (mg)	68.4
Rb (ppm)	1.310
Sr (ppm)	141.5
$^{87}Rb/^{86}Sr$	0.0268 ± 3
$^{87}Sr/^{86}Sr$	0.70072 ± 6
T_B	4.22 ± 0.20
T_L	4.40 ± 0.20

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

77035

Micropoikilitic Impact Melt Breccia
5727 g, 15 x 15.5 x 22 cm

INTRODUCTION

Sample 77035 is primarily a non-descript impact melt rock that has partially dissolved the original clasts or welded them into its recrystallized matrix such that they cannot be easily extracted. It does contain one large, pristine clast of norite (Fig. 1).

PETROGRAPHY

The main mass of 77035 is a micropoikilitic impact melt breccia, apparently very similar to the matrix of the large boulders at Stations 6 and 7 (Simonds et al., 1974). It is dense, nonvesicular, and except for one large white clast, relatively free of obvious clasts (Fig. 2) The micropoikilitic matrix (Fig. 3) is uniform throughout the rock, and the sawn surfaces are aphanitic and nondescript. The relict clastic texture of the matrix is obscured.

WHOLE-ROCK CHEMISTRY

Boynton et al. (1975) and Wanke et al. (1975) have analyzed the matrix of 77035 (Table 1 and Fig. 4). Wanke et al. (1977) report V analyses and Garg and Ehmann (1977) have determined the Zr and Hf contents. The Zr/Hf ratio is high for 77035. Hughes and Schmitt (1985) have utilized the composition of 77035 to discuss the Zr-Hf-Ta fractionation during lunar evolution. Jovanovic and Reed (1974) have determined Cl, F, Br, and I. Petrowski et al. (1974) have determined C and S.

SIGNIFICANT CLASTS

Sample 77035 has one large white clast (~100 g) that has been studied by Warren and Wasson (1979) and Warren and Kallemyen (1984) (Table 1). Warren (1993) lists this large clast as probably pristine (Fig. 1). It is a cataclastic norite, apparently monomict, with approximately 60% plagioclase (An_{93}) and 40% orthopyroxene ($Wo_2En_{89}Fs_9$). The pyroxene

Figure 1: Photograph of 77035 showing the large white clast of pristine norite. S78-27393.

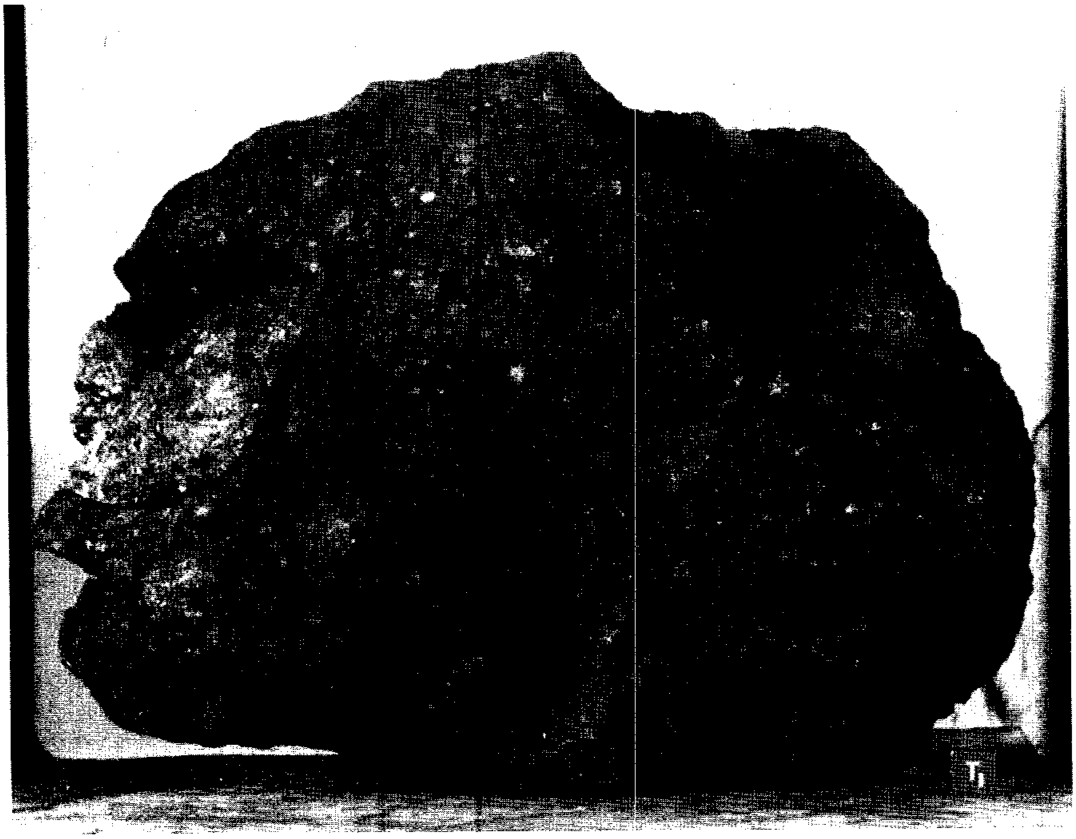


Figure 2: Photograph of 77035. Cube is 1 cm. S73-15907.

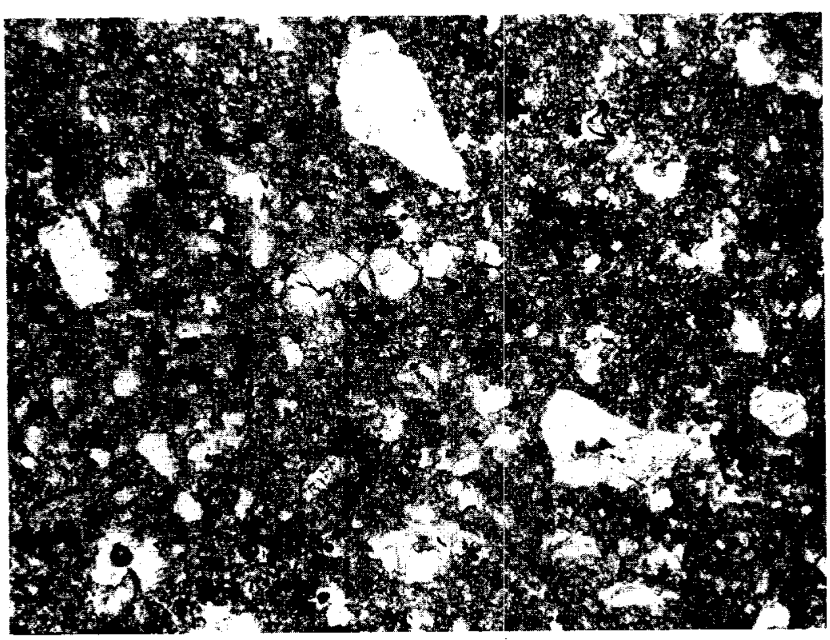


Figure 3: Photomicrograph of matrix in thin section 77035,92. Field of view is 3 x 4 mm.

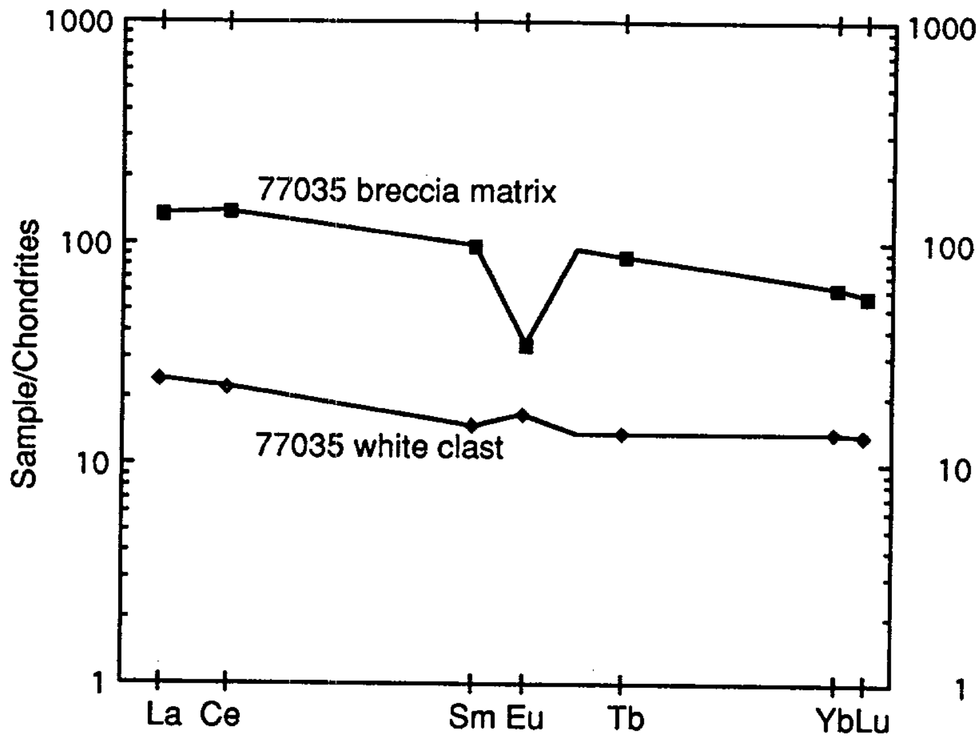


Figure 4: Normalized rare earth element diagram for 77035 showing matrix and large white norite clast. Data from Boynton et al. (1975) and Warren and Wasson (1978).

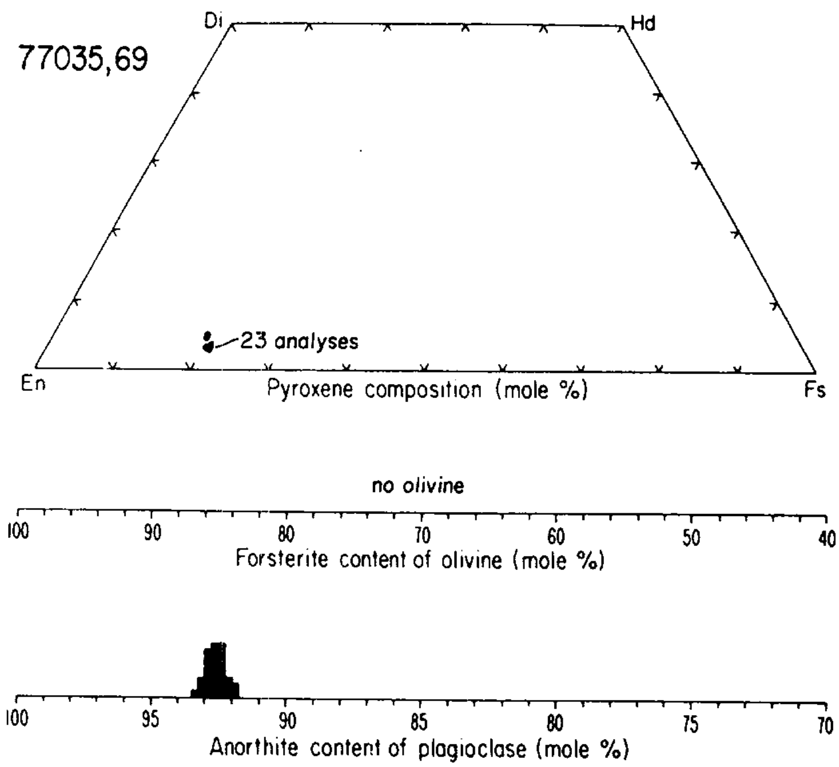


Figure 5: Pyroxene composition of large norite clast in 77035. From Warren and Wasson (1979).

diagram (Fig. 5) is from Warren and Wasson (1979). Fig. 6 gives the position on the plutonic rock diagram, showing that it is within the Mg-norite suite of lunar highland rocks. Bersch et al. (1991) have precisely determined the composition of pyroxene in 77035,69. Papike et al. (1994) have determined the REE in the orthopyroxene of this brecciated norite clast using the ion microprobe method. Much of this clast has been shocked into diaplectic glass and thoroughly comminuted.

Eckert et al. (1991), Neal et al. (1992), and Neal et al. (1994) have studied additional lithic clasts in 77035 (Table 2). They report one "dunite," two "norite," and two "anorthosite" clasts. It was very difficult to extract these clasts from the crystalline matrix of this rock, and the trace element data for these clasts (Fig. 7) may be compromised because these sample splits may have been contaminated by breccia matrix. All the small clasts studied by Neal et al. contained high Au; some have very high Ir (Table 2). Warren (1993) lists these clasts as only "marginally pristine."

Clast ,206 has 37 ppm Ir. The REE profile is flat (Fig. 7). It has about 66% plagioclase (An_{93-96}), 12% orthopyroxene ($Wo_4En_{73}Fs_{23}$), ~14% high-Ca pyroxene, and ~7% olivine (Fo_{71-74}).

Clast ,229 is a gabbronorite with ~75% plagioclase (An_{85-87}), ~11% orthopyroxene (En_{71-72}), ~11% high-Ca pyroxene ($Wo_{43}En_{44}Fs_{13}$), and ~3% olivine (Fo_{69-73}). It has a positive Eu anomaly (Fig. 7) and is reported as pristine by Neal et al. (1994).

Clast ,226 is essentially all olivine (dunite?) Fo_{80-89} and has a deep negative Eu anomaly (Fig. 7).

Bickel and Warner (1978) report a small clast (plutonic fragment?) in thin section 77035,71.

RADIOGENIC ISOTOPES

Murthy and Coscio (1977) have reported Sr isotope measurements for a plagioclase clast in 77035.

PHYSICAL PROPERTIES

Sugiura et al. (1978) studied the thermal remanent magnetization in 77035 (Fig. 8). Simmons et al. (1975) studied differential strain and crack closure in 77035. *(These results proved applicable to the microcracks in the Vietnam Memorial!)* Horai and Winkler (1976) studied the thermal diffusivity of 77035 (Fig. 9).

PROCESSING

The main portion of 77035 was very hard, and it was extremely difficult to separate the small clasts that were welded into it.

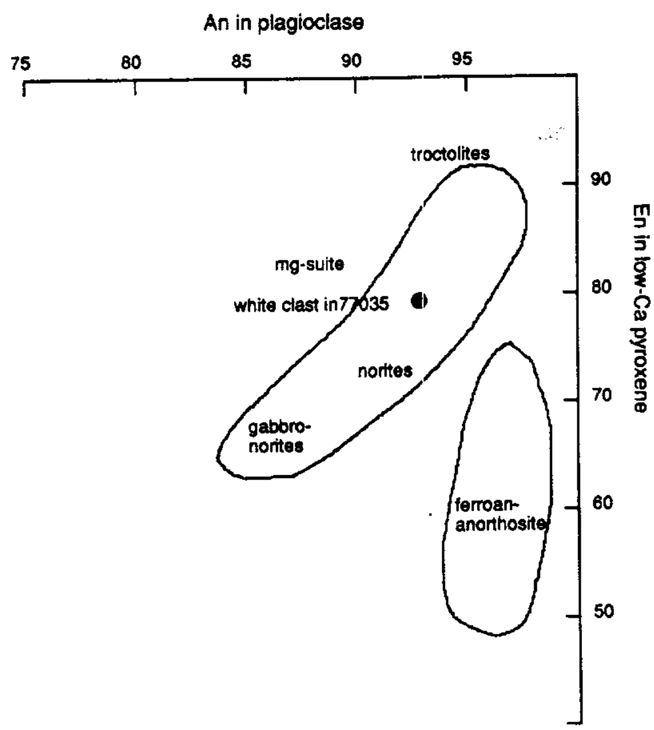


Figure 6: Position of norite clast on the plagioclase-pyroxene diagram for pristine lunar samples. Fields from James and Flohr (1983).

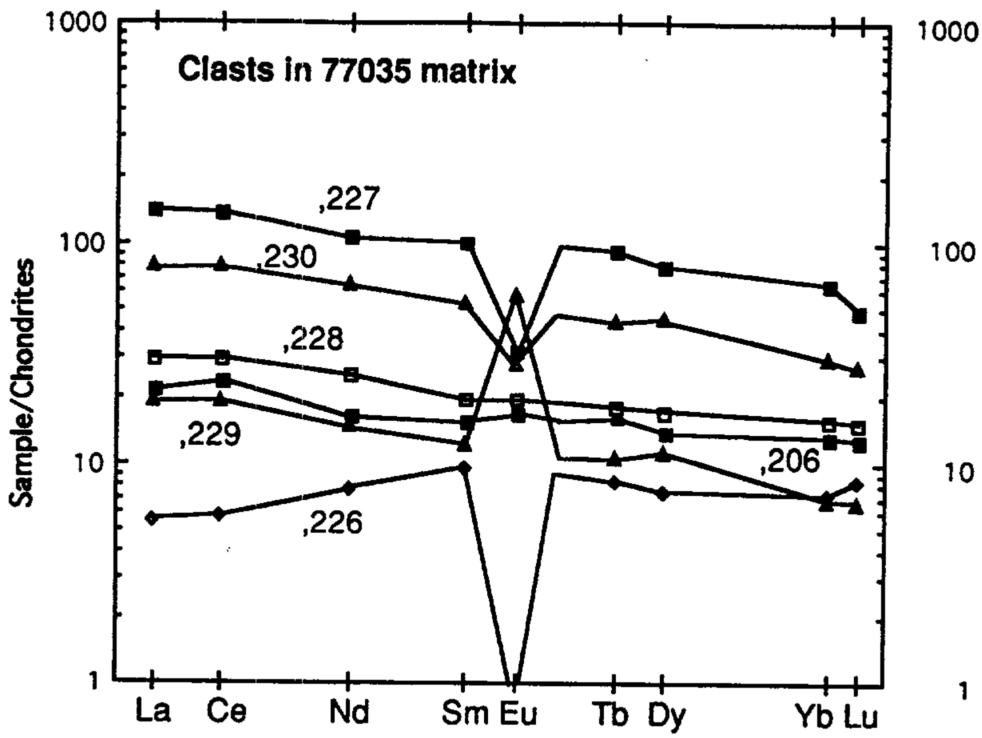


Figure 7: Normalized rare earth element diagram for small clasts in 77035. Data from Neal et al. (1994).

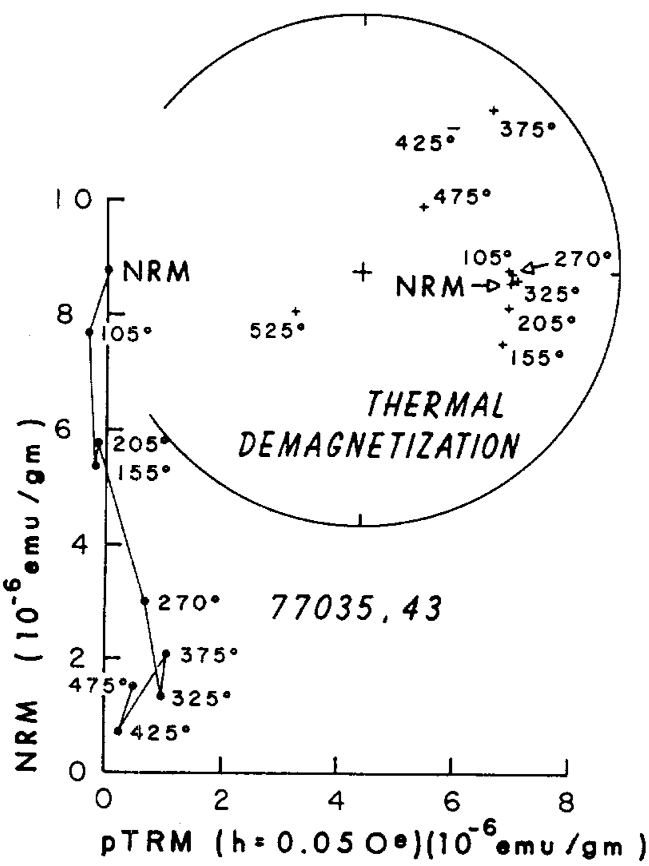


Figure 8. Remanent magnetization of 77035. From Sugiura et al. (1978).

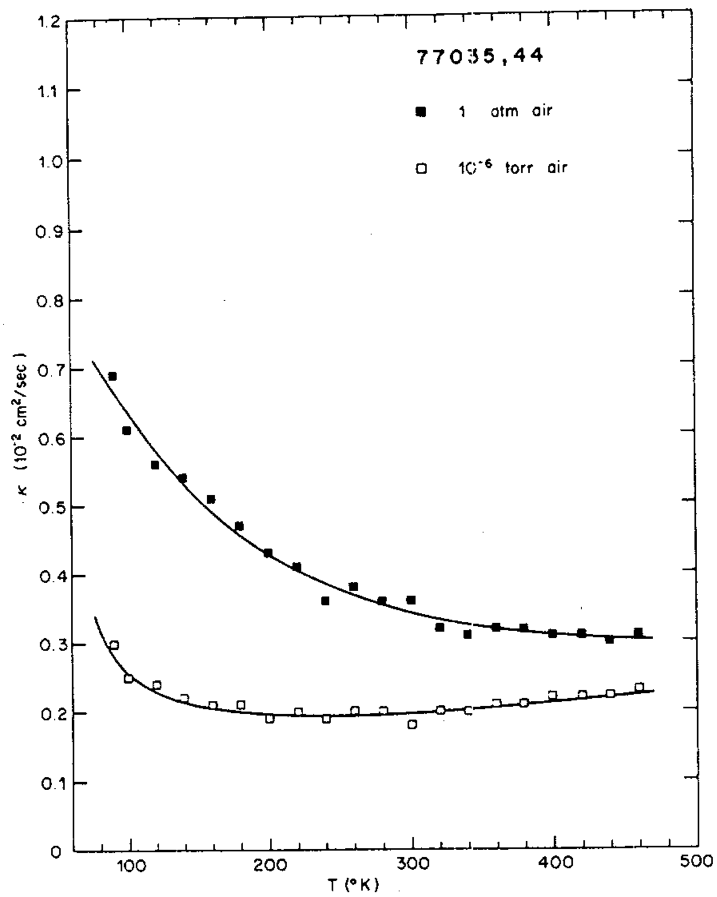


Figure 9: Thermal diffusivity of 77035. From Horai and Winkler (1976).

Table 1: Whole-rock chemistry of 77035.
a) Boynton et al. (1975); b) Wanke et al. (1975); c) Warren and Wasson (1979)

Split Technique	,84 (a) RNAA breccia	,84 (a) RNAA breccia	,61 (b) INAA breccia	,130 (c) INAA large white clast
SiO_2 (wt%)	–	–	46.87	–
TiO_2	1.38	1.38	1.52	0.20
Al_2O_3	17.4	18.1	18.1	19.09
Cr_2O_3	0.18	0.20	0.20	0.32
FeO	6.94	9.00	8.87	2.64
MnO	0.12	0.11	0.11	0.09
MgO			12.2	11.95
CaO	9.24	11.76	11.23	11.76
Na_2O	0.60	0.62	0.62	0.44
K_2O			0.26	0.09
P_2O_5				
Nb (ppm)				
Hf	7.4	10.6	10.8	1.9
Ta	–	1.8	1.46	0.20
U				0.31
Th	3.7	5.5	4.5	1.1
Sr			210	
Ba	–	360	370	96
Zn	2.2	2.4		1.7
Ni	281	333	360	9.5
Co	25	32	32.1	22
Sc	13.6	16.8	16.0	10.9
La	23.4	34.0	32.2	5.5
Ce	63	101	85	13
Nd			55	8.6
Sm	10.7	15.2	14.3	2.19
Eu	1.37	1.90	1.95	0.93
Tb	1.7	3.0	3.2	0.49
Dy	–	14	19.1	
Yb	7.6	11.1	10.2	2.2
Lu	1.12	1.50	1.39	0.32
Ga	5.13	5.02		
Ge (ppb)	444	433		3.9
Ir	5	6.9	9	0.050
Au	4.6	5		0.026

Table 2: Clast chemistry of 77035.
From Neal et al. (1994) (with permission).

Split Technique	,206 INAA	,226 INAA	,227 INAA	,228 INAA	,229 INAA	,230 INAA
SiO_2 (wt%)	–	–	–	–	–	–
TiO_2	0.22	nd	1.48	0.21	0.69	0.68
Al_2O_3	23.9	0.28	17.1	19.7	27.4	32.1
FeO	5.80	11.0	8.4	5.8	3.9	2.0
MnO	0.07	0.12	0.11	0.09	0.05	0.03
MgO	7.9	49.0	11.7	11.9	5.9	4.8
CaO	14.6	nd	9.7	12.2	14.2	18.2
Na_2O	0.43	0.02	0.65	0.46	1.21	0.55
K_2O	0.08	nd	0.3	0.11	0.18	0.32
Nb (ppm)						
Cr	810	510	1170	1950	440	300
Hf	1.72	0.44	12.8	1.71	0.9	5.2
Ta	0.2	1.7	1.44	0.24	0.19	0.76
U	0.2	nd	1.5	0.29	nd	0.8
Th	0.93	0.33	5.3	1.38	0.47	2.7
Sr	180	nd	240	160	410	200
Rb	nd	nd	12	4	nd	9
Ba	110	nd	350	100	130	240
Cs	nd	nd	0.34	0.4	nd	0.32
Ni	560	110	300	26	nd	35
Co	41	62	38	21.4	5.8	4.3
Sc	9.4	5.6	15.7	10.1	3.0	5.0
La	5.1	1.28	33	7	4.5	18.1
Ce	14.1	3.5	81	17.8	11.3	47
Nd	7.5	3.4	48	11.3	6.7	29
Sm	2.27	1.38	14.8	2.89	1.81	7.7
Eu	0.96	0.026	1.78	1.10	3.19	1.58
Tb	0.59	0.3	3.3	0.65	0.38	1.6
Dy	3.4	1.8	19	4.1	2.7	11
Yb	2.12	1.18	10.3	2.5	1.09	4.8
Lu	0.31	0.2	1.19	0.37	0.16	0.66
Ge (ppb)						
Ir	37	nd	nd	nd	nd	nd
Au	11	6	9	5	6	15

Introduction to Boulder at Station 7
Samples 77075, 77076, 77077, 77115, 77135, and 77215

The boulder at Station 7 is about 3 meters in size and is thought to have tumbled downslope from high on the North Massif (Wolfe and others, 1981). Fig. 1 is a map of the location of samples at Station 7. Although the Station 7 Boulder has nearly the same exposure age as the larger boulder at Station 6 (28 m.y. instead of 22 m.y.), the Station 7 Boulder has no boulder track that would allow us to know where exactly it came from on the North Massif.

Field observations of the boulder by the astronauts showed that it was composed of four main lithologies: a large white norite clast (represented by sample 77215), cut by dark dikelets (77075, 77076, and 77077), enclosed in a blue-grey breccia (77115), which is in turn surrounded by a vesicular, green-grey breccia (77135). Fig. 2 is a photo of the southeast side of the boulder showing the locations of 77115 and 77135. The contact between the vesicular and nonvesicular lithologies is apparent. Fig. 3 is a sketch of the north side of the boulder showing the large (0.5 x 1.5 m) clast of norite with penetrating black veins. While the norite clast appeared off-white (light grey) in surface photography, the fresh surfaces of the samples (i.e., 77215) are pure white in the laboratory. At the time of sampling, Schmitt (in Schmitt and Cernan, 1973) observed that the dike material was continuous with the "blue-grey matrix-rich breccia" (represented by 77115) that surrounds the off-white norite clast that the dike cuts.

The Station 7 Boulder has a chemical composition that is distinctly different from the local soil on which it rests (Fig. 4). The composition of the matrix of the Station 7 Boulder (both 77115 and 77135) is similar to the composition of the matrix of the Station 6 Boulder, as well as that of several of the boulders from the South Massif (Fig. 5). In addition, the trace element data for siderophile and volatile elements by the Anders group show that these boulders are related (e.g., Hertogen et al., 1977). These similarities have led various authors to conclude that these boulders represent ejecta from the Serenitatus impact event (e.g., Winzer et al., 1975; Spudis and Ryder, 1981). James (1994) has reviewed the siderophile and volatile element composition.

CONSORTIUM

The boulder at Station 7 was systematically studied by the international consortium led by E.C.T. Chao (see the final report by Minkin et al., 1978). The original distribution of samples is recorded in Butler and Dealing (1974). Several interesting clasts have been identified (Fig. 6).

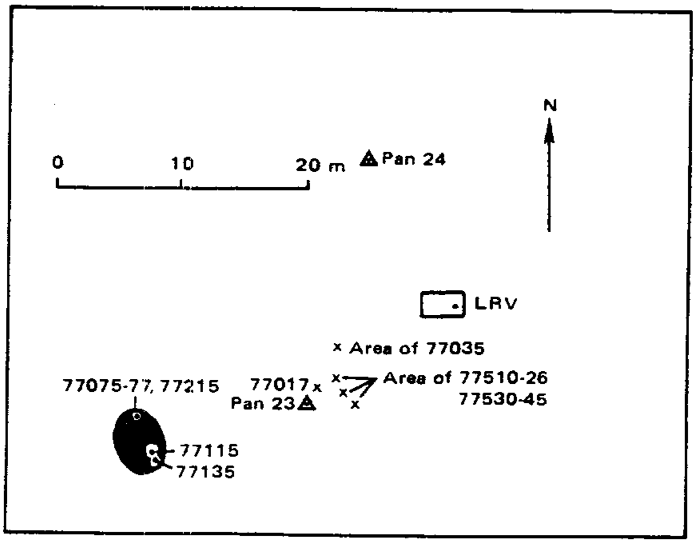


Figure 1: Planimetric map of Station 7. Map from Wolfe and others (1981).

HISTORY

The history of the Station 7 Boulder is discussed by Winzer et al. (1977), Nakamura and Tatsumoto (1977), Stettler et al. (1978), and Minkin et al. (1978). A summary of the age data for samples of the Station 7 Boulder is given in Table 1, taken from Minkin et al. (1978). Measured ^{39}Ar-^{40}Ar ages are generally consistent with the apparent stratigraphic sequence (Fig. 7). The large white norite clast, represented by sample 77215, has been dated by Rb-Sr and Sm-Nd at about 4.4 b.y. (Nakamura et al., 1976), while the plagioclase in a norite clast within 77215 gave an ^{39}Ar-^{40}Ar plateau age of 3.98 (Stettler et al., 1978).

The dike through the clast (77075) was dated at 4.07 b.y. by Nakamura and Tatsumoto and at 3.97 b.y. by Stettler et al. The matrix of the breccia (77115 and 77135) has a Rb-Sr age of ~ 3.75 b.y. by Nakamura and Tatsumoto, while Stettler et al. determined about 3.9 b.y. (see the age discussion of individual samples). It is worth noting that the different ages for the dike (77075, age 3.97 ± 0.04 b.y.) and the surrounding breccia (77115, age 3.90 ± 0.03 b.y.) are not in agreement, which is surprising because of Schmitt's observation that the dike was continuous with the breccia matrix (see discussion in 77075).

According to Arvidson et al. (1975), the final emplacement of the Station 7 Boulder is one of only a few well-dated events on the Moon. The ^{81}Kr-Kr exposure age is 28.6 m.y. (Crozaz et al., 1974), while its Ar spallation age is reported as 27.5 m.y. (Stettler et al., 1974). The apparently discrepant young cosmic ray track ages (5.4 m.y.) are explained by loss of a few centimeters of boulder surface about 5 m.y. ago (Arvidson et al., 1975).

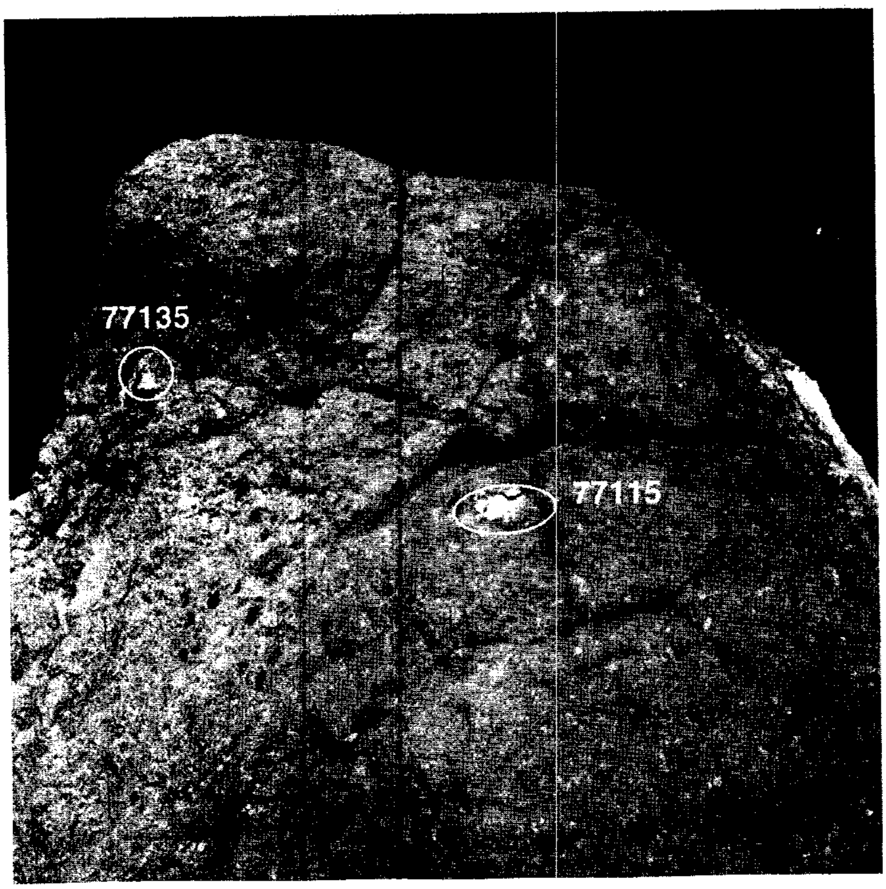


Figure 2: Photo of southeast side of 3-meter boulder at Station 7 showing location of samples taken. AS17-146-22336.

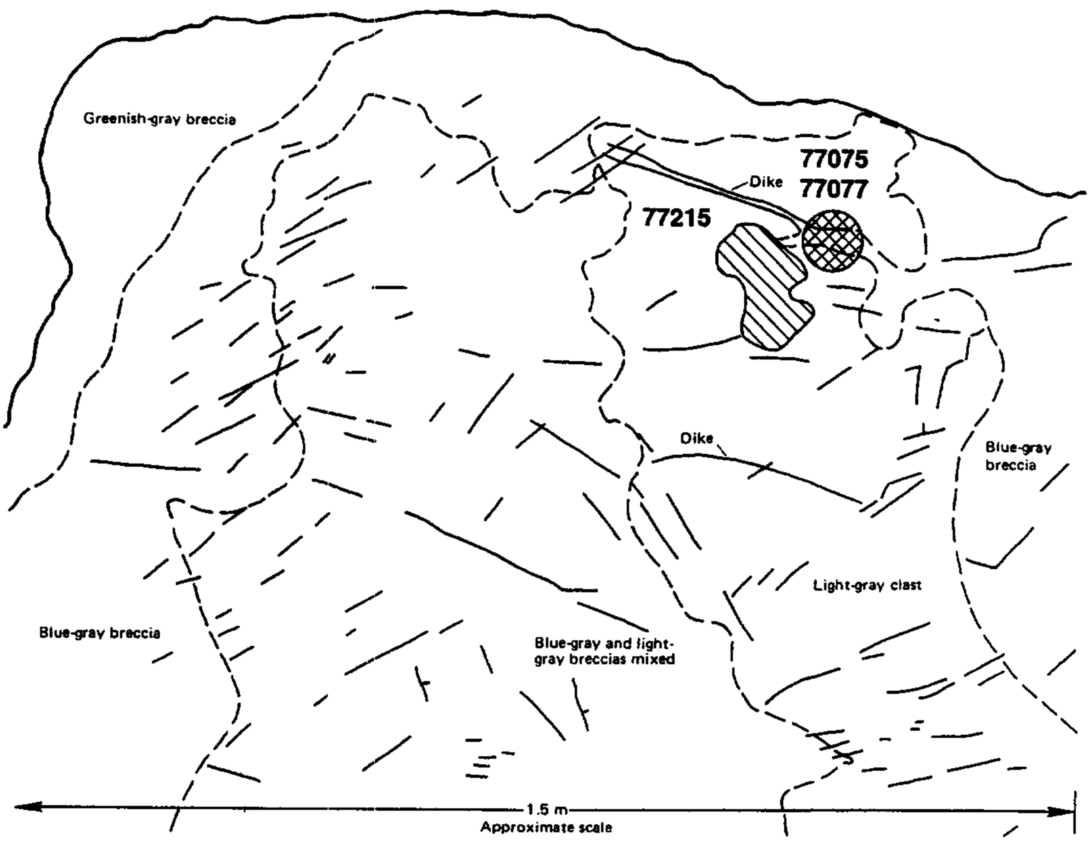


Figure 3: Sketch of north side of Station 7 Boulder, showing large norite clast (light grey clast) with penetrating veins and the location of the samples taken (from Wolfe and others, 1981).

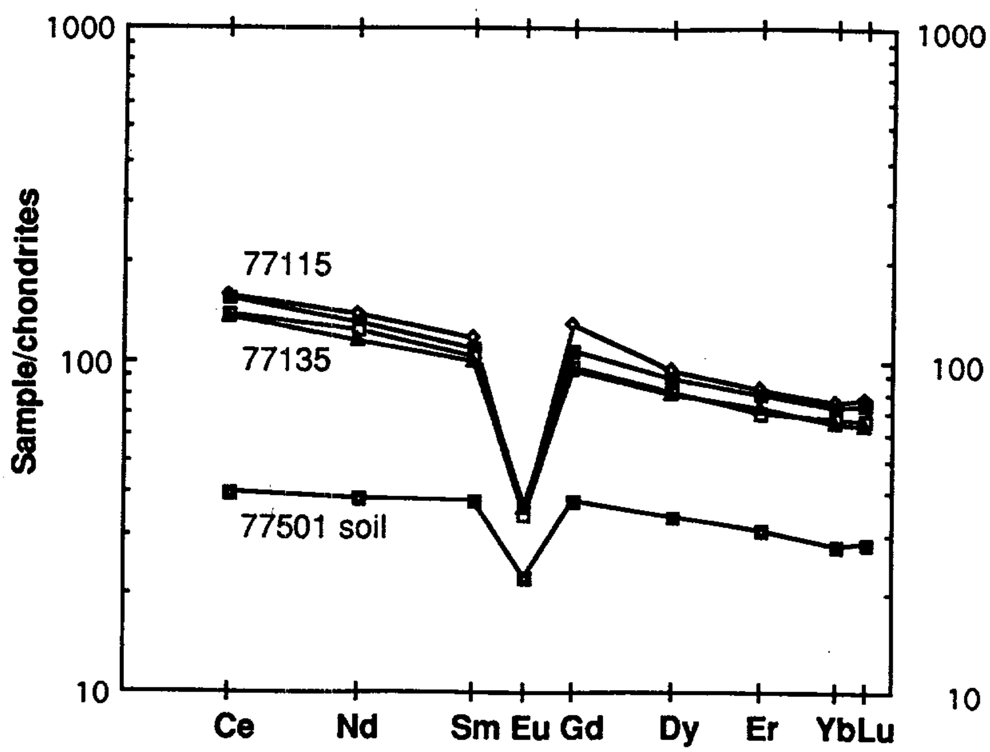


Figure 4: Normalized rare earth element data for Station 7 matrix samples compared with Station 7 soil sample (77501). Data from Wiesmann and Hubbard (1975).

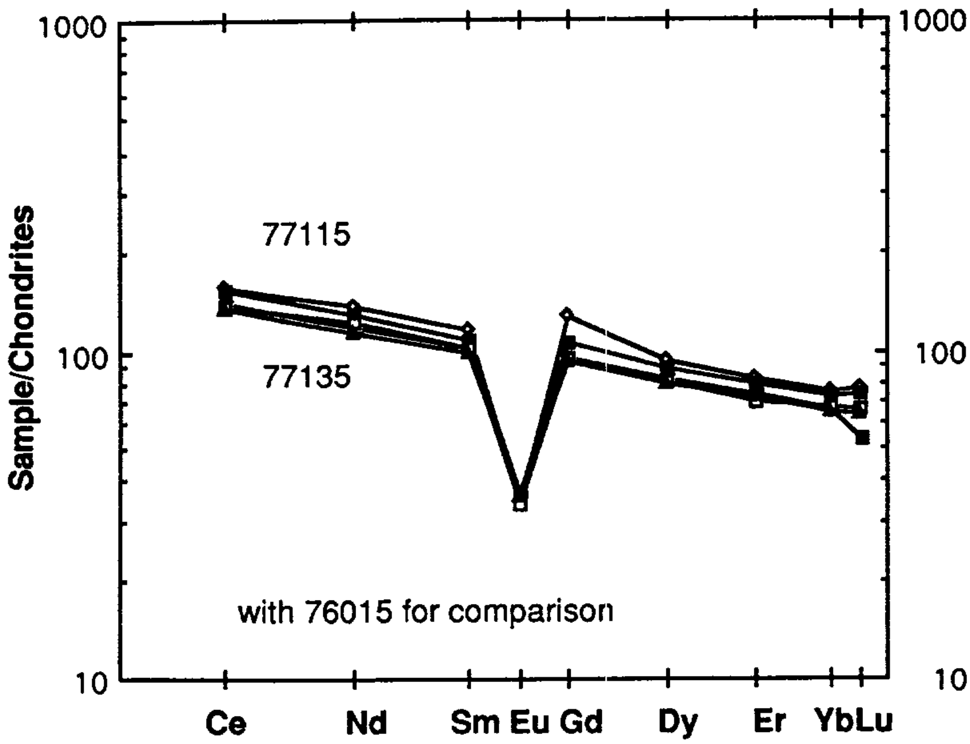


Figure 5: Normalized rare earth element data for Station 7 matrix samples compared with Station 6 Boulder sample (76015). Data from Wiesmann and Hubbard (1975).

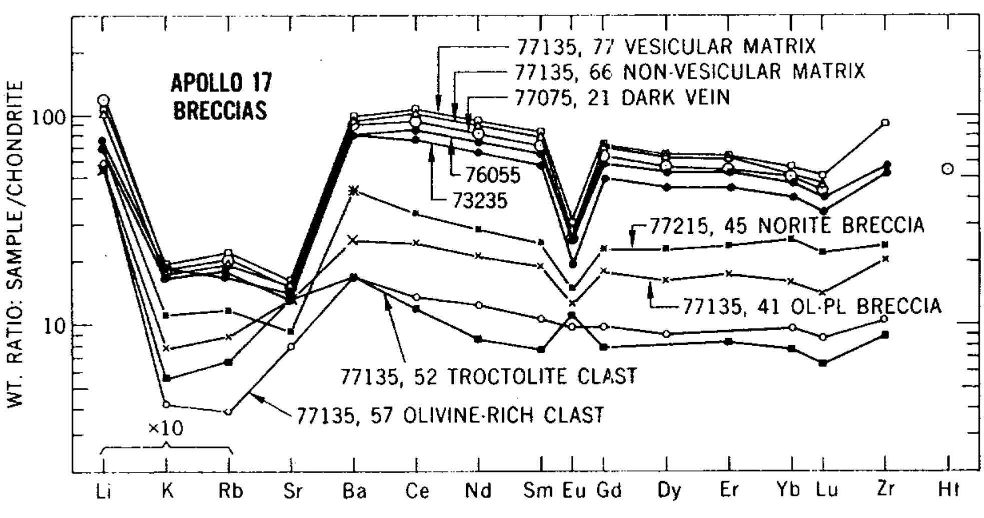


Figure 6: Normalized rare earth diagram from Philpotts et al. (1974) comparing compositions of Apollo 17 breccias and clasts in Station 7 Boulder.

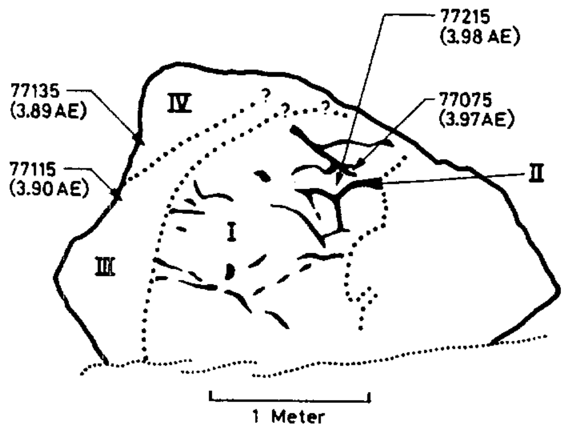


Figure 7: Summary of Ar plateau ages of different lithologies in Boulder 7. From Stettler et al. (1978).

Table 1: Summary of ages of Station 7 Boulder samples (b.y.).
From Minkin et al. (1978).

Sample	$^{40}Ar/^{39}Ar$	Rb/Sr	Sm/Nd	U-Pb	$^{207}Pb/^{206}Pb$
77075					
Dikelet	3.97 ± .04(2)	4.07 ± .09(3)			4.48(6)
77115					
Matrix	3.90 ± .03(2)	3.8 ± .2(5)			4.45(6)
77135					
Matrix	3.90 ± .04(4)	~3.75(5)			4.40(6)
Clast type 1	3.88 ± .05(2)	3.89 ± .08(6)			4.37(6)
Clast type 2	3.99 ± .02(1)				
77215	3.98 ± .03(2)	4.42 ± .04(5)	4.37 ± .07(5)	3.8 ± .2(6)	4.49(6)

(1)Stettler et al. (1974)
(2)Stettler et al. (1978)
(3)Nakamura and Tatsumoto (1977)
(4)Stettler et al. (1975)
(5)Nakamura et al. (1976)
(6)Nunes et al. (1974a)

77075

Impact Melt Dike in Cataclastic Norite
172.4 g; 4 x 4 x 4 cm, 1.2 x 1.5 x 1.5 cm, 1 x 1 x 0.5 cm (3 fragments)

INTRODUCTION

Sample 77075 was sampled from one of the dark dikes within the large, "off-white" clast in the boulder at Station 7 *(see the section on the Station 7 Boulder, page 235)*. The dike material is a fragment-laden melt rock with a matrix texture and chemical composition similar to that of 77115, but with a finer grain size. Friable white cataclastic norite (equivalent to samples 77077 and 77215) is attached to the black dike. Sample 77076 and piece 19 of 77215 are also from the same dark dike. The dark dike was about 3 cm thick (Minkin et al., 1978)

PETROGRAPHY

Sample 77075 consists of three pieces that fit together (Fig. 1). The dark dike material is a fragment-laden, micropoikilitic impact melt breccia that is a fine-grained equivalent of the boulder sample 77115. Schmitt (in Schmitt and Cernan, 1973) observed that the dike material was continuous with the "blue-grey, matrix-rich breccia" (represented by 77115) that surrounds the off-white norite clast that the dike cuts (Fig. 2). Indeed, the chemistry, age, mineralogy, and texture of the thin sections all confirm this field observation (or is it the other way around?). The white material attached to the sides of 77075 is the same noritic material as that of 77215 and is part of the large, "off-white" boulder clast.

Chao et al. (1974) and Minkin et al. (1978) have described 77075. Megascopically, the dark vein in 77075 is aphanitic with scattered small xenoliths of calcic plagioclase, pyroxene, and olivine. The matrix is holocrystalline with very fine grain size (Fig. 3). The average grain size of the matrix of 77075 is 5-10 μm, with poikilitic pyroxene averaging 10-20 μm (McGee et al., 1980). The principal minerals in the matrix are calcic plagioclase (An_{89-92}), pigeonite, and olivine (Fo_{74-78}). Orthopyroxene xenocrysts have a uniform composition of $Wo_{3-4}En_{66-69}Fs_{28-30}$. Augite was not observed in the matrix of the dike material in 77075. The dense, dark dike has a sharp boundary with the porous, noritic microbreccia.

McGee et al. (1980) have studied the microstructures in the pyroxenes from the different lithologies of the Station 7 Boulder, including the 77075 dike. They measured exsolution lamellae that were ~10 μm wide in pigeonite compared with 20-25 μm wide in pyroxenes in 77115 and 77135, leading McGee et al. to conclude that the 77075 dike

Figure 1: Photograph of 77075. Scale is 1 cm. S73-24005.

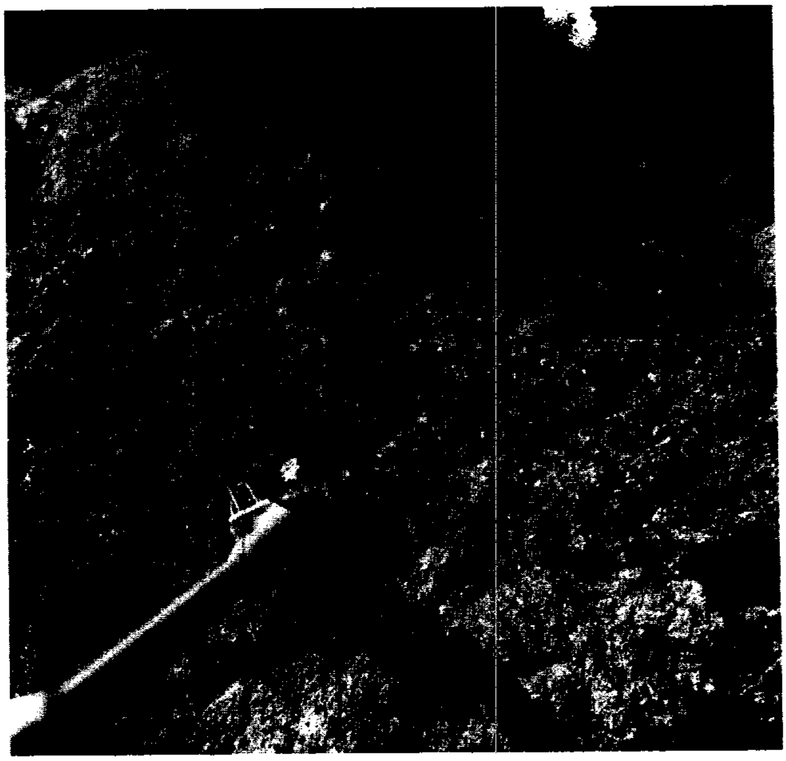


Figure 2: Closeup photograph of the boulder at Station 7. The vein through the off-white norite clast can be clearly seen through the brown patina. Schmitt observed that this vein (77075) is continuous with the surrounding breccia (77115). AS17-146-22327.

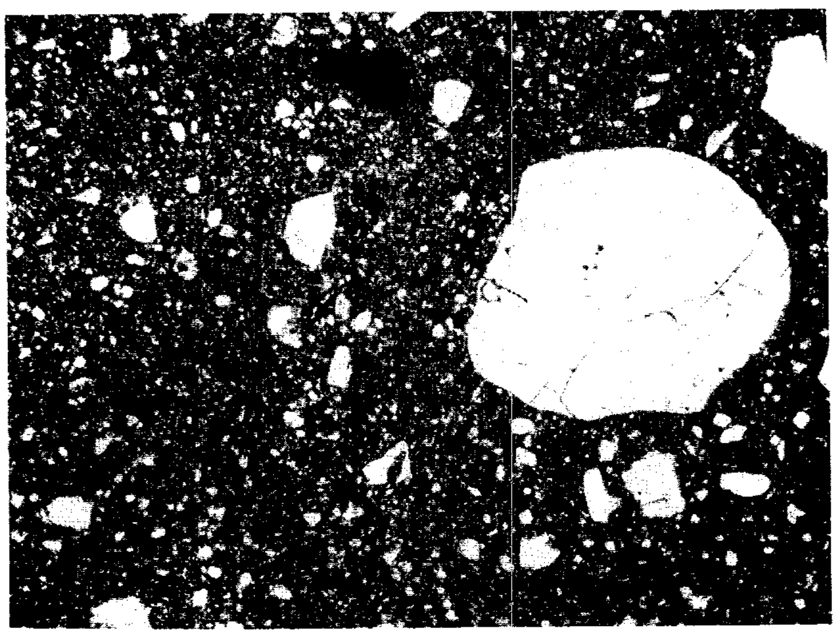


Figure 3: Photomicrograph of 77075,11, showing the poikilitic texture of the dike material. Rounded olivine xenocryst is included. Field of view is 3 x 4 mm.

crystallized and cooled through the solidus more rapidly than did the enclosing rocks 77115 and 77135. Presumably, the relatively rapid cooling of the dike rock also inhibited precipitation of matrix augite and resulted in coprecipitation of ilmenite and pigeonite. The abundant population of cooler, unmelted fragments in 77075 probably contributed to the rapid initial cooling rate and favored fine grain size by providing a high initial density of nuclei. Rapid quenching of the dike rock by injection into a cooler clast, 77215, probably also contributed to the faster cooling time (McGee et al., 1980). Sanford and Heubner (1980) have also discussed the cooling rate for the dark dike in 77075.

Warren and Wasson (1978) find that chemical composition of the white noritic portion of 77075 is "extremely similar" to the composition of the same lithology on 77077 and 77215, which are from the same sample location on the boulder at Station 7. All three rocks are the same crushed norite (Fig. 4). The plagioclase in the norite is An_{90-92}; the orthopyroxene is $Wo_{4.5}En_{65-70}Fs_{26-30}$. Bersch et al. (1991) have precisely determined the composition of pyroxene in the white, noritic portion of 77075. Fig. 5 shows that the white portion of 77075 plots within the Mg-norite suite of lunar rocks.

WHOLE-ROCK CHEMISTRY

Winzer et al. (1974) have reported the chemical composition of the dark vein in 77075, and Warren and Wasson (1988) have reported the composition of the white norite material (Table 1 and Fig. 6). The composition of the dark dike is the same as for the continuous boulder matrix 77115 and similar to many other lunar impact melt breccias. The attached white norite is the same composition as 77215.

Morgan et al. (1974a) determined the trace siderophile and volatile elements in the dark dike material and found that it had high Ir (Table 2), while Warren and Wasson (1978) found that the siderophile elements were very low in the white, noritic portion of 77075 (Table 1).

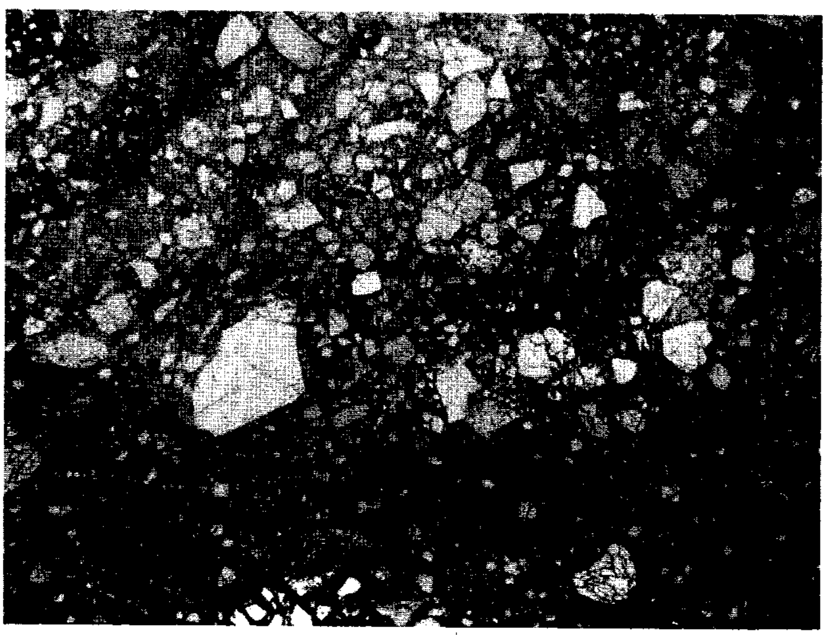


Figure 4: Photomicrograph of 77075 white norite material. Field of view is 3 x 4 mm.

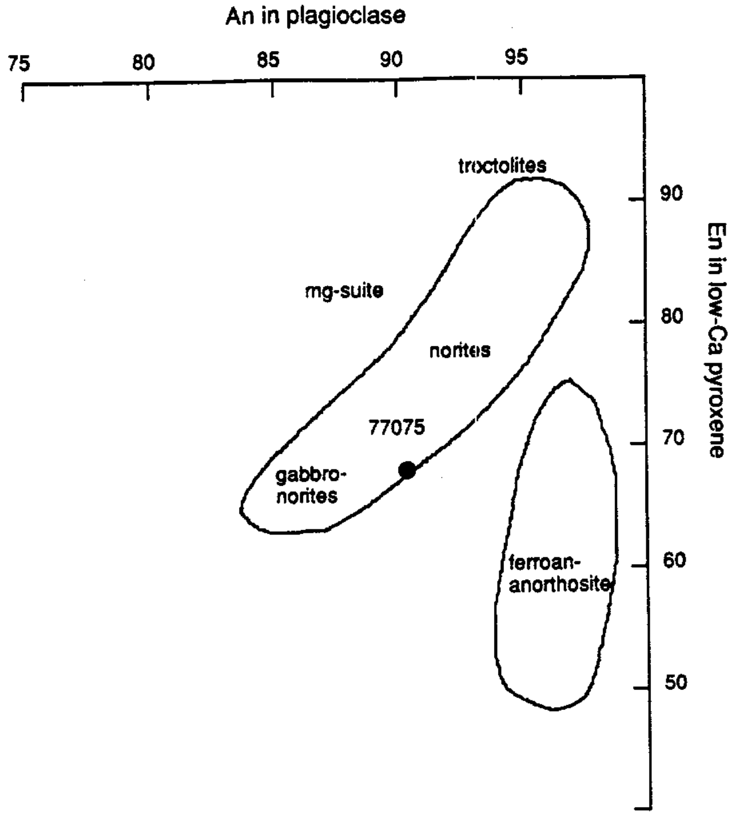


Figure 5: Plagioclase and pyroxene composition of the white portion of 77075. Fields from James and Flohr (1975).

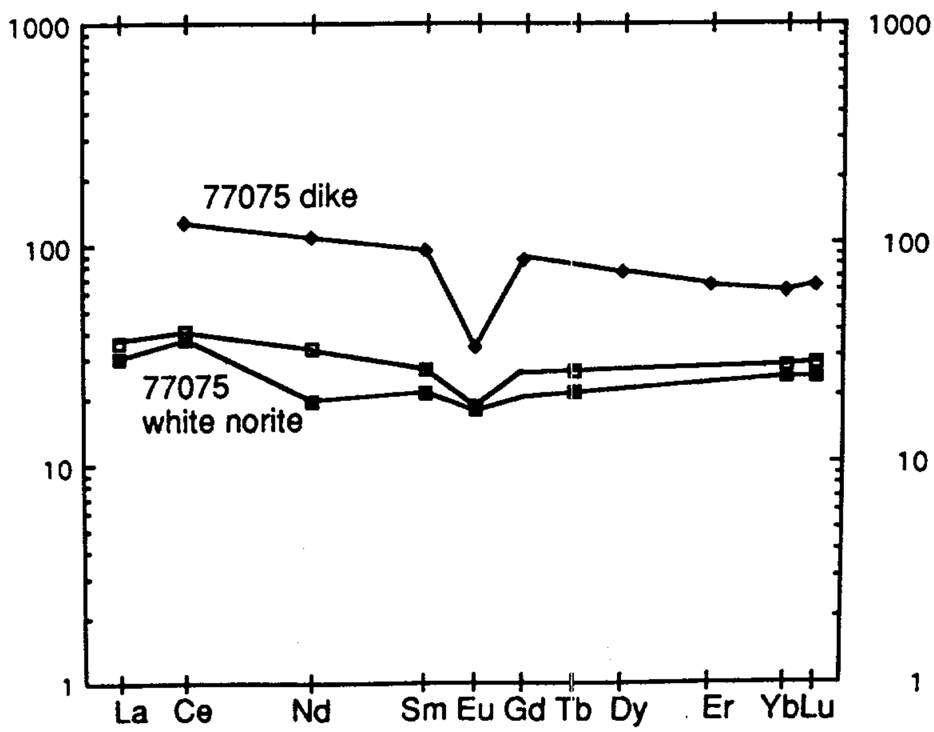


Figure 6. Normalized rare earth element plot for 77075. The data from the dike are from Winzer et al. (1974), and the data for the white norite material are from Warren and Wasson (1978).

SIGNIFICANT CLASTS

The white material attached to 77075 is the same material as the cataclastic norite in 77077 and 77215.

RADIOGENIC ISOTOPES

Stettler et al. (1974) determined ages of 3.99 ± 0.03 b.y. and 3.96 ± 0.08 b.y. by the ^{39}Ar-^{40}Ar plateau technique (Fig. 7). Stettler et al. (1978) reported an age of 3.98 ± 0.03 b.y. for a third split of the dark dike and concluded that the age was 3.97 ± 0.04 b.y. (weighted average of three analyses).

Nakamura and Tatsumoto (1977) have determined an internal Rb-Sr "isochron" for the matrix of 77075 dike material after separating as many of the xenocrysts as possible (Table 3). They obtained an age of 4.18 ± 0.08 b.y. (Fig. 8). However, this apparent "isochron" may be misleading because the mineral splits may have included small plagioclase xenocrysts.

Nunes et al. (1974) have reported U-Th-Pb data (Table 4), and Nakamura and Tatsumoto (1977) have determined a Sm-Nd "isochron" (Table 5).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Stettler et al. (1974) obtained an exposure age of about 25.5 m.y. by the Ar method.

PROCESSING

The initial processing and distribution of 77075 is outlined in Butler and Dealing (1974). It was studied by the international consortium led by E.C.T. Chao (see final report by Minkin et al., 1978). A detailed description of the splits is given in open-file report 78-511.

Sample 77075 has five thin sections. The three largest pieces are: ,13 (57 g); ,14 (41 g); and ,15 (53 g).

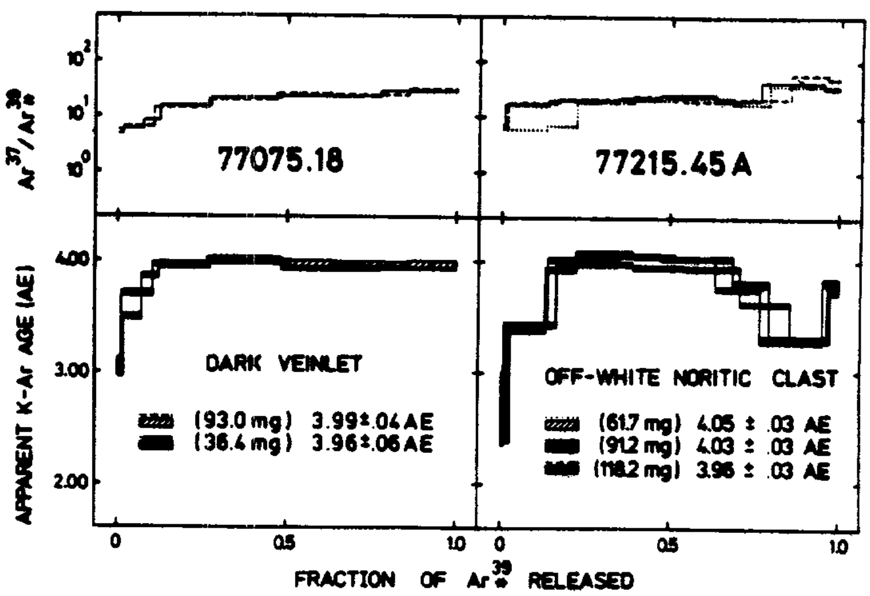


Figure 7. Ar-Ar plateau data for two splits of 77075. From Stettler et al. (1974).

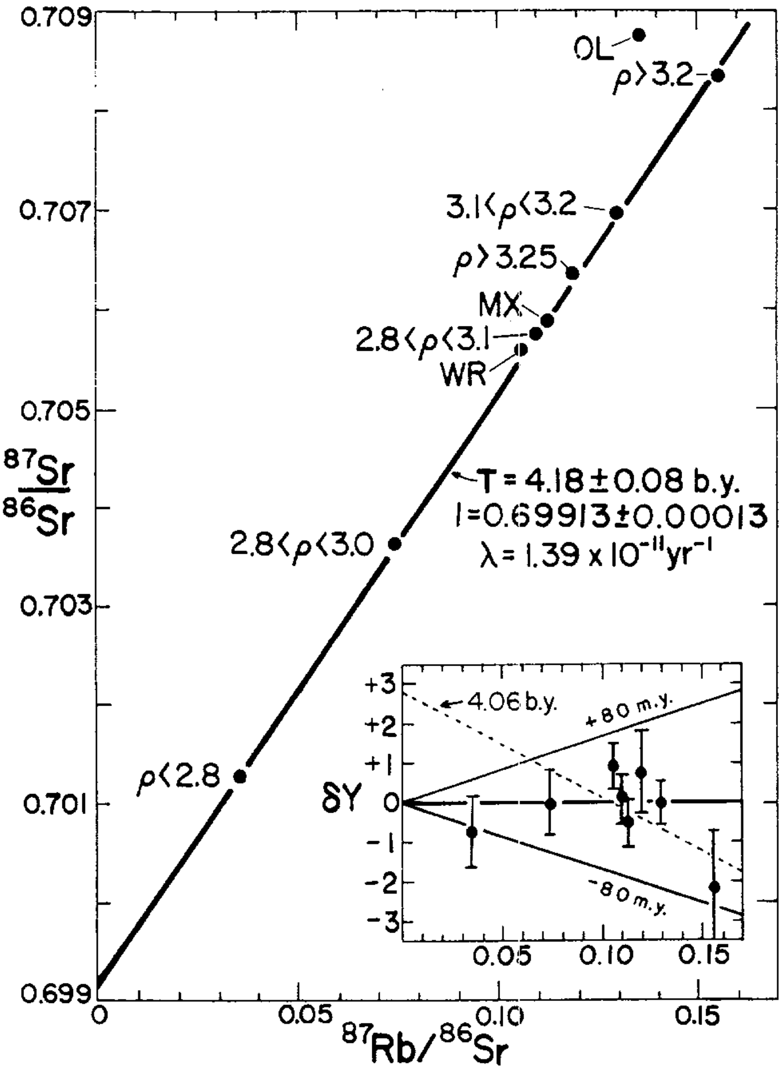


Figure 8. Rb-Sr isochron for dark dike material from 77075. From Nakamura and Tatsumoto (1978).

Table 1: Whole-rock chemistry of 77075.
a) Winzer et al. (1974); b) Warren and Wasson (1978)

Split Technique	,21 (a) AA, IDMS dark vein	,27 (b) INAA white	,27 (b) INAA white
SiO_2 (wt%)	46.4	51.1	50.9
TiO_2	1.38	0.34	0.35
Al_2O_3	18.17	14.97	14.00
Cr_2O_3	0.17	0.38	0.41
FeO	9.31	10.67	10.16
MnO	0.11	0.17	0.18
MgO	12.57	12.9	13.78
CaO	10.55	8.82	8.82
Na_2O	0.65	0.38	0.36
K_2O	0.23	0.18	0.16
P_2O_5	0.26		
Nb (ppm)			
Zr	–	210	170
Hf	10.8	3.5	3.5
Ta		0.34	0.40
U		0.5	0.58
Th		1.57	1.8
Sr	165		
Rb	6.1		
Li	21.5		
Ba	333	160	158
Zn		3.25	3.31
Ni		6.1	<1.1
Co		33	25.9
Sc		16.6	16.5
La		7.2	8.3
Ce	74.3	22	24
Nd	47.5	8.5	15
Sm	13.4	3.0	3.9
Eu	1.84	0.98	1.01
Gd	16.4		
Tb		0.74	0.92
Dy	17.2		
Er	10.0		
Yb	9.53	3.9	4.4
Lu	1.5	0.59	0.68

Table 1: (Concluded).

Split Technique	,21 (a) AA, IDMS dark vein	,27 (b) INAA white	,27 (b) INAA white
Ga		4.03	4.1
Ge (ppb)		10.9	16.8
Ir		0.25	0.0084
Au		0.026	0.088

Table 2: Trace element data for dark dike in 77075. Concentrations in ppb.
From Morgan et al. (1974a).

	Sample 77075,19
Ir	8.89
Os	
Re	0.781
Au	5.09
Pd	
Ni (ppm)	286
Sb	1.92
Ge	532
Se	112
Te	6.3
Ag	1.2
Br	81
In	
Bi	0.34
Zn (ppm)	2.8
Cd	7.5
Tl	2.4
Rb (ppm)	6.4
Cs	270
U	1450

Table 3: Rb-Sr analytical data for 77075.
From Nakamura and Tatsumoto (1977).

Sample	Weight (mg)	K (%)	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$ [1]	$^{87}Sr/^{86}Sr$ [2]
Handpicked fraction						
Whole rock	22.75	0.1937	5.927	161.72	0.1060	0.70554 ± 4
Matrix	5.13	0.1996	5.978	153.49	0.1126	0.70583 ± 4
Olivine	0.62	0.0160	0.878	18.78	0.1352	0.70869 ± 8
Density separates of >74 μm fraction						
$\rho<2.8$ [3]	9.42	0.1132	2.604	211.24	0.0356	0.70123 ± 6
$2.8<\rho<3.1$	38.33	0.2090	6.274	165.35	0.1098	0.70571 ± 4
$3.1<\rho<3.2$	6.05	0.1834	6.079	135.35	0.1299	0.70690 ± 4
$\rho>3.2$	2.81	0.0961	3.554	66.25	0.1552	0.70827 ± 10
Density separates of <74 μm fraction						
$2.8<\rho<3.0$	0.9	0.1247	3.613	140.56	0.0743	0.70358 ± 6
$\rho>3.25$	0.75	0.0505	1.764	42.92	0.1189	0.70630 ± 8

[1] Uncertainties are estimated to be ≤0.3%.
[2] Uncertainties correspond to last significant figure and are 2σ mean.
[3] Combined with the $\rho<2.8$ separate of <74 μm fraction. Density is in g/cm^3.

Table 4: U-Th-Pb for 77075.
From Nunes et al. (1974).

Split	77075,22
wt (mg)	98.2
U (ppm)	1.425
Th (ppm)	5.299
Pb (ppm)	3.083
$^{232}Th/^{238}U$	3.84
$^{238}U/^{204}Pb$	2110

Table 5: Sm-Nd analytical data for 77075.
From Nakamura and Tatsumoto (1977).

Sample	Weight (mg)	Sm (ppm)	Nd (ppm)	$\frac{^{147}Sm}{^{144}Nd}$	$\left(\frac{^{143}Nd}{^{144}Nd}\right)^1$
$\rho<2.8$ [2]	9.42	10.23	37.59	0.1645 ± 2	0.511801 ± 37
$2.8<\rho<3.1$	38.33	15.18	53.04	0.1732 ± 1	0.512040 ± 19
Whole rock	22.75	14.10	49.00	0.1739 ± 1	0.512050 ± 19
$\rho>3.2$	2.81	6.58	22.86	0.1740 ± 4	0.512094 ± 40

[1] Normalized to $^{150}Nd/^{144}Nd = 0.236433$. Errors correspond to last significant figures and are 2σ mean.
[2] Density is in g/cm^3.

77076

Impact Melt Dike in Cataclastic Norite
13.97 g, 3 x 2 x 2 cm

INTRODUCTION

Sample 77076 was sampled from a dark dike in the large white clast in the boulder at Station 7 *(see the section on the Station 7 Boulder, page 235)*. The dike is a fragment-laden melt rock with a matrix similar to that of 77115, but with a finer grain size. This rock has not been studied. It is essentially another piece of 77075 (Fig. 1). Note the fine black veins extending into the white portion.

This sample has not been allocated or studied.

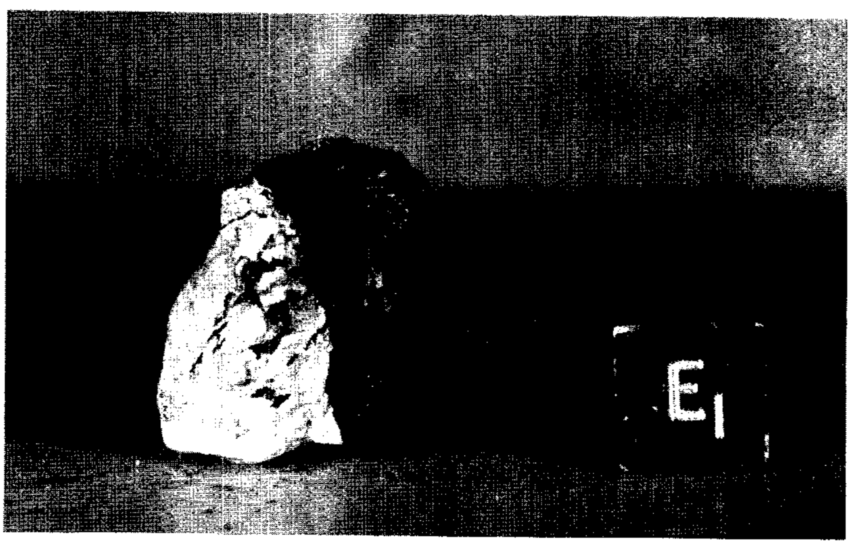


Figure 1. Photograph of 77076. Cube is 1 cm. S73-17101.

77077

Cataclastic Norite with Black Veinlets
5.45 g, 2 x 2 x 1.5 cm

INTRODUCTION

Sample 77077 was sampled along with the dark dike in the large "off-white" clast in the boulder at Station 7 *(see the section on the Station 7 Boulder, page 235)*. This sample is friable white cataclastic norite with thin black veinlets (Fig. 1).

Warren and Wasson (1978) find that the mineralogy of the white portion of 77077 is "extremely similar" to the same lithology on 77075 and 77215, which are from the same sample location on the boulder at Station 7. All three rocks are the same crushed norite with plagioclase (An_{90-92}) and orthopyroxene ($Wo_{4-5}En_{65-70}Fs_{26-30}$).

WHOLE-ROCK CHEMISTRY

Warren and Wasson (1978) found that the siderophile elements were very low in 77077 (Table 1). It has the same chemical composition as 77215 and the white material attached to 77075 (Fig. 3).

PETROGRAPHY

Sample 77077 is cataclastic norite equivalent to sample 77215 and the white material that is attached to the black dike 77075. Thin sections show that it is crushed with schliern of very fine material (Fig. 2). It is about half pyroxene and half plagioclase.

MINERAL CHEMISTRY

Bersch et al. (1991) have precisely determined the composition of pyroxene in 77077. Hansen et al. (1979) report the trace elements in plagioclase.

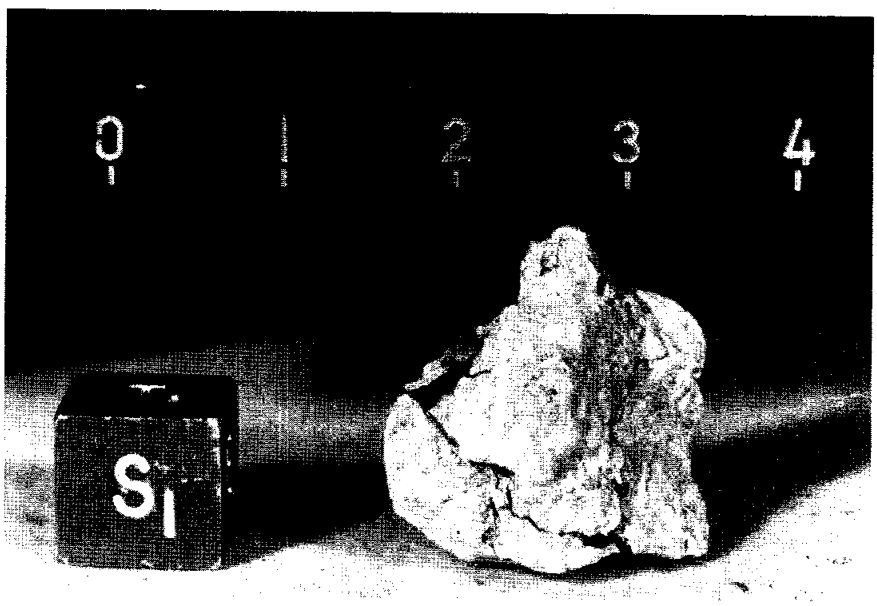


Figure 1: Photograph of 77077. Scale is 1 cm. S73-17182.

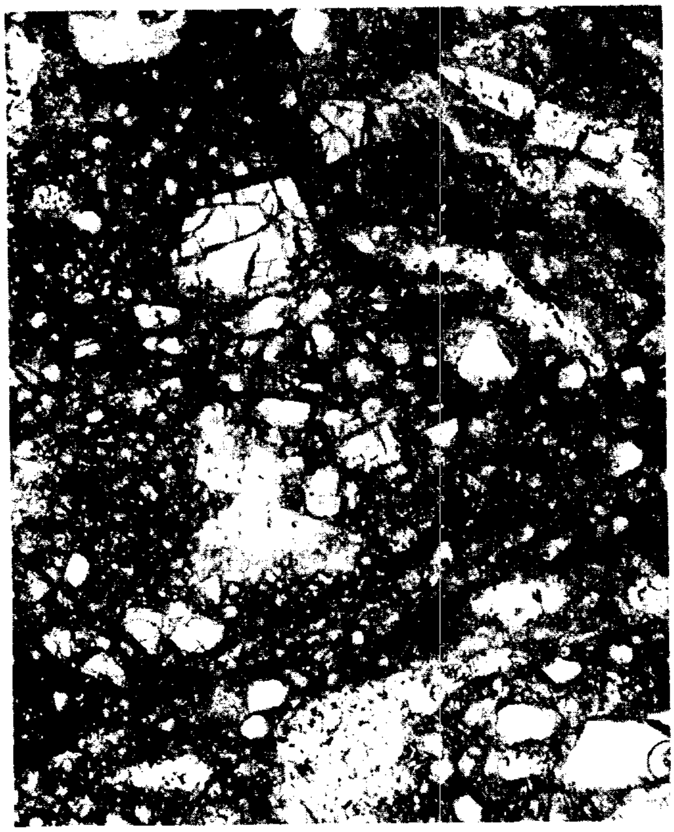


Figure 2: Photomicrograph of thin section 77077,6. Field of view is 1 x 2 mm.

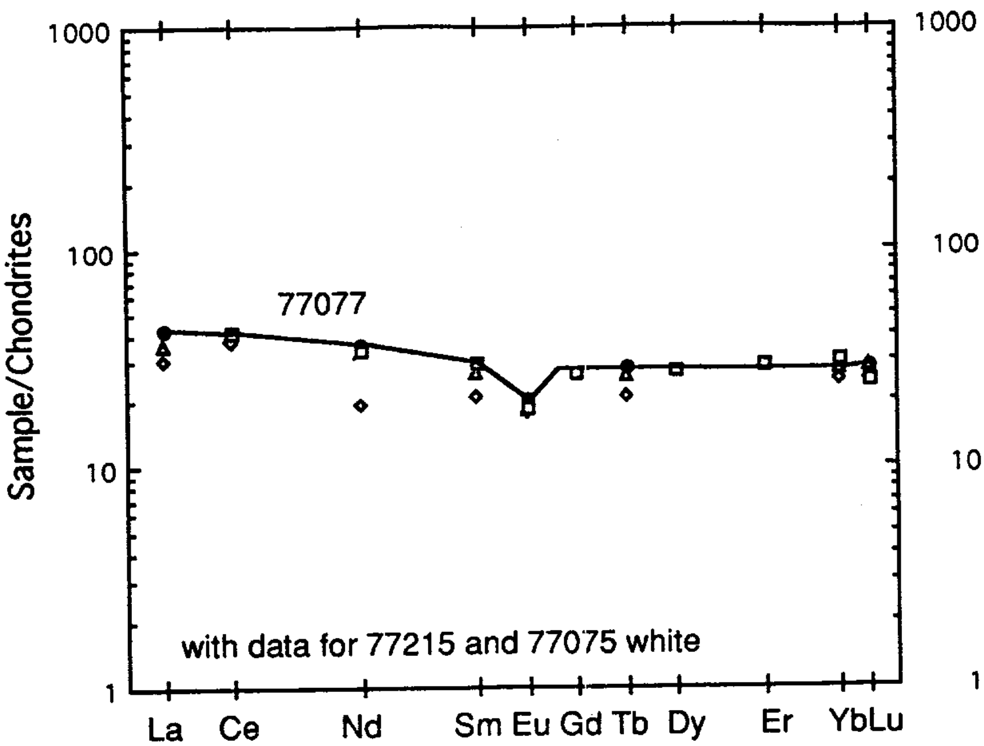


Figure 3: Normalized rare earth element data for 77077 plotted with data from 77215 and 77075 white portion. Data from Warren and Wasson (1978).

Table 1: Whole-rock chemistry of 77077.
From Warren and Wasson (1978).

Split Technique	,1 (a) INAA white
SiO_2 (wt%)	50.9
TiO_2	0.30
Al_2O_3	16.16
Cr_2O_3	0.32
FeO	8.74
MnO	0.15
MgO	10.6
CaO	9.94
Na_2O	0.44
K_2O	0.22
Nb (ppm)	
Zr	150
Hf	3.4
Ta	0.38
U	0.59
Th	2.0
Ba	220
Zn	2.84
Ni	<1.7
Co	25.2
Sc	13.8
La	9.9
Ce	25
Nd	16
Sm	4.28
Eu	1.12
Tb	1.0
Yb	4.5
Lu	0.67
Ga	5.0
Ge (ppb)	18.7
Ir	0.0029
Au	0.056

77115
Micropoikilitic Impact Melt Breccia
115.9 g, 6.5 x 5.5 x 3.5 cm

INTRODUCTION

Sample 77115 was sampled as "blue-grey breccia" from the boulder at Station 7 *(see the section on the Station 7 Boulder, page 235)*. It is a sample of the boulder matrix that incorporated the large white norite clast (77215). It contains obvious large lithic clasts, as seen in the hand specimen (Fig. 1), and has numerous small lithic and mineral clasts in the matrix. The texture and chemical composition of 77115 is similar to that of the black dike in 77075, although it is somewhat coarser grained. Schmitt had observed that these rocks are closely related in origin (see discussion in 77075).

Sample 77115 is a grey, vuggy, very fine-grained, fragment-laden, crystalline-matrix breccia containing abundant xenoliths (clasts). It consists of two parts: a grey, fine-grained matrix making up most of the rock and a thin layer that is part of a brown granular breccia clast (Minkin et al., 1978). Chao et al. (1975) state that 77115 is "not a breccia in a normal sense, but is a crystalline rock, formed by crystallization of a fragment-laden melt." The probable origin of impact melt breccias has been explained by Simonds (1975) and Onorato et al. (1976).

PETROGRAPHY

The fine-grained matrix of 77115 (Fig. 2) consists largely of an interlocking network of anhedral and lath plagioclase surrounded by pyroxene in a micropoikilitic texture generally typical of the matrix of the other impact melt rocks from Apollo 17 (i.e., 76035, 72435, 73155, etc.). The plagioclase and pyroxene form a subophitic-to-poikilitic intergrowth in which the maximum grain size of pyroxene oikocrysts is approximately 25-30 μm and of matrix plagioclase is less than 15 μm (McGee et al., 1980).

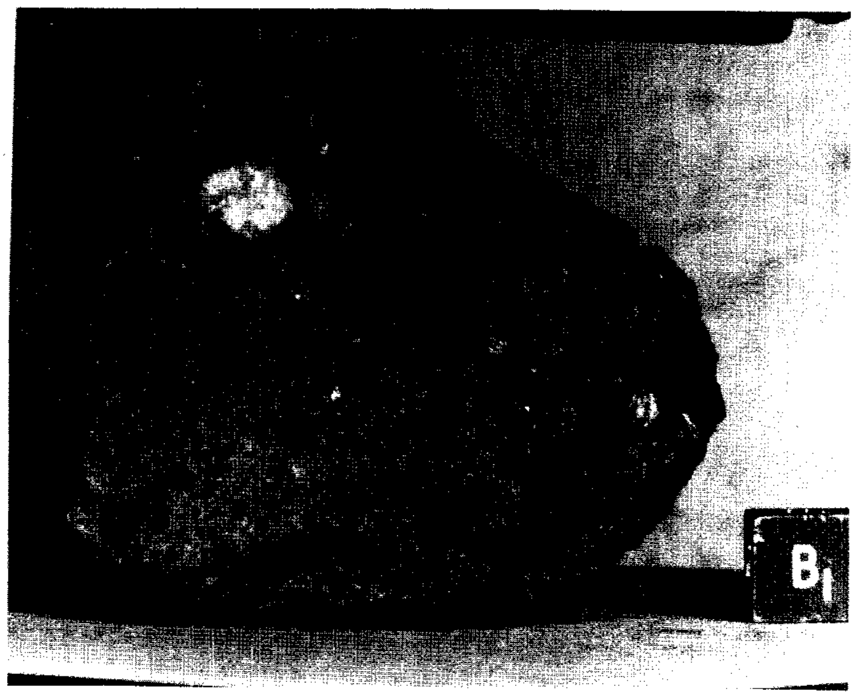


Figure 1: Photograph of broken surface of 77115. Note the dark clasts as well as the large white clast. S73-24122.

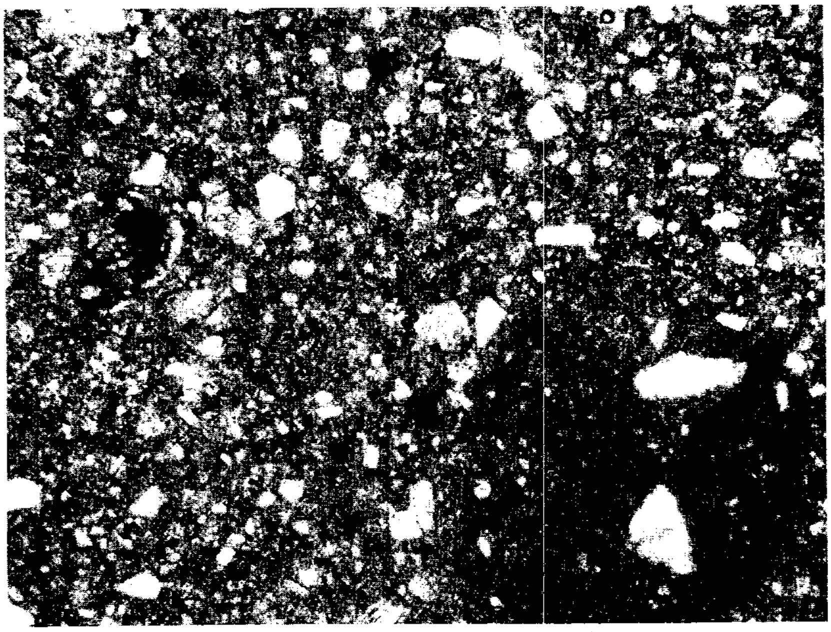


Figure 2: Photomicrograph of thin section 77115,60, showing the crystalline matrix with partially dissolved clasts. Field of view is 3 x 5 mm.

Chao et al. (1975) reports the modal mineralogy of the matrix of 77115 (Table 1). The matrix has ~60% plagioclase, ~30% pigeonite, and ~6% olivine, with minor amounts of augite, phosphate, troilite, mesostasis, and metallic iron. Equant grains of olivine are scattered throughout the matrix. Clusters of ilmenite platelets mold against grains of plagioclase and pyroxene and poikilitically enclose plagioclase, olivine, and pyroxene. Small amounts of a K-rich mesostasis and associated small grains of phosphate minerals, metallic iron, troilite, and ilmenite occur interstitially. Some pyroxene and plagioclase occur as euhedral crystals in the vugs. The grain size of the plagioclase, pyroxene, and ilmenite in the matrix ranges from 1 µm to about 30 µm, with most grains about 5-10 µm. Olivine grains are generally larger, about 6-8 µm across.

In the matrix, plagioclase is An_{85-88}, low-Ca pyroxene ranges from $Wo_{4-13}En_{66-77}Fs_{19-21}$, and minor amounts of high-Ca pyroxene range from $Wo_{30-40}En_{46-54}Fs_{14-16}$. Olivine is Fo_{66-72}.

77115 contains a large variety of lithic clasts, and according to Chao et al. (1975), the clast population appears different from that of 77135 (which is from the breccia that surrounds the 77115 lithology). Figs. 3 and 4 are photomicrographs of a small compound lithic clast in thin section 77115,11, illustrating a small anorthosite clast within a larger granulated noritic clast.

Chao et al. (1975) and Huebner (1976) reported diffusively rimmed xenocrysts in 77115. This occurs where the enclosed mineral clast has a composition different from the matrix. Thornber and Heubner (1980) and Sanford and Heubner (1979 and 1980) discuss cation diffusion and cooling rates for 77115. They use chemical gradients in olivine (Fig. 5) to calculate a cooling rate of 10-25 °C/hr. from 1230 °C to 1180 °C and <7 °C/hr. below 1180 °C.

Thornber and Heubner (1980) have also performed an experimental study of the phase equilibria relations of a melt with the composition of 77115 (Fig. 6).

MINERAL CHEMISTRY

Chao et al. (1975) report the compositions of pyroxene, olivine, and plagioclase. McGee et al. (1980) have carefully studied the composition (Fig. 7) and microstructures in the pyroxenes from the different lithologies of the Station 7 Boulder, including 77115. They measured exsolution lamellae in pigeonite ~20-25 µm wide in pyroxenes in 77115 and 77135 as compared with ~10 µm wide for 77075 dike rock, leading McGee et al. to conclude that the 77075 dike crystallized more rapidly and cooled through the solidus more rapidly than did the enclosing rocks 77115 and 77135.

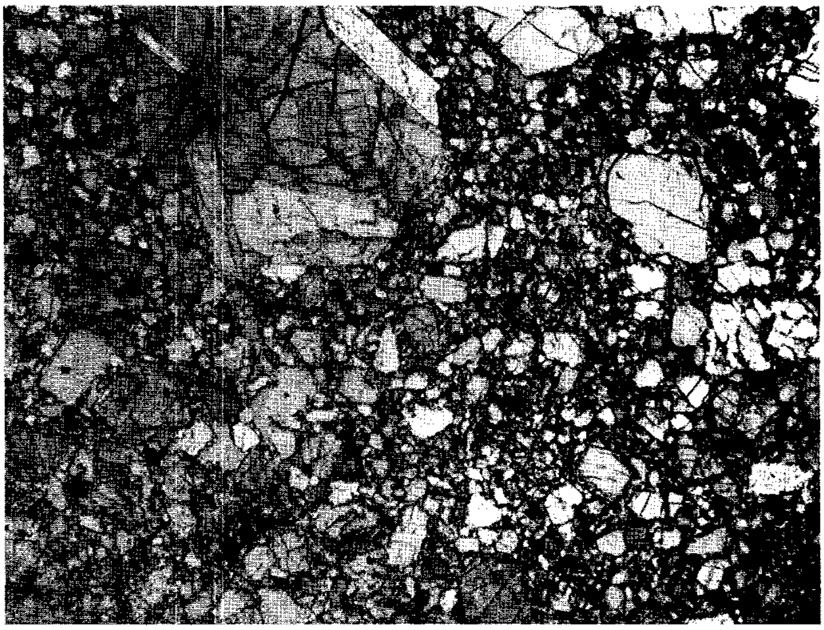


Figure 3: Photomicrograph of an "anorthositic" clast in thin section 77115,11. Field of view is 3 x 5 mm.

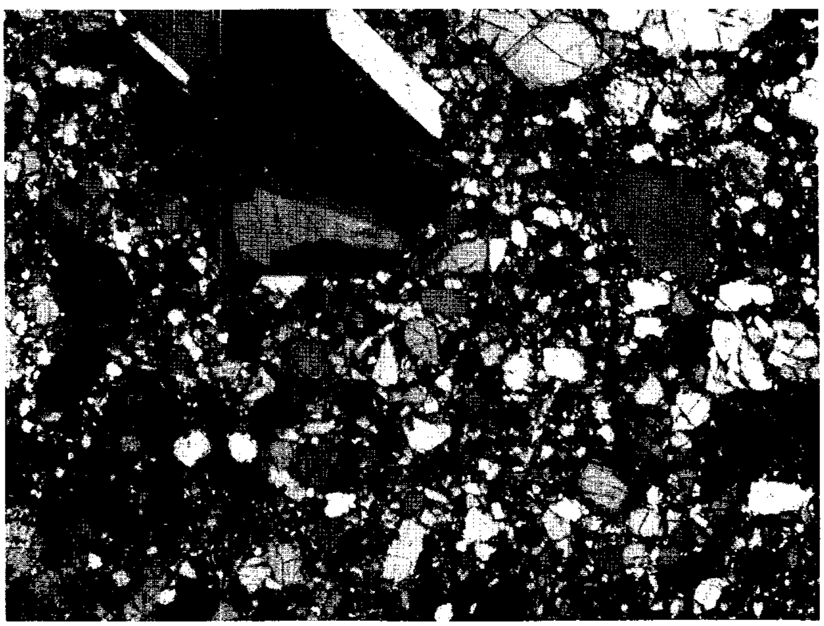


Figure 4: Cross-polarized view of same area as Fig. 3.

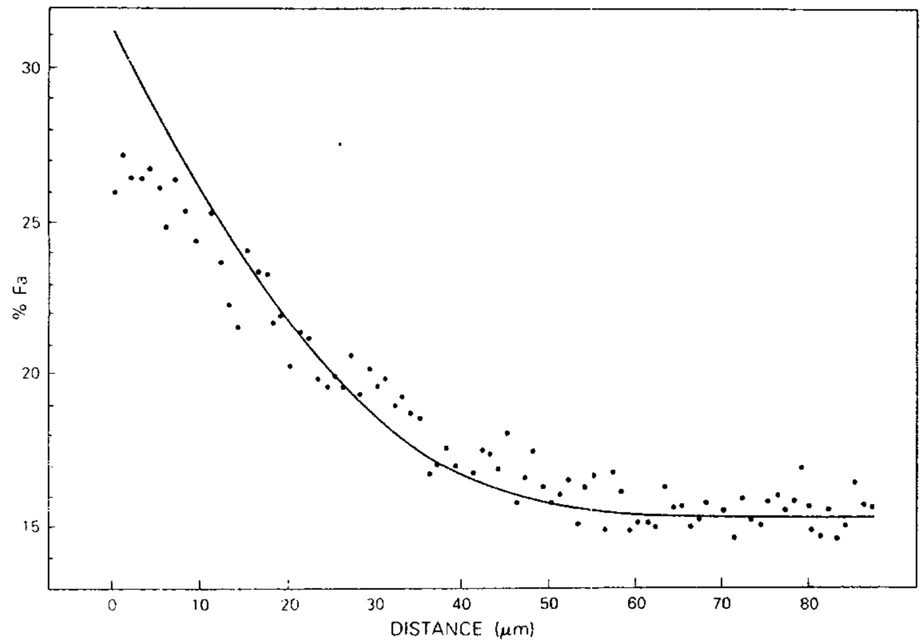


Figure 5: Composition gradient at edge of olivine xenocryst in 77115. From Sanford and Huebner (1979).

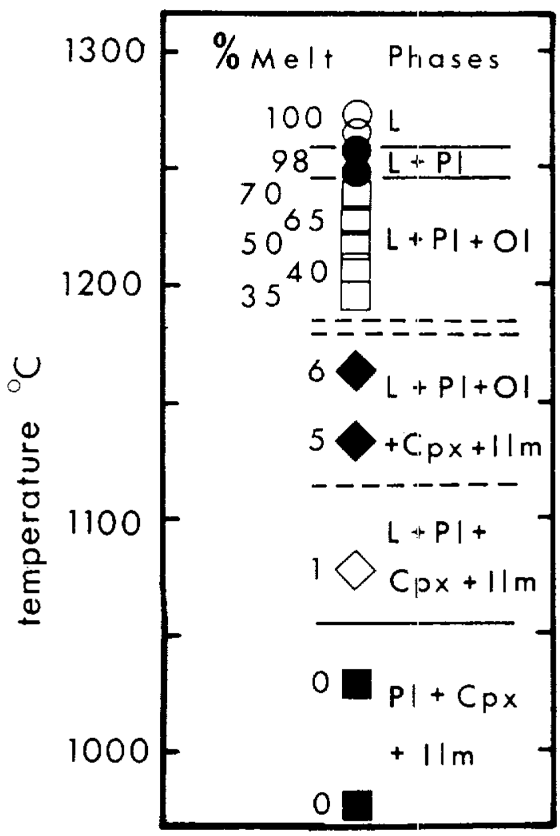


Figure 6: Phase relationships from experimental study by Thornber and Huebner (1980).

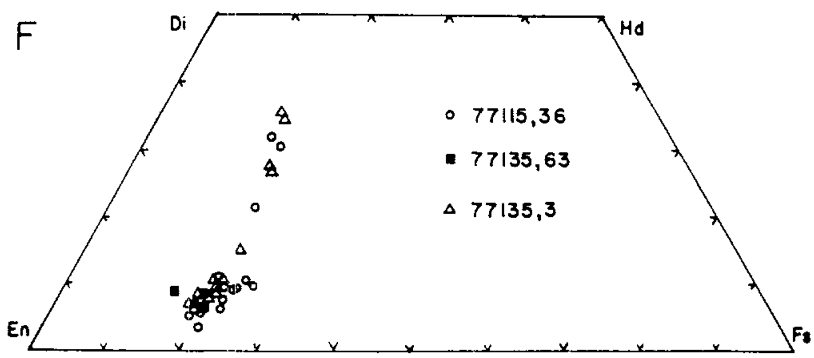


Figure 7: Pyroxene composition in 77115 matrix. From McGee et al. (1980).

Bersch et al. (1991) have precisely determined the compositions of olivine in 77115. Engelhardt (1979) has reported the composition of the ilmenite. Hansen et al. (1979) report the trace element content of plagioclase. Warren and Kallemeyn (1993) report that an uncommonly magnesian Cr-spinel is present in the troctolitic anorthosite clast.

WHOLE-ROCK CHEMISTRY

Winzer et al. (1974) reported the chemical composition of 77115 (Table 2 and Fig. 8). Note the high trace element and phosphate content of the "troctolite" clast. Ebihara et al. (1991) report the trace compositions of siderophile and volatile elements (Table 3). Fruchter et al. (1975) report K, U, and Th contents.

SIGNIFICANT CLASTS

Chao et al. (1975) discuss a brownish-grey xenolith that is found as a thin veneer on the surface that was attached to the boulder (presumably why it broke this way). This clast is a recrystallized breccia with a bimodal grain-size distribution (but not cataclastic) containing millimeter-size clasts of granulated clinopyroxene set in a matrix of smaller, slightly fractured yellow-green olivine (Fo_{69}) and colorless to light grey plagioclase.

Warren and Kallemeyn (1993) have restudied the "troctolite" clast in 77115 that was originally reported by Winzer et al. (1974). Warren and Kallemeyn conclude that this clast should be properly called a troctolitic anorthosite and be classified as a member of the "alkalic suite." This unusual clast has very high REE abundance (Fig. 8). In this clast, plagioclase is An_{95}, olivine is Fo_{89}, and pyroxene is $Wo_{1.7}En_{88}Fs_{10}$.

RADIOGENIC ISOTOPES

Stettler et al. (1978) have restudied the ages of 77115 and confirmed their results of 1974. They have determined a pronounced intermediate temperature plateau at 3.90 ± 0.03 b.y. (Fig. 9). This is a problematical puzzle because this rock was observed to be continuous with the dike rock (77075), which has been dated by the same laboratory at 3.97 ± 0.03 b.y. Possibly the enclosure of 77115 within the "green-grey" breccia 77135 (age 3.89 b.y.) has reset the age of 77115 without resetting the age of 77075.

Nakamura et al. (1976) have determined a Rb-Sr isochron (Table 4) with an imprecise "age" of 3.75 ± 0.20 b.y. (Fig. 10).

Nunes et al. (1974) have reported U-Th-Pb data for 77115 (Table 5).

MAGNETIC STUDIES

Cisowski et al. (1983) have determined the thermal remanent magnetization of 77115. Hale et al. (1978) also attempted (unsuccessfully) to determine the magnetization of this sample.

PROCESSING

The initial processing and distribution of 77115 is outlined in Butler and Dealing (1974). It was studied by the international consortium led by E.C.T. Chao (see final report by Minkin et al., 1978). Detailed description of the splits is given in open-file report 78-511.

The largest remaining piece of 77115 is 76 g. Twenty-eight thin sections of 77115 have been prepared.

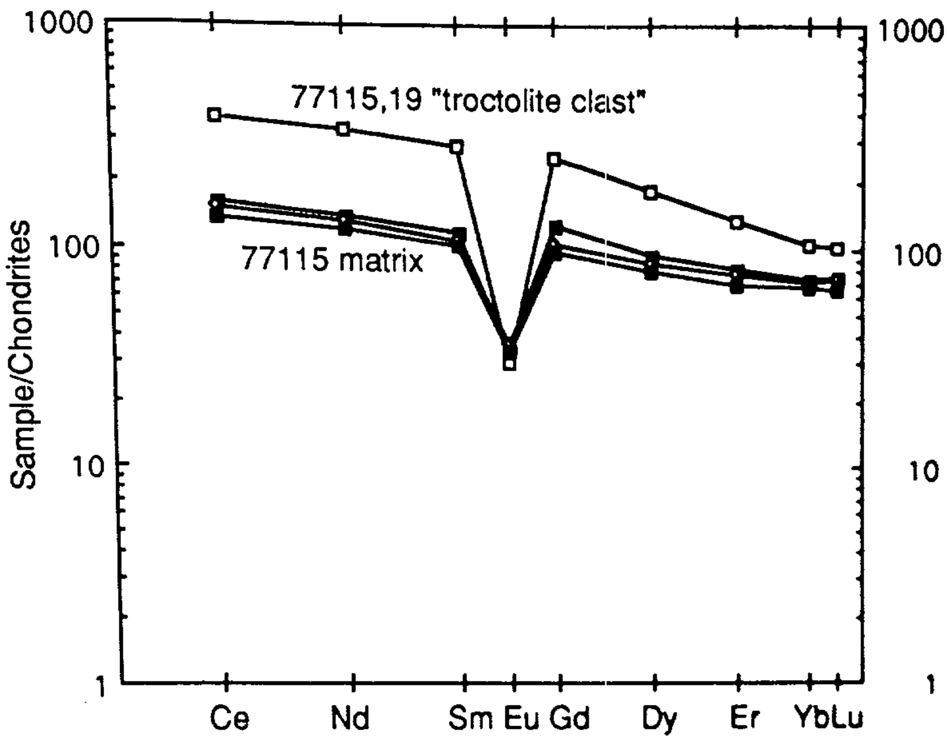


Figure 8: Normalized rare earth element composition of 77115 matrix and clast. Data from Winzer et al. (1974) and Warren and Kallemeyn (1993).

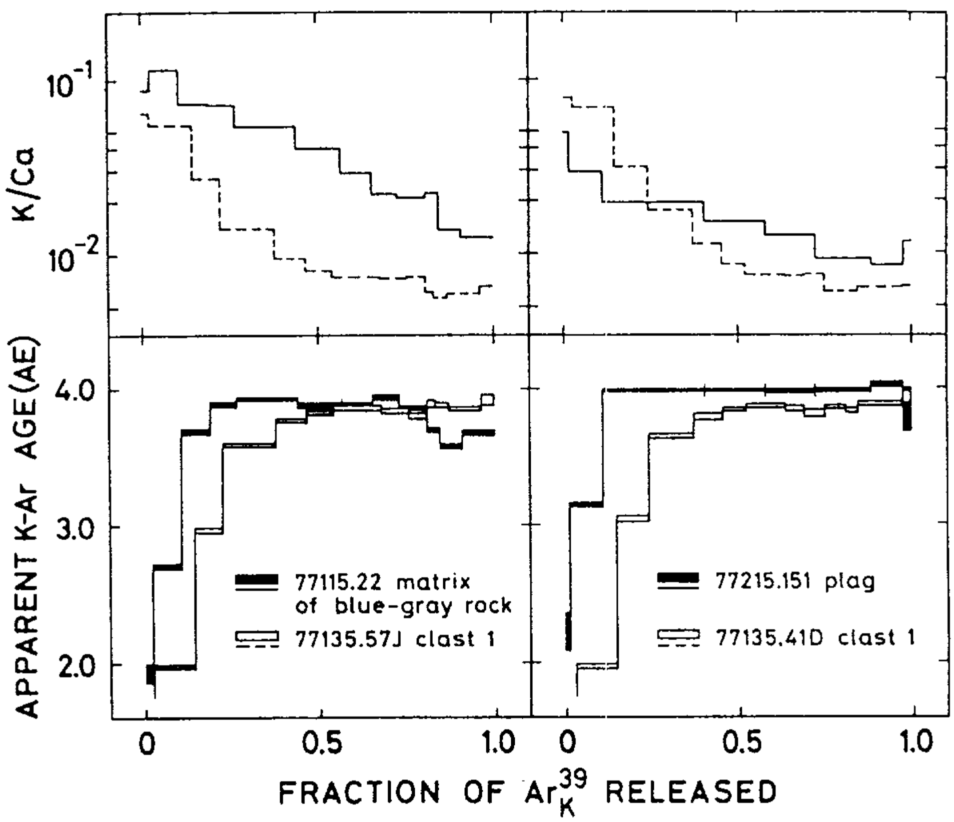


Figure 9: ^{39}Ar-^{40}Ar thermal release pattern for 77115. From Stettler et al. (1978).

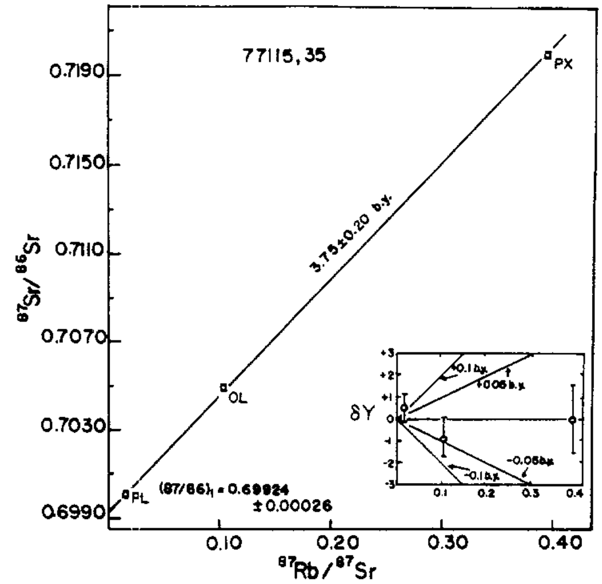


Figure 10: Rb-Sr isochron for 77115. From Nakamura et al. (1976).

Table 1: Mineral modes for 77115.*
From Chao et al. (1975).

	77115,52	Matrix †	77115,53	Matrix †	77115,56	Matrix †	Average	Average matrix †
Plagioclase								
(A) Matrix, anhedral and laths	46.3	59.2	49.3	61.4	50.2	61.1	48.6	60.5
(B) Xenocrysts	10.5	–	13.3	–	11.2	–	11.7	–
Clinopyroxene								
(A) Matrix	24.7	31.6	22.4	27.9	22.4	27.2	23.2	28.9
(B) Xenocrysts	2.6	–	1.5	–	0.7	–	1.6	–
Olivine								
(A) Matrix, granular	4.5	5.7	5.3	6.6	5.5	6.7	5.1	6.3
(B) Xenocrysts	3.8	–	2.4	–	3.4	–	3.2	–
Orthopyroxene xenocrysts	3.5	–	1.5	–	1.8	–	2.3	–
Ilmenite	2.0	2.6	2.5	3.1	3.6	4.4	2.7	3.4
K-rich material	0.4	0.5	0.6	0.7	0.2	0.2	0.4	0.5
Phosphate	0.1	0.1	0.2	0.3	0.2	0.2	0.2	0.2
Ni-Fe material	1.4	–	0.9	–	0.7	–	1.0	–
Troilite	0.2	0.3	0	0	0.2	0.2	0.1	0.2
Fe metal	TR.	TR.	TR.	TR.	TR.	TR.	TR.	TR.
Total	100.0	100.0	99.9	100.0	100.1	100.0	100.1	100.0

*Normalized after subtracting voids and xenoliths.
†Normalized after subtracting xenocrysts.
Done in reflected and transmitted light by C. L. Thompson.

Table 2: Whole-rock chemistry of 77115.
From Winzer et al. (1974).

Split Technique	,69 AA, IDMS matrix	,70 AA, IDMS matrix	,71 AA, IDMS matrix	,19 AA, IDMS "troctolite" clast	,19 AA, IDMS chilled margin
SiO_2 (wt%)	47.1	47.1	47.2	41.8	46.6
TiO_2	1.31	1.23	1.34	0.17	1.15
Al_2O_3	17.35	18.86	17.55	16.78	18.63
Cr_2O_3	0.17	0.16	0.18	0.04	0.19
FeO	8.90	8.39	9.51	6.08	8.44
MnO	0.11	0.11	0.11	0.06	0.11
MgO	12.33	10.98	12.43	23.54	11.96
CaO	10.79	11.11	10.89	10.24	11.01
Na_2O	0.66	0.69	0.67	0.31	0.67
K_2O	0.26	0.32	0.24	0.08	0.25
P_2O_5	0.33	0.31	0.31	0.53	0.37
Nb (ppm)					
Zr	538	524	477	160	549
Hf	12.9				
Sr	170	180	167	134	176
Rb	6.82	8.82	6.35	1.24	6.10
Li	17.6	16.8	19.3	12.1	18.1
Ba	416	461	393	243	386
Ce	95.4	92.4	82.7	226	120
Nd	62.4	59.3	55.5	155	76.5
Sm	17.3	16.1	15.2	42.2	21.4
Eu	1.93	2.06	1.91	1.68	1.96
Gd	25.2	20.8	18.9	50.8	26.3
Tb					
Dy	22.7	21.4	19.5	44.2	28.6
Er	13.2	12.5	11.1	21.6	15.9
Yb	12.1	11.7	11.0	17.2	14.5
Lu	1.86	1.80	1.59	2.51	2.20

Table 3: Trace element data for 77115. Concentrations in ppb.
From Ebihara et al. (1991).

	Sample 77115,38 (a)	**Sample 77115,74 (b)**
Ir	8.62	7.15
Os	8.19	7.99
Re	0.894	0.715
Au	5.52	4.43
Pd	18.1	10.9
Ni (ppm)	332	287
Sb	3.01	1.99
Ge	512	462
Se	101	104
Te	5.48	6.15
Ag	11.8	1.21
Br		
In	6.61	9.95
Bi	0.46	0.33
Zn (ppm)	2.19	2.34
Cd	4.15	16.3
Tl	3.51	1.83
Rb (ppm)	8.93	7.43
Cs	230	281
U	1480	1500

(a) Fine-grained impact melt breccia matrix
(b) Troctolitic anorthosite clast (?)

Table 4: Rb-Sr composition of 77115,35.
Data from Nakamura et al. (1976).

Separate	Plag.	Olivine	"Pyroxene"
wt (mg)	4.74	4.63	0.80
K (%)	0.078	0.0291	0.1129
Rb (ppm)	1.300	0.700	4.465
Sr (ppm)	243.6	19.6	32.81
$^{87}Rb/^{86}Sr$	0.01543	0.1033	0.3942
$^{87}Sr/^{86}Sr$	0.70002 ± 4	0.70491 ± 6	0.72000 ± 11

Table 5: U-Th-Pb for 77115.
From Nunes et al. (1974).

Split	77115,35
wt (mg)	192.4
U (ppm)	1.453
Th (ppm)	5.436
Pb (ppm)	3.116
$^{232}Th/^{238}U$	3.87
$^{238}U/^{204}Pb$	2415

77135
Vesicular Poikilitic Impact Melt Rock
337.4 g, 10.3 x 8.0 x 4.0 cm

INTRODUCTION

Sample 77135 was sampled as "green-grey breccia" from the boulder at Station 7 *(see the section on the Station 7 Boulder, page 235)*. It is similar in texture and composition to 76015 and other rocks from the boulders on the North Massif (Chao et al., 1975, and Winzer et al., 1975). The probable origin of impact melt breccias has been explained by Simonds (1975) and Onorato et al. (1976). However, members of the international consortium were impressed with arguments that this rock may have an igneous origin (see for example Chao and Minkin, 1974).

Sample 77135 is a vesicular, grey, fragment-laden, fine-grained, crystalline-matrix breccia (Minkin et al., 1978). It has two parts: a larger, highly vesicular part and a smaller, less vesicular, finer-grained part (Figs. 1-3). The highly vesicular part includes clasts of recrystallized troctolitic anorthosite. Major clasts present in the less vesicular part include recrystallized troctolitic breccia. 77135 is stratigraphically the youngest lithology on the Station 7 Boulder, and this seems to be confirmed by age dating.

PETROGRAPHY

Chao et al. (1974), Bence et al. (1974), Chao and Minkin (1975), and McGee et al. (1980) have provided descriptions of 77135. Sample 77135 contains two textually distinct fragment-laden melt rock units (seen in Fig. 3): a coarser-grained matrix fraction that contains vesicles 100-500 μm in diameter and a finer-grained matrix fraction that contains 50-150 μm vesicles. Bence et al. (1974) describe the texture as poikiloblastic, while members of the international consortium (Minkin et al., 1978) refer to it as "fragment-

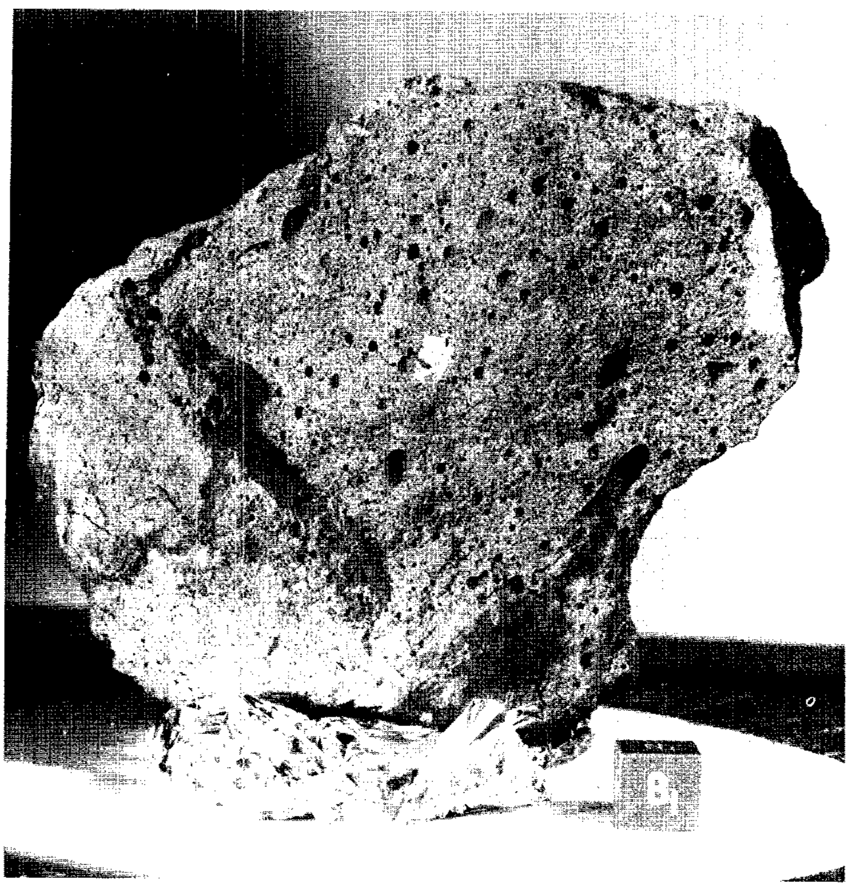


Figure 1: Photograph of 77135, illustrating vesicles and clasts. Cube is 1 cm. S72-56391.

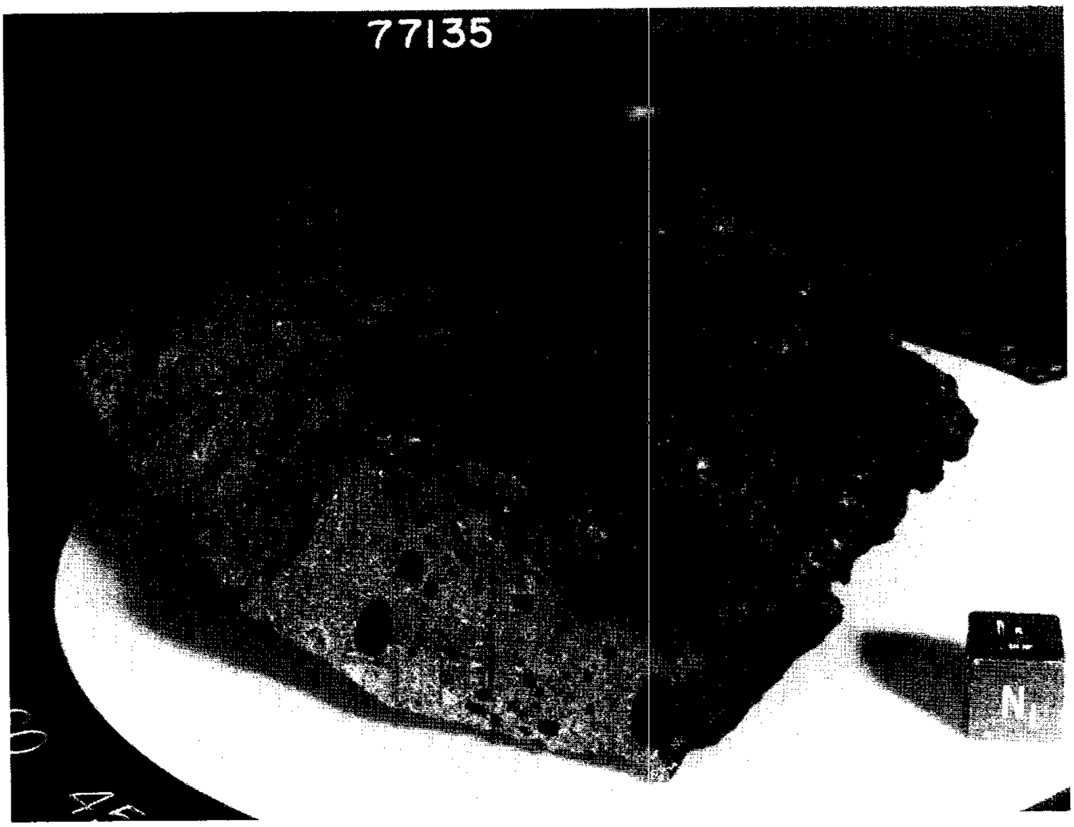


Figure 2: Photograph of a piece of 77135 showing dark patina. Cube is 1 cm. S72-56387.

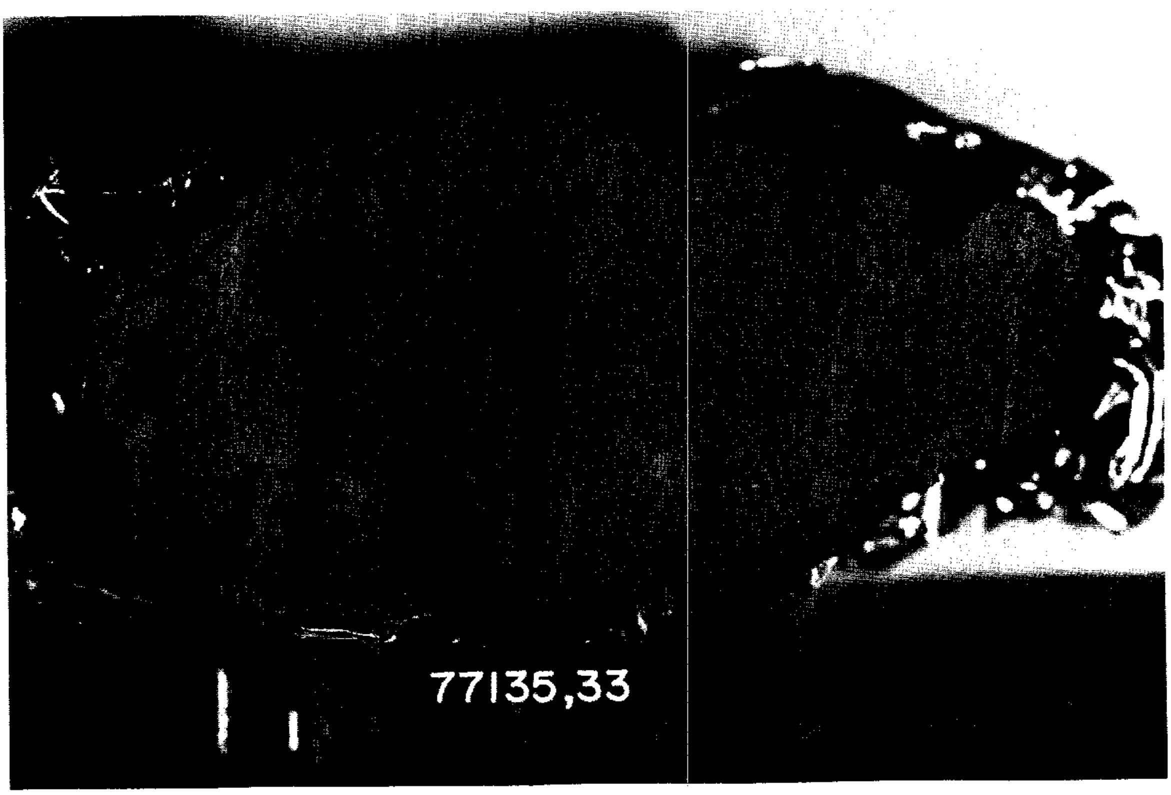


Figure 3: Photograph of slab surface of 77135. S73-34469.

laden, pigeonite basalt." Mineral fragments, mostly plagioclase and olivine, are more abundant in the coarser fraction. The matrix of the coarser fraction consists predominantly of poikilitic pyroxene (mostly pigeonite with minor augite) enclosing subhedral to euhedral plagioclase (Fig. 4). Borders between the pyroxene oikocrysts contain granular olivine, ilmenite plates and rods, and mesostasis. The pyroxene oikocrysts generally are 200-600 µm in size, but some oikocrysts are larger than 1 mm. The finer fraction commonly surrounds or is adjacent to large lithic clasts. The matrix of the finer fraction also consists predominantly of poikilitic pyroxenes (75-200 µm) enclosing plagioclase. Plagioclase grains are finer and more irregular than in the coarser fraction. Intergrowths of rounded, small (<20 µm) olivine grains and irregular plagioclase grains form aggregates of approximately the same size as the pyroxene oikocrysts. Plates and rods of ilmenite mark the borders between the oikocrysts and olivine-plagioclase intergrowths.

Chao and Minkin (1975) calculate the CIPW norm as 53% plagioclase, 31% pyroxene, 13% olivine, and 3% ilmenite. Vaniman and Papike (1979) give the mode of the matrix as 41.1% plagioclase, 30% pyroxene, 15% olivine, and 1.4% ilmenite (with 6.2% plagioclase and 2% pyroxene clasts). Plagioclase in the matrix occurs in two distinct morphological types: as small, sharply defined laths or elongated platy inclusions (An_{91}) in the poikilitic pyroxene, and as stubby laths and anhedral grains associated with granular olivine grains (An_{89}). The dominant pyroxene in the matrix is pigeonite ($Wo_{5-12}En_{67-76}Fs_{19-21}$). Augite is minor. The olivine occurs both as rounded inclusions in the pigeonite (Fo_{66-79}) and as irregular grains associated with the anhedral plagioclase (Fo_{64-72}).

The poikilitic texture of 77135 is the result of enhanced growth of pyroxene and ilmenite enclosing smaller grains of feldspar and olivine. Olivine may also enclose feldspar laths. Simonds et al. (1973) suggest that poikilitic texture is a result of two-stage cooling: initial rapid cooling near the coetectic with nucleation of feldspar and olivine at many foci, followed by slower cooling and crystallization at the point where pyroxene saturation is reached, allowing the growth of large pyroxene grains encompassing the previous crystals. Ryder and Bower (1976) and Lofgren (1977) suggest that nucleation effects (e.g., many nucleation sites) are important in the origin of this texture.

Storey et al. (1974) and Ford (1976) have studied 77135 experimentally. Storey et al. have concluded that 77135 would not be a liquid at less than 1280 °C, 1 atmosphere pressure.

Note: This sample was chosen as part of the "suite" of reference samples for the Basaltic Volcanism Study. It was considered a "highland" basalt even though it had a texture of an impact melt! Its apparent importance is that its composition is very near the coetectic of the low-pressure phase diagram of Walker et al. (1973).

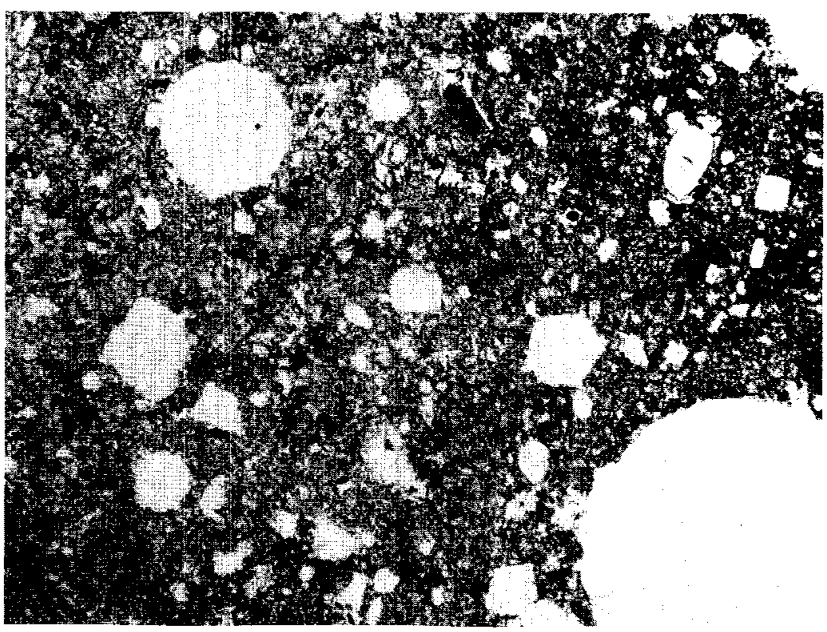


Figure 4: Photomicrograph of 77135,7, showing vesicles and the micropoikilitic texture of the matrix. Field of view is 3 x 5 mm.

MINERAL CHEMISTRY

The composition of minerals in 77135 is given in Bence et al. (1974), Chao and Minkin (1974), Vaniman and Papike (1980), and McGee et al. (1980) (Figs. 5 and 6). McGee et al. have studied the microstructures in the pyroxenes from the different lithologies of the Station 7 Boulder, including 77135. Steele et al. (1980) have analyzed the plagioclase by ion probe. Smith et al. (1980) and Ryder (1992) have analyzed olivine, and Engelhardt (1979) has studied the ilmenite in 77135. Hewins and Goldstein (1975) report Ni-rich metal grains in a clast in 77135.

WHOLE-ROCK CHEMISTRY

Winzer et al. (1974 and 1977), Rhodes et al. (1974), and Hubbard et al. (1974) have analyzed 77135 (Tables 1 and 2 and Fig. 7). Higuchi and Morgan (1975) and Morgan et al. (1974) have measured the trace siderophile and volatile element contents of 77135 (Table 3). None of the clasts was found to have low Ir.

Gibson and Moore (1974) report sulfur abundances, and Gibson et al. (1987) reported the hydrogen content.

SIGNIFICANT CLASTS

Winzer et al. (1974) present trace element data (Table 2, Fig. 7) for two pronounced clasts in 77135 ("troctolite" clast 77135,52 and "olivine-rich" clast 77135,57). The numbering and original distribution of splits of these two clasts are given in Butler and Dealing (1974). Chao et al. (1974) give petrographic descriptions and mineral analyses of these xenoliths. Minkin et al. (1978) also discuss the clast types in 77135, but it is sometimes difficult to tell which data are from which clast.

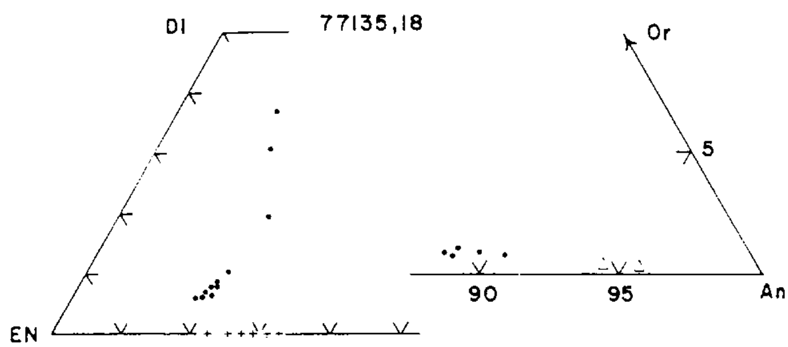


Figure 5: Pyroxene diagram for the matrix of 77135. From Bence et al. (1974).

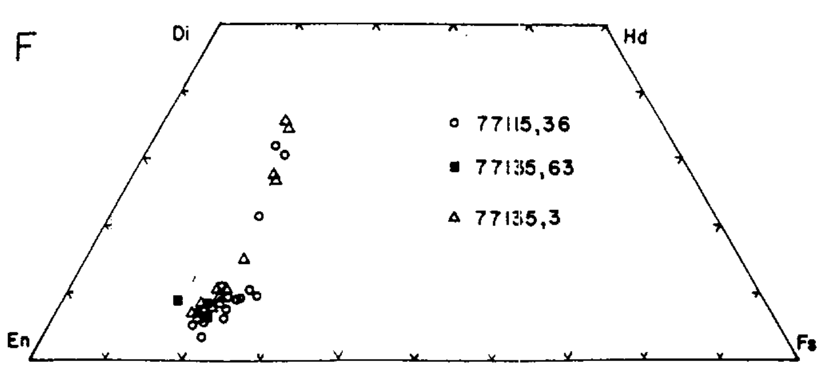


Figure 6: Pyroxene diagram for 77135 compared with 77115. From McGee et al. (1980).

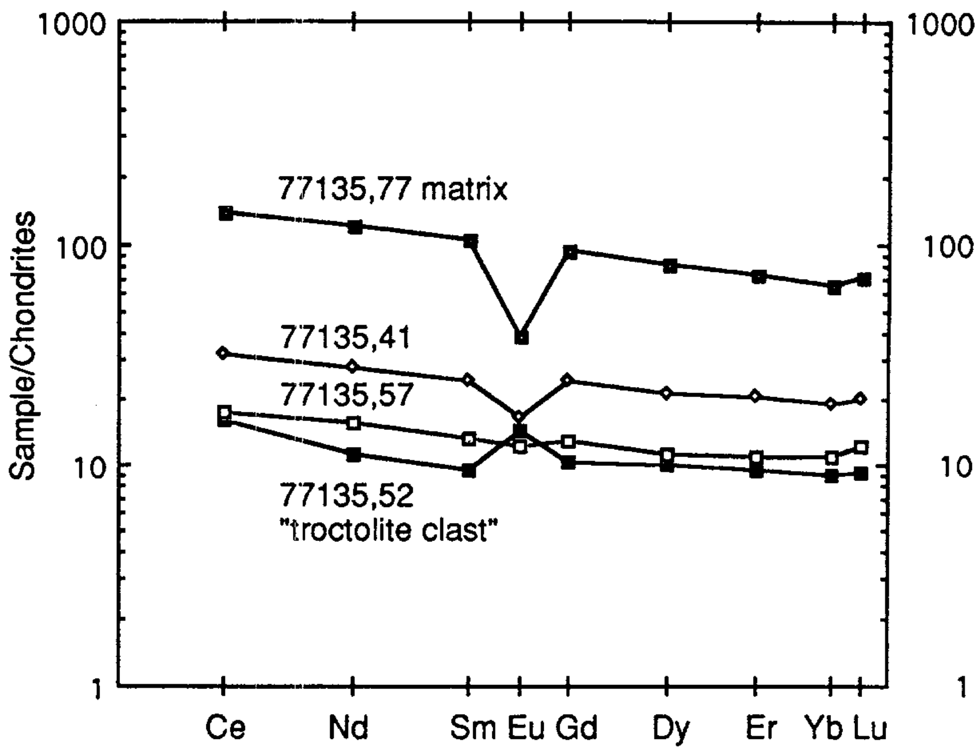


Figure 7: Normalized rare earth element diagram for the matrix and selected clasts in 77135. Data from Winzer et al. (1977) and Hubbard et al. (1974).

Clast 1 (the "olivine-rich" clast ,57) was found to have very high Ir by Higuchi et al. (1975). Nunes et al. (1974) determined a Rb-Sr internal isochron of 3.89 ± 0.08 b.y. for clast 1 (Fig. 8) and Stettler et al. (1978) dated clast 1 at 3.88 ± 0.05 b.y. (Fig. 9) by the Ar-Ar plateau technique.

Clast 2 (the "troctolite" clast ,52) was also studied by Morgan et al. (1974), who again found high Ir. Stettler et al. (1974) dated a split (,51) of this clast at 3.99 ± 0.02 b.y. (Fig. 10).

RADIOGENIC ISOTOPES

Turner and Cadogan (1975) found that 77135 gave a very poor Ar release pattern, preventing an accurate age determination. Stettler et al. (1974) determined ^{39}Ar-^{40}Ar ages of 3.83 ± 0.04 b.y. and 3.78 ± 0.08 b.y. for the vesicular matrix and 3.99 ± 0.02 b.y. and 4.00 ± 0.03 b.y. for the troctolitic clast in 77135 (Figs. 9, 10, and 11). Stettler et al. (1975) report an age of 3.90 ± 0.03 b.y. for a matrix sample and an olivine-rich clast (,57). Stettler et al. (1978) determined ages of 3.88 ± 0.05 b.y. and 3.87 ± 0.04 b.y. for the recrystallized clast 1 (Fig. 9) and concluded that the cooling age of the green-grey breccia was 3.89 ± 0.04 b.y. This is the same age as determined for 77115 by the same laboratory.

Nunes et al. (1974) report a Rb-Sr internal isochron age of 3.89 ± 0.08 b.y. for clast 1 (,57) of 77135 (Fig. 8). Nyquist et al. (1974) report Rb-Sr data for the matrix of 77135 (Table 4) and note that the Rb-Sr systematics for "noritic breccias" at Apollo 17 are probably partially reset by the Serenitatus impact event (Fig. 12). Nakamura et al. (1976) determined an apparent age of 4.14 ± 0.08 b.y. (Fig. 13), but they surmise that this "isochron" is a mixing line between partially reset old plagioclase xenoliths and the young matrix (Table 5). In this case, no age significance should be given to this mixing line.

Nunes et al. (1974) report U-Th-Pb data for 77135 (Table 6).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Turner and Cadogan (1975) determined an exposure age of 23 m.y., Crozaz et al. (1974) determined an age of 28.6 m.y., and Stettler et al. (1974) determined an age of 28.5 and 29.6 m.y. Eberhardt et al. (1975) determined 31.8 ± 1.6 m.y. by ^{81}Kr-Kr and 20 ± 2 m.y. by ^{37}Ar-Ar. The Ar exposure age is sensitive to

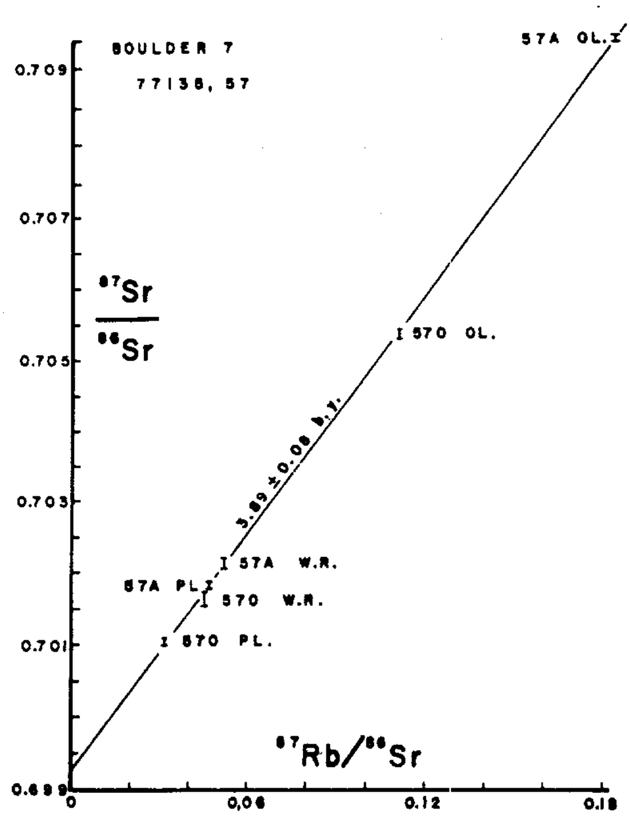


Figure 8: Rb-Sr internal isochron of an olivine-rich clast (,57) in 77135. From Nunes et al. (1974).

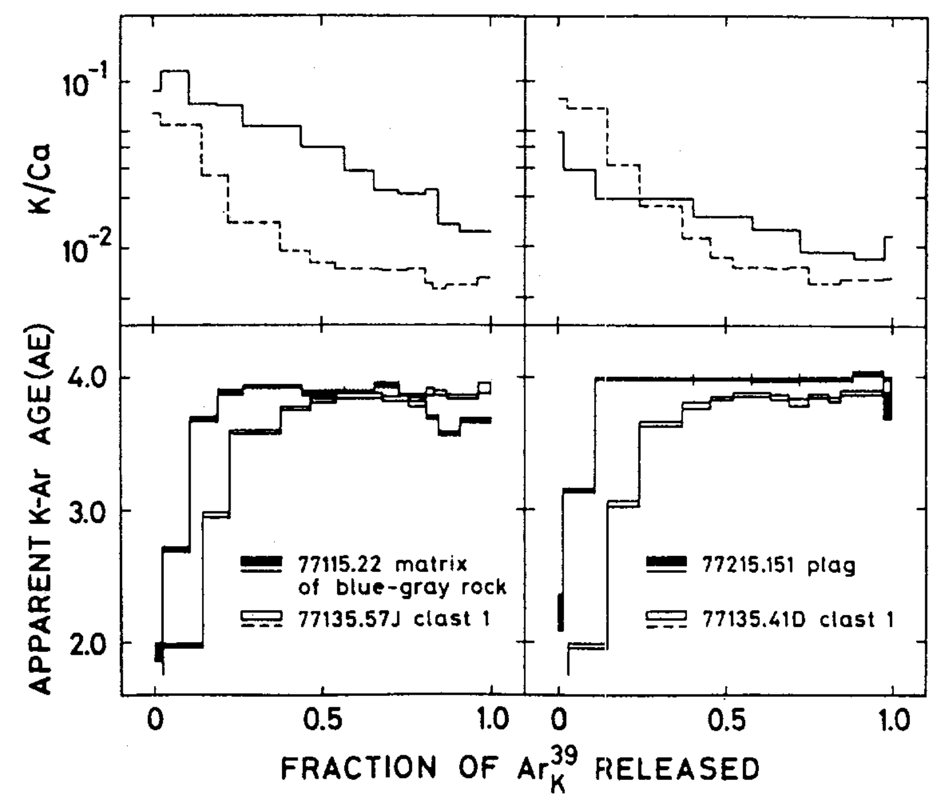


Figure 9: ^{39}Ar-^{40}Ar temperature release pattern for 77135 clast 1 (,57). From Stettler et al. (1978).

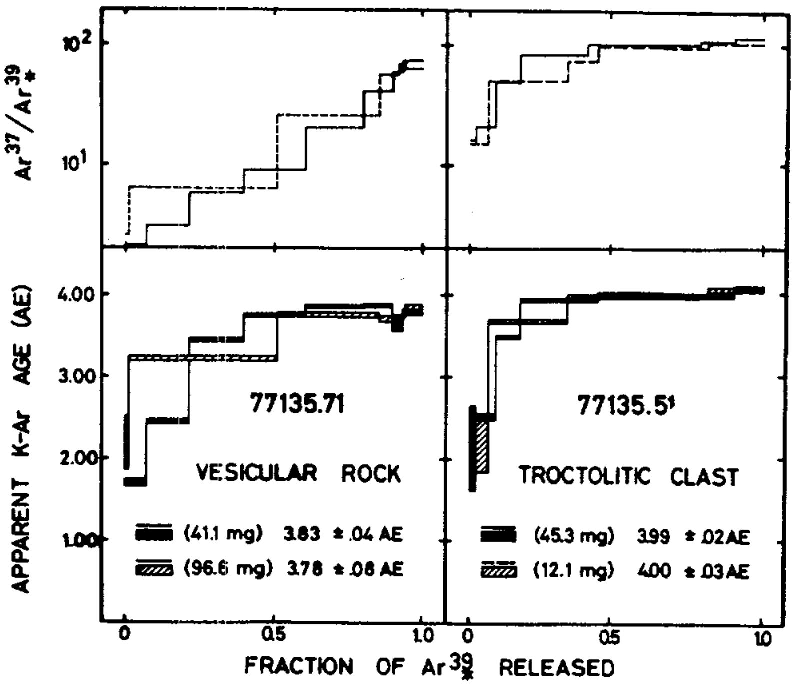


Figure 10: ^{39}Ar-^{40}Ar temperature release patterns for 77135 clast 2 (,51) and vesicular matrix. From Stettler et al. (1974).

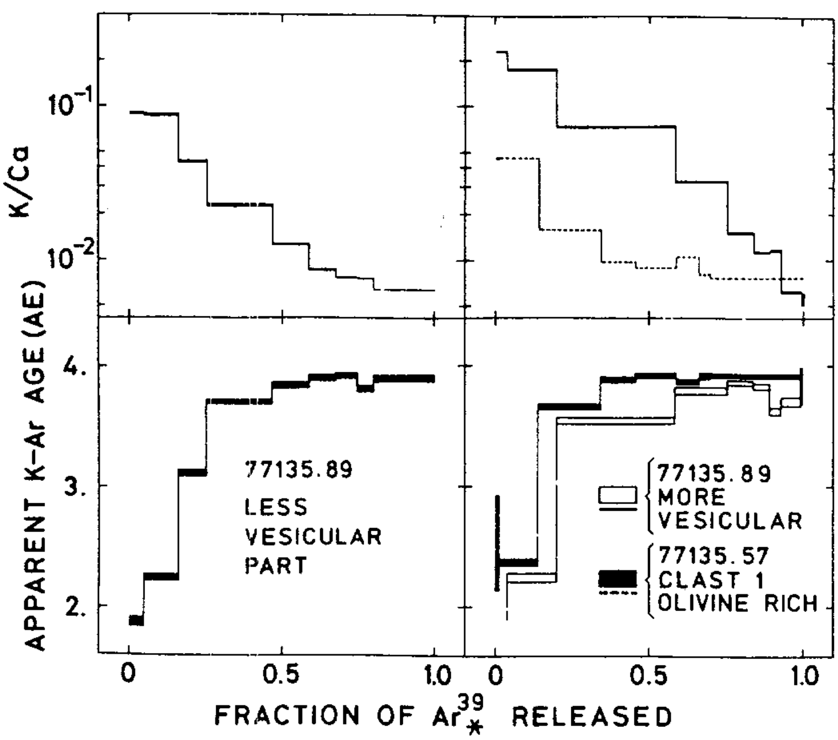


Figure 11: ^{39}Ar-^{40}Ar temperature release patterns for 77135 vesicular matrix. From Stettler et al. (1975).

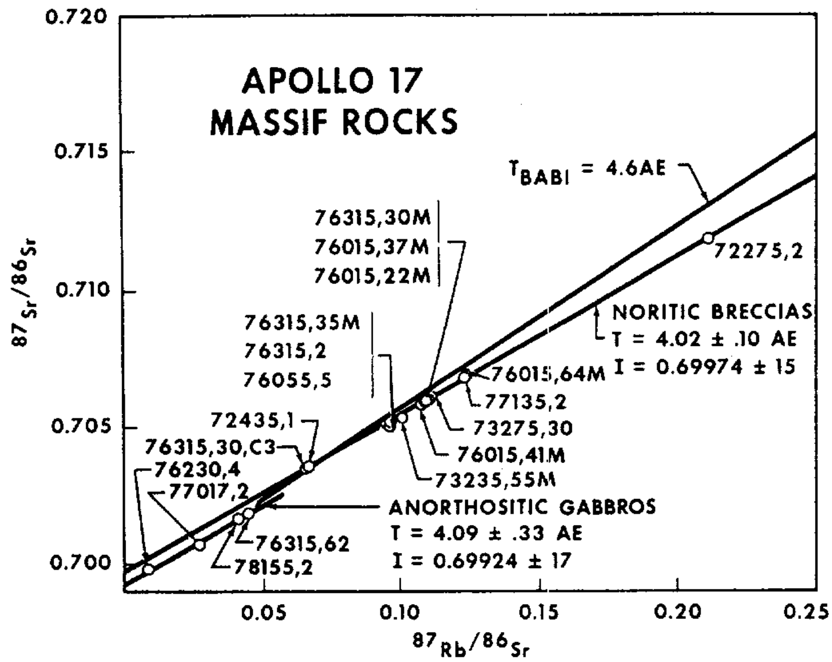


Figure 12: Whole-rock isochron for noritic breccias from Apollo 17, including 77135. From Nyquist et al. (1974).

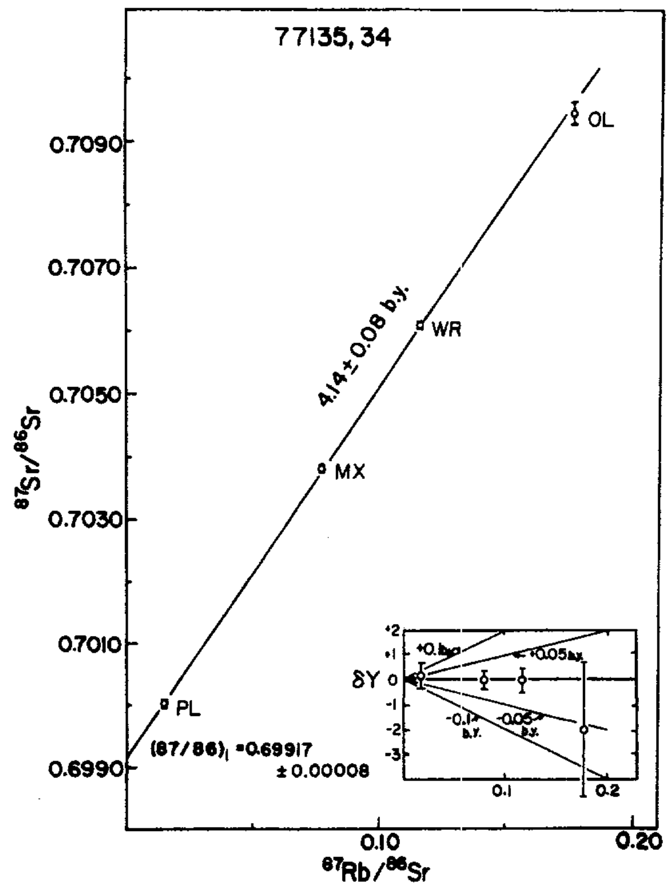


Figure 13: Apparent Rb-Sr internal "isochron," or mixing line, for the 77135 matrix, including small plagioclase xenoliths. No significance should be given to this "age" (see discussion). Figure from Nakamura et al. (1976).

shielding by part of the boulder, whereas the Kr exposure age is not. Eugster et al. (1984) have also discussed the exposure age of 77135.

Some of the Apollo 17 samples (including 77135) provided a unique opportunity to study the energy spectrum (and potential angular anisotropy) of the incident proton flux from the August 1972 solar flare (Rancitelli et al., 1974; Keith et al., 1974). Table 7 compares the induced activity of 77135 with other samples of Apollo 17 (see also table for 76215). Yokoyama et al. (1974) discussed the cosmogenic isotopes.

MAGNETIC STUDIES

77135 has been used for numerous studies of the magnetic properties of an old, well-dated lunar rock. Cisowski et al. (1983) have determined the thermal remanent magnetization of 77135. Nagata (1975) has reported the intensity of saturation magnetization for 77135. Pierce et al. (1974) and Brecher (1975) have studied the direction of magnetization, and Brecher (1977) has discussed apparent alignment with petrofabric. Hale et al. (1978) have used microwave heating to improve demagnetization experiments (Fig. 15).

Brecher (1975) has determined the Mössbauer spectra of 77135 (Fig. 14).

SURFACE STUDIES

Adams and Charette (1975) have determined the spectral reflectance of 77135 (Fig. 16). Fechtig et al. (1974) have studied the microcraters on the surface of 77135.

PROCESSING

The initial processing and distribution of 77135 is outlined in Butler and Dealing (1974). It was studied by the international consortium led by E.C.T. Chao (Minkin et al., 1978). Detailed description of the splits is given in open-file report 78-511.

The largest remaining piece of 77135 weighs 234 g. There have been 34 thin sections prepared.

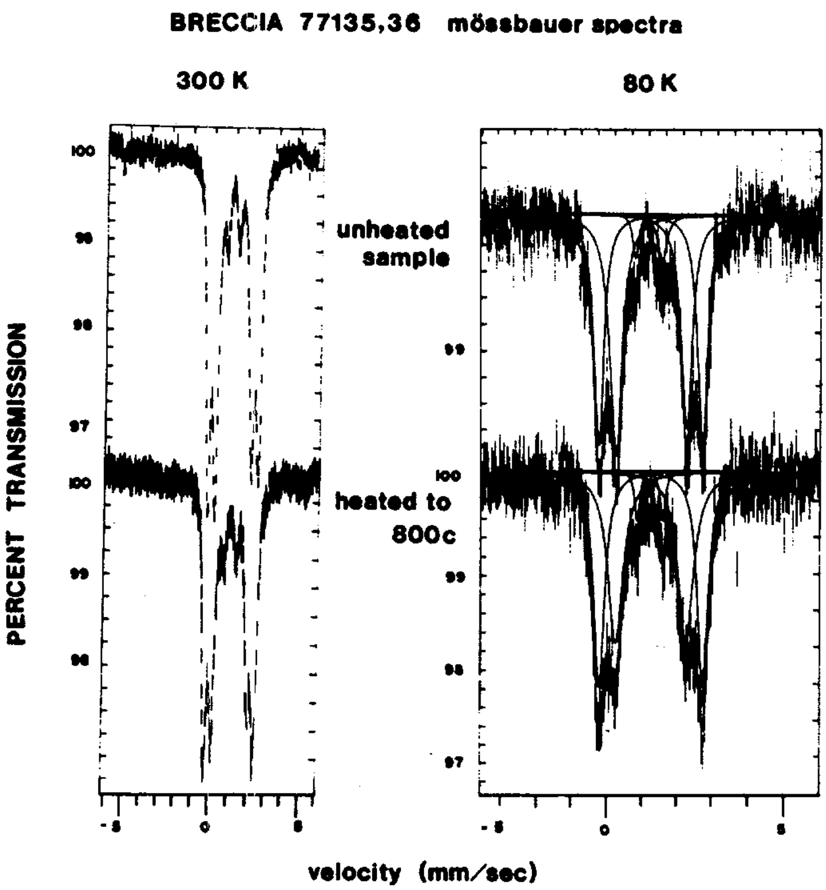


Figure 14: Mössbauer spectra for 77135. From Brecher (1975).

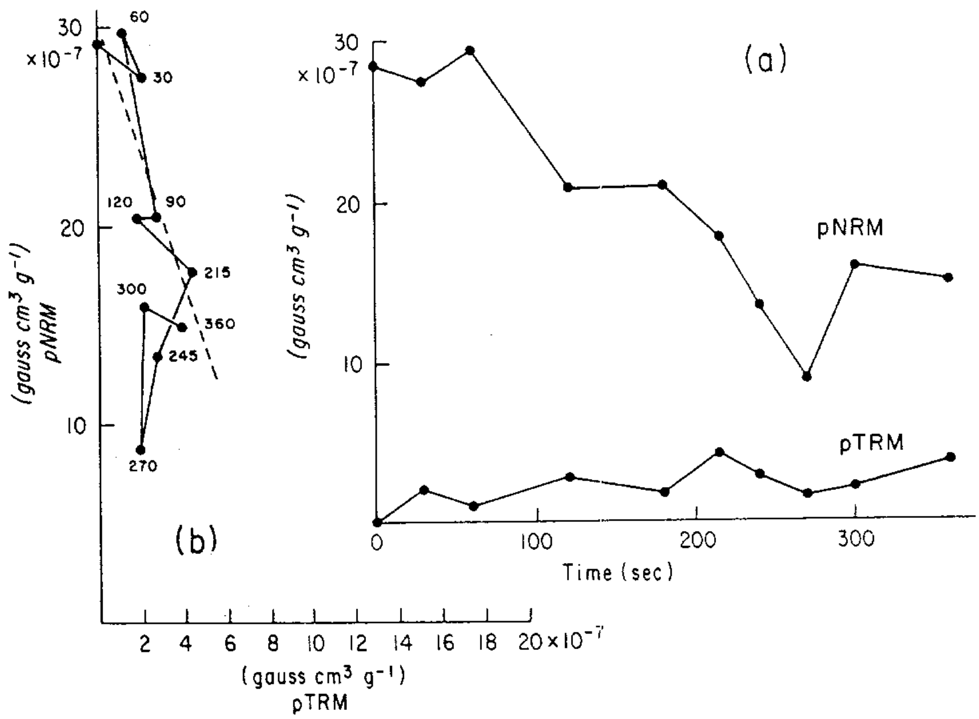


Figure 15: Demagnetization curve for 77135. From Hale et al. (1978).

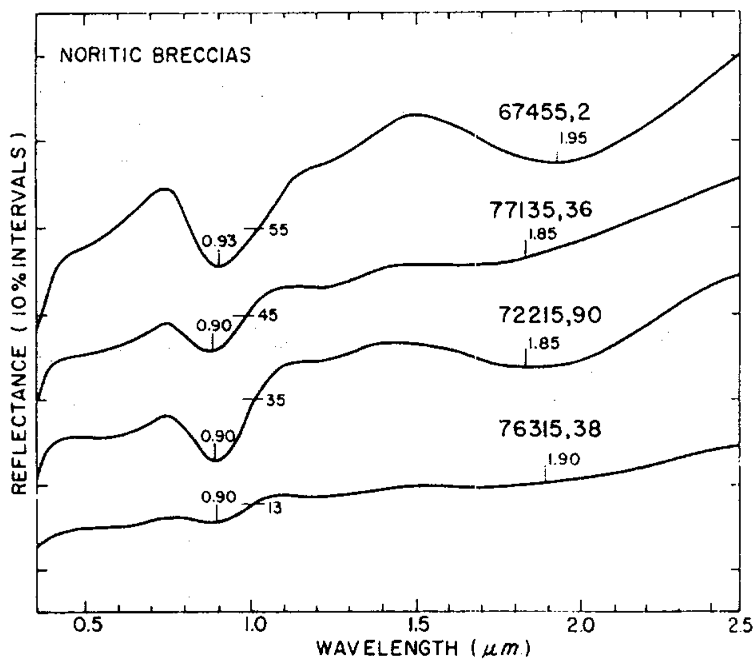


Figure 16: Spectral reflectance of 77135. From Adams and Charette (1975).

Table 1: Whole-rock chemistry of 77135.
a) Rhodes et al. (1974); b) LSPET (1973); c) Hubbard et al. (1974);
d) Wiesmann and Hubbard (1975); e) Winzer et al. (1977)

Split Technique	,2 (b, c, d) XRF, ID	,5 (a) XRF	,82 (e) AA, IDMS matrix	,92 (e) AA, IDMS matrix
SiO_2 (wt%)	46.13	46.17	47.5	46.3
TiO_2	1.54	1.53	1.45	1.31
Al_2O_3	18.01	17.83	17.18	19.82
Cr_2O_3	0.20	0.21	0.18	0.16
FeO	9.11	9.14	9.01	8.28
MnO	0.13	0.13	0.11	0.10
MgO	12.63	12.39	12.66	11.78
CaO	11.03	11.08	10.91	11.74
Na_2O	0.53	0.69	0.66	0.56
K_2O	0.30	0.27	0.41	0.21
P_2O_5	0.28	0.30	0.29	0.21
S	0.08	0.07		
Nb (ppm)	33	33		
Zr	494	508		
U	1.50			
Th	5.60			
Y	107	111		
Sr	172	174	177	171
Rb	7.32	6.2		
Li	19.3			
Ba	337		360	294
Zn	4	4		
Ni	110	62		
La	32.1			
Ce	81.2		82.8	59.2
Nd	51.6		53.2	41.1
Sm	14.6		14.8	11.2
Eu	1.99		1.97	1.80
Gd	18.5			
Dy	19.1		18.3	15.1
Er	11.4		(1.4)	8.16
Yb	10.5		10.6	8.11
Lu	1.55		1.18	1.17

Table 2: Whole-rock and clast chemistry of 77135.
a) Winzer et al. (1974); b) Winzer et al. (1977)

Split Technique	,66 (a) AA, IDMS matrix	,77 (a) AA, IDMS matrix	,41 (a) AA, IDMS Ol-Pl breccia	,52 (a, b) AA, IDMS Troctolite	,57 (a) AA, IDMS Ol-rich
SiO_2 (wt%)	45.3	46.3	45.3	44.4	
TiO_2	1.72	1.48	0.43	0.24	
Al_2O_3	18.03	18.39	25.13	27.81	
Cr_2O_3	0.18	0.18	0.13	0.09	
FeO	9.56	9.48	5.98	4.19	
MnO	0.11	0.11	0.06	0.05	
MgO	13.38	12.19	8.59	7.96	
CaO	10.64	10.96	13.95	15.09	
Na_2O	0.61	0.65	0.40	0.41	
K_2O	0.22	0.23	0.09	0.07	
P_2O_5	0.28	0.28	0.10	0.03	
Nb (ppm)					
Zr	308	643	146	62.1	71.8
Sr	169	181	147	147	87.4
Rb	5.99	6.63	2.67	2.00	1.18
Li	18.4	19	10.2	10.1	10.6
Ba	343	359	96.6	63.3	60.8
La					
Ce	81.2	83.3	19.4	9.63	10.5
Nd	52.2	54.6	12.7	4.99	7.14
Sm	14.7	15.4	3.62	1.41	1.96
Eu	2.02	2.16	0.919	0.80	0.687
Gd	18.6	18.6	4.73	2.03	2.51
Dy	19.3	20.0	5.07	–	2.69
Er	11.4	11.6	3.24	1.50	–
Yb	–	10.6	3.08	1.45	1.79
Lu	1.56	1.75	0.481	0.223	0.293

Table 3: Trace element data for 77135. Concentrations in ppb.
From Morgan et al. (1974a) and Higuchi and Morgan (1975a).

	Sample 77135,10	Sample 77135,50	Sample 77135,62	Sample 77135,57	Sample 77135,69
Ir	3.78	7.2	15.1	17.4	10.5
Os					
Re	0.485	0.662	1.42	1.38	1.06
Au	3.57	1.46	4.74	3.09	6.45
Pd					
Ni (ppm)	205	174	412	221	438
Sb	1.21	0.58	0.47	0.778	2.16
Ge	295	50	78	113	618
Se	137	11.3	33	40	144
Te	3.6	1.32	1.1	5	8.84
Ag	1.1	0.38	0.58	0.7	1.2
Br	47	11.6	17.6	35.7	45
In					
Bi	0.18	0.17	0.14	0.25	0.23
Zn (ppm)	2.9	2.6	2.4	2	3.3
Cd	10.5	6.8	3.7	2.4	3.5
Tl	2.6	0.48	0.58	0.8	2.3
Rb (ppm)	6.5	1.8	2.6	3.59	6.1
Cs	270	74	73	95.3	250
U	1390	260	450	590	1380

Table 4: Rb-Sr composition of 77135.
Data from Nyquist et al. (1974).

Sample	77135,2
wt (mg)	52.6
Rb (ppm)	7.32
Sr (ppm)	172.2
$^{87}Rb/^{86}Sr$	0.1230 ± 10
$^{87}Sr/^{86}Sr$	0.70688 ± 7
T_B	4.41 ± 0.08
T_L	4.45 ± 0.08

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

Table 5: Rb-Sr composition of 77135,34.
Data from Nakamura et al. (1976).

Separate	Plag.	Olivine	Whole Rock	Matrix
wt (mg)	4.94	6.36	7.23	5.35
K (%)	0.056	0.028	0.226	0.116
Rb (ppm)	0.911	0.818	6.77	3.77
Sr (ppm)	157.4	13.27	167.5	140.2
$^{87}Rb/^{86}Sr$	0.01547	0.1766	0.1168	0.0777
$^{87}Sr/^{86}Sr$	0.70007 ± 4	0.70943 ± 19	0.70608 ± 3	0.70381 ± 3

Table 6: U-Th-Pb for 77135.
From Nunes et al. (1974).

Split	77135,33	,34	,57A
wt (mg)	133.2	125	122.1
U (ppm)	0.4674	1.390	0.5461
Th (ppm)	1.863	5.224	2.136
Pb (ppm)	0.9713	2.840	1.115
$^{232}Th/^{238}U$	4.12	3.88	4.04
$^{238}U/^{204}Pb$	1387	2755	1191

Table 7: Solar flare induced activity from large solar flare, August 1972.
a) Rancitelli et al. (1974); b) Keith et al. (1974); c) O'Kelley et al. (1974)

	Sample 77135 (a)	**Sample 78135 (b)**	**Sample 78235 (b)**	**Sample 78255 (b)**	**Sample 78597 (c)**
dpm/Kg					
^{26}Al	111 ± 6	42 ± 4	77 ± 7	65 ± 6	48 ± 4
^{22}Na	100 ± 5	74 ± 5	111 ± 8	50 ± 5	33 ± 4
^{54}Mn	21 ± 15	180 ± 20	55 ± 8	10 ± 5	80 ± 10
^{56}Co	66 ± 4	240 ± 20	52 ± 9	30 ± 20	80 ± 20
^{46}Sc	7.2 ± 2.2	76 ± 5	1.4 ± .9	<15	25 ± 10
^{48}V		18 ± 5	<12		
Th (ppm)	5.51	.26	.59	.83	
U (ppm)	1.42	.107	.196	.227	
K (%)		.0525	.049	.059	

77215

Cataclastic Norite

846.4 g; largest piece is 6.5 x 4.5 x 2.5 cm (41 or more pieces)

INTRODUCTION

Sample 77215 was sampled from the large white clast in the Station 7 Boulder *(see the section on the Station 7 Boulder, page 235)*. It was quite friable and broke up into many pieces on the way back from the Moon (Fig. 1). One of the pieces (,19, now ,80 ,81 and ,82) contains the dark dike similar to 77075 (Fig. 2) and other pieces contain black dikelets (similar to 77077). Some pieces have small areas of unbrecciated norite with primary igneous texture (Fig. 3). The large cataclastic "norite" sample may itself contain other clasts of similar igneous material (Fig. 4). Most of the lithic clasts in 77215 have been crushed and fractured, and some have been intensely granulated and stretched or smeared out to form schlieren, so that the relict host rock types are only represented by very small clasts (Chao et al., 1976). This made consortium work very difficult to coordinate because samples representative of the major lithic clasts in 77215 were generally too small for allocation to all consortium members (Minkin et al., 1978). Selected subsamples were therefore assigned to individual consortium participants for analysis on the basis of suitability for their experiments, and the resulting data cannot now be exactly correlated for this sample as a whole (as is sometimes done). In general, the whole sample seems to be one material, but care should be exercised because of the cataclastic nature of the sample.

PETROGRAPHY

Sample 77215 is a pristine norite that has been shocked and crushed in place. It contains lithic fragments of "norite" and apparent "anorthosite" set in a porous mass of fine mineral fragments and thin glass veins (Fig. 5). The modal mineralogy is approximately 41% orthopyroxene and 54% plagioclase with trace amounts of troilite, ilmenite, clino-pyroxene, spinel, silica, K-feldspar, zirconolite, whitlockite, and Fe-Co metal (Table 1). The fragments of "anorthosite" may be plagioclase-rich regions within the original norite (Chao et al., 1976).

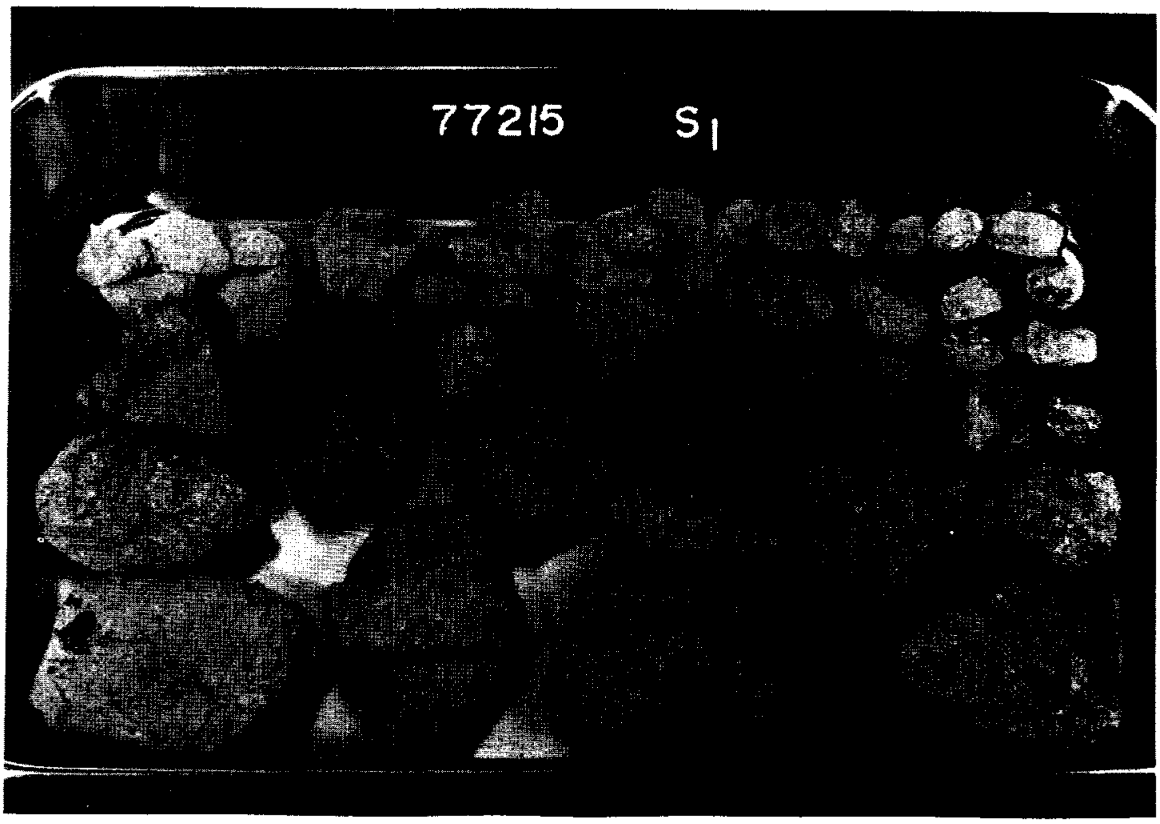


Figure 1: Tray full of 77215. Note that some pieces have "off-white" patina. S73-17778.

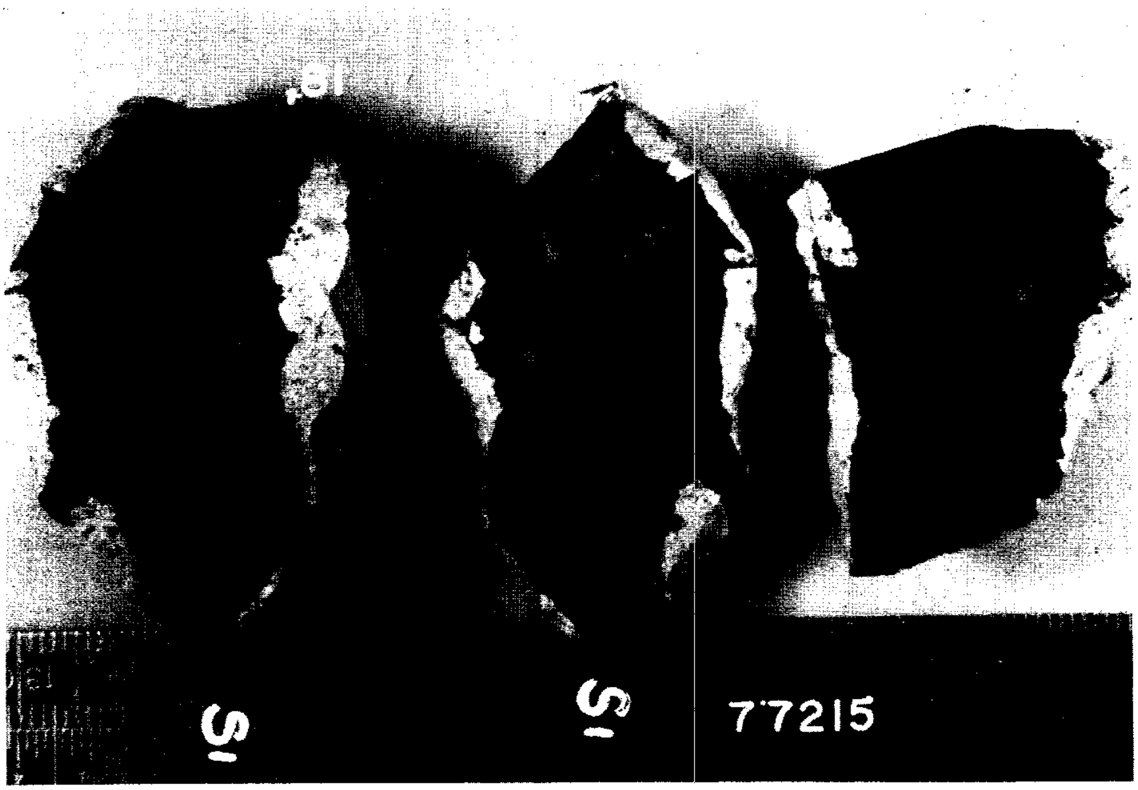


Figure 2: Photograph of sawn surfaces of slab and butt ends of 77215,19. Cube is 1 cm. S75-21992.

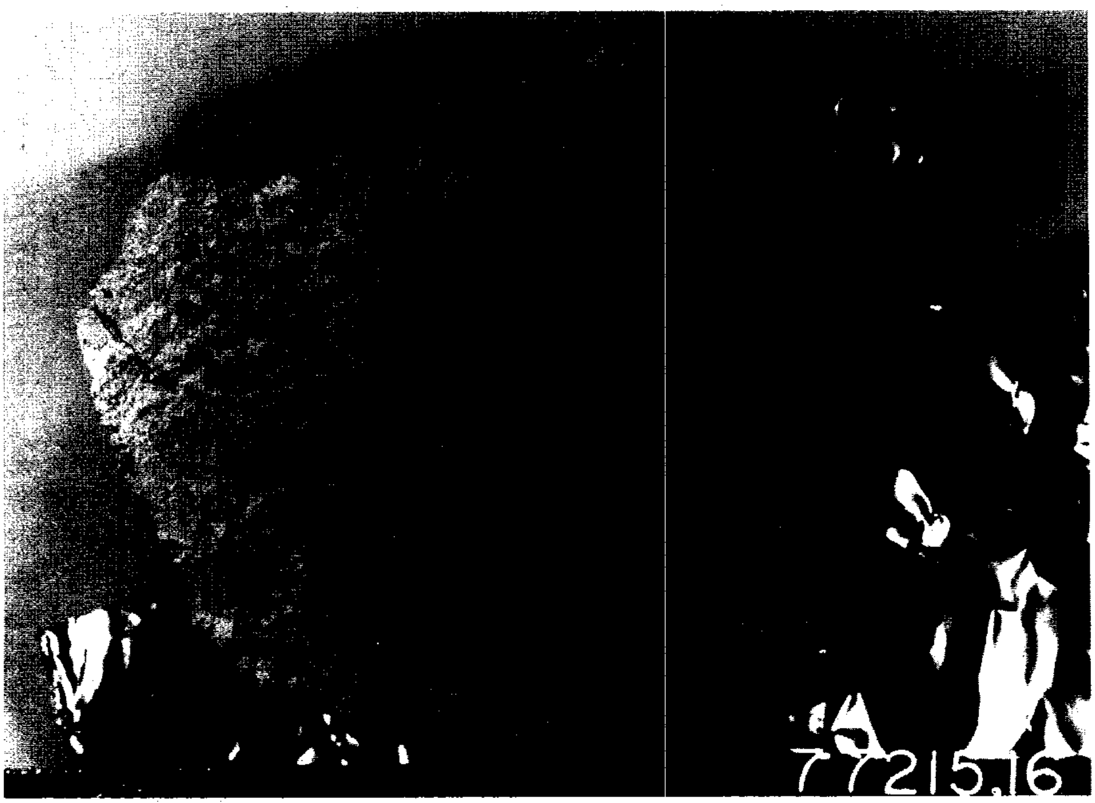


Figure 3: Photograph of 77215,16, showing igneous textures of some regions in the rock. Cube is 1 cm. S83-34595.

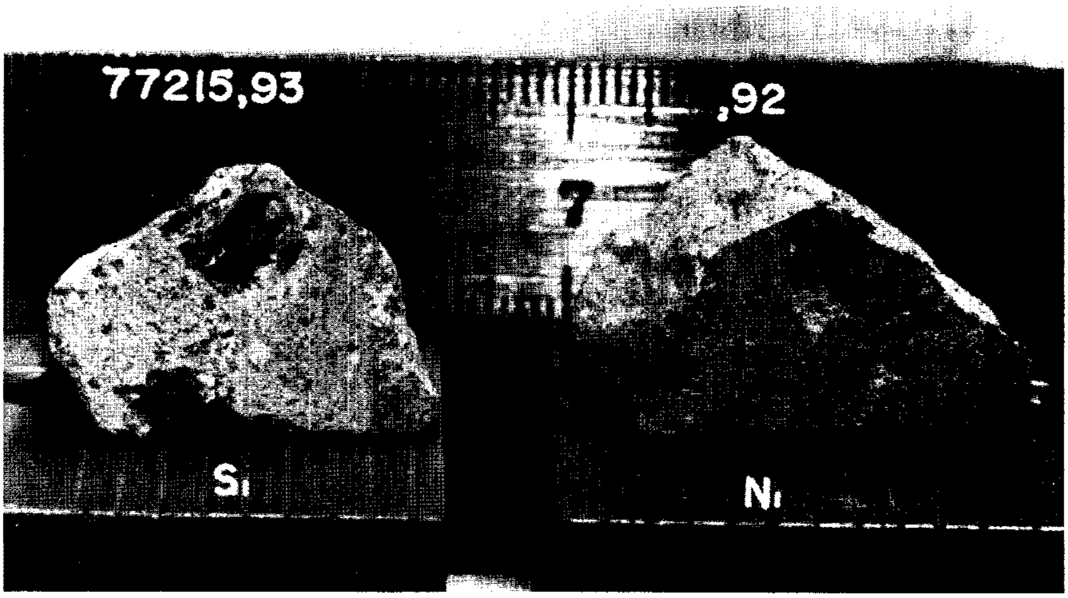


Figure 4: Photograph of saw cut through 77215,92. S75-21980. Scale bar is in cm.

Figure 5: Photomicrograph of thin section 77215,12. Field of view is 4 x 5 mm.

According to Chao et al. (1976), the original uncrushed norite is medium- to coarse-grained (up to 3 mm, with an average of about 1 mm) and has a holocrystalline igneous texture. Its principal assemblage consists of idiomorphic greenish-yellow orthopyroxene and clear to milky white calcic plagioclase. The plagioclase has a narrow compositional range ($An_{88-92}Ab_{11-7}Or_{1}$), mostly An_{90-91}. Plagioclase grains frequently contain small inclusions of K-feldspar ($An_2Ab_1Or_{97}$), silica, and granitic glass. The plagioclase is not chemically zoned and has not been converted to maskelynite by the shock pressure. The orthopyroxene also has a narrow compositional range ($Wo_{3-5}En_{63-68}Fs_{29-32}$). The orthopyroxene in 77215 is notable for having well-developed, yet texturally diverse, augite blebs and lamellae ($Wo_{41-43}En_{44-47}Fs_{12-13}$). Huebner et al. (1975) distinguish these blebs as "worms, planes, hachures, and septa." Within a single orthopyroxene, all augite is in the same optical orientation, but this does not seem to be crystallographically controlled. Augite lamellae are 5-10 μm thick, rarely 30 μm thick. The host and exsolved pyroxenes are optically and chemically homogeneous (Fig. 6).

Pyroxenes in 77215 show some of the features of "inverted pigeonites." Huebner et al. (1975) explain that the misoriented nature of the augite, relative to the host orthopyroxene, is a common feature of pyroxenes that originally crystallized as homogeneous pigeonite crystals at high temperatures. According to Huebner et al., coarse pyroxene exsolution lamellae can form in geologically short periods of time (<30,000 yr.) at elevated temperatures (>300 °C). Huebner et al. argue that such conditions could have been met in the upper levels of the lunar crust during early lunar history as a consequence of the cooling of anorthositic crustal material. According to Huebner et al., the exsolved pyroxenes do not necessarily suggest the deep-seated origin as originally proposed by Chao et al. (1974). Anderson and Lindsley (1982) have carefully calculated the equilibrium temperature of the pyroxene pairs in 77215.

The anorthite, orthopyroxene, and minor augite account for 97.3% of the norite. The rest, 2.7%, consists of mesostasis, with a variety of accessory minerals, that occurs in the interstitial areas between the anorthite and orthopyroxene. K-feldspar with a fine network of thin silica lamellae is a common accessory mineral in these interstitial areas. Clusters of accessory minerals occur in the norite clast and in the brecciated matrix. Fe-Co metal, troilite, ilmenite, chromite, plagioclase (An_{91-92}), orthopyroxene ($Wo_4En_{64-72}Fs_{24-32}$), silica, rare augite, whitlockite, zirconolite, and rare armalcolite occur in these clusters. All these accessory phases are thought to be from the parent norite (Chao et al., 1976).

MINERAL CHEMISTRY

Chao et al. (1974), Huebner et al. (1975), and Chao et al. (1976) report the compositions of the minerals in 77215. The plagioclase and pyroxene are uniform in composition (Fig. 7).

Winzer et al. (1977) report analyses of orthopyroxene and plagioclase mineral separates for the white noritic portion of 77215 (Fig. 8). Papike et al. (1994) have also used the ion probe to determine the REE in orthopyroxene from 77215,203.

WHOLE-ROCK CHEMISTRY

Winzer et al. (1974 and 1977) report analyses of various portions of the 77215 sample, including dikes, glass, and the white noritic material (Table 2 and Fig. 9). The grey glass appears to be melted norite, while the black glass has been injected from the surrounding matrix. Wolf et al. (1979) report the trace siderophile and volatile elements (Table 3). This rock is a pristine norite. James (1994) has also reviewed the siderophile and volatile element composition.

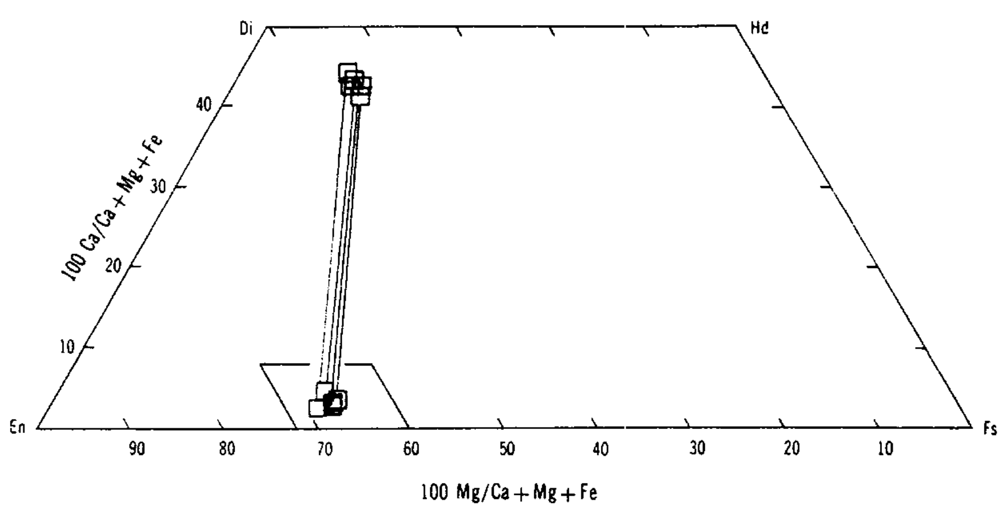


Figure 6: Pyroxene composition for 77215 norite. From Huebner et al. (1975).

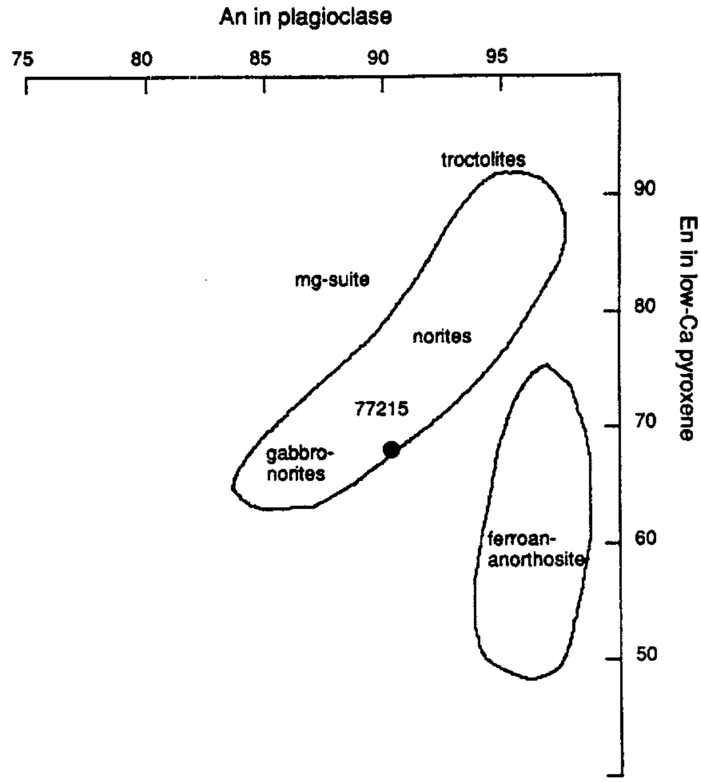


Figure 7: Plagioclase and pyroxene composition of 77215. Fields from James and Flohr (1983).

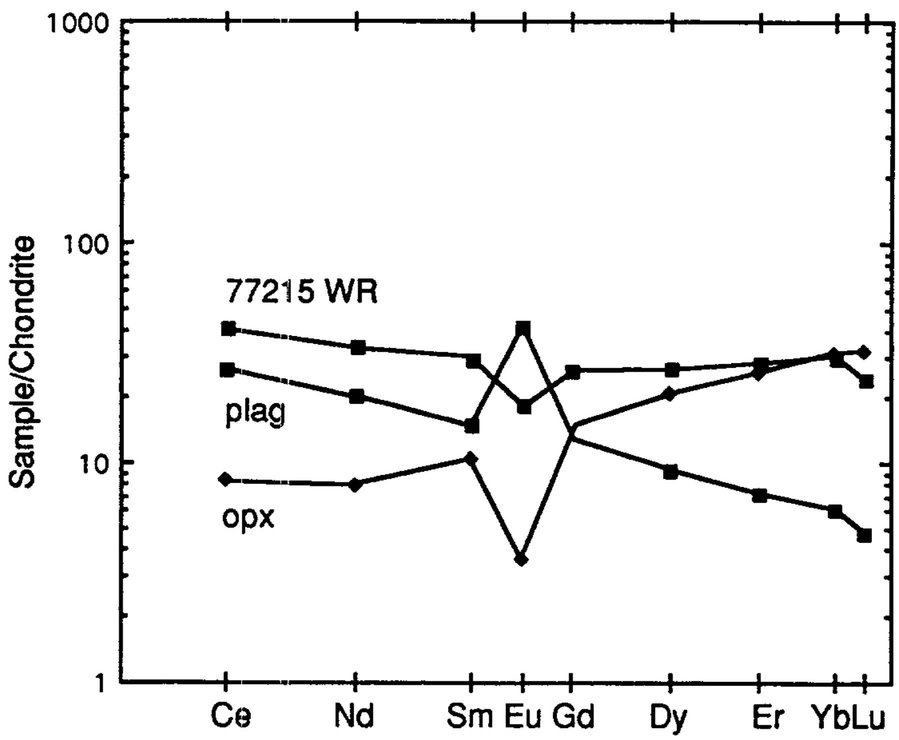


Figure 8: Normalized rare earth element diagram for whole rock and minerals in the noritic portion of 77215. Data from Winzer et al. (1977).

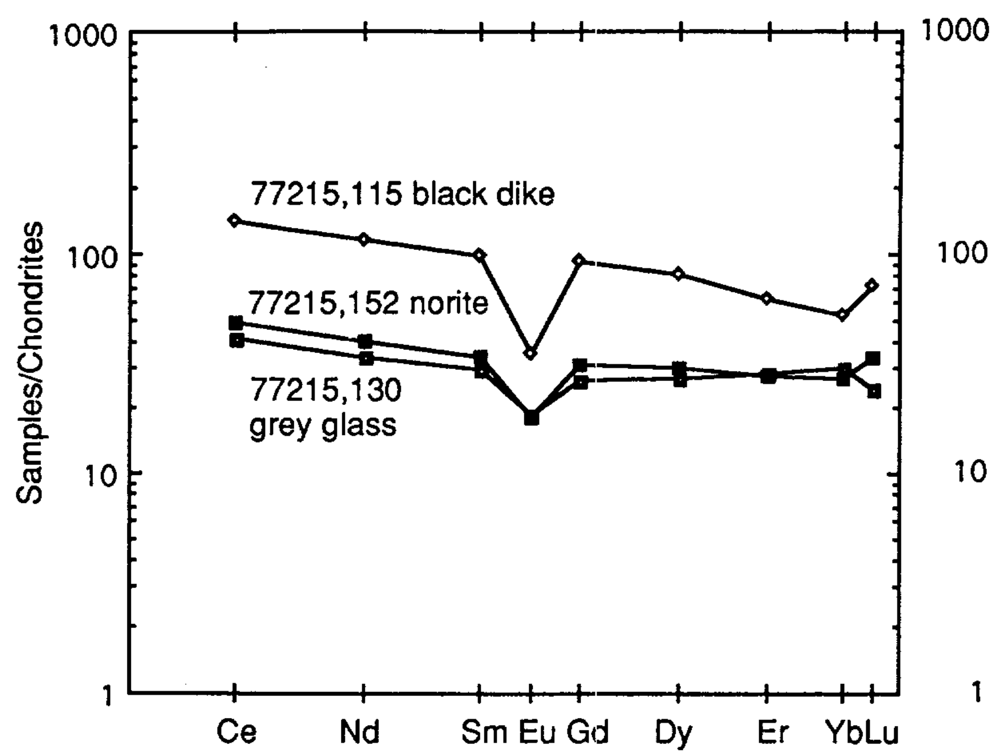


Figure 9: Normalized rare earth element data for portions of 77215. Data from Winzer et al. (1977).

SIGNIFICANT CLASTS

Chao et al. (1976) describe two clasts (1 and 2) of least-shocked norite that they separated from fragment 77215,22 and distributed for age dating.

Chao et al. (1976), Huebner et al. (1975), and Minkin et al. (1978) describe a region (or "clast") within 77215 that has highly magnesian olivine grains (Fo_{83-97}) and calcic plagioclase (An_{90-91}).

Huebner et al. (1975) briefly describe a small clast in thin section 77215,13 that consists entirely of ortho-pyroxene and plagioclase in equal proportions with a subophitic texture. The composition of the pyroxene and plagioclase is the same as for the isolated grains and grain fragments observed elsewhere in the sample. The orthopyroxene within the clast contains the exsolved augite. This norite clast is probably a small sample of the source material for the breccia—a relict that escaped granulation.

RADIOGENIC ISOTOPES

Stettler et al. (1978) separated feldspar from clast 2 (sample ,151) from fragment 77215,22 and obtained a well-defined ^{39}Ar-^{40}Ar plateau age of 3.98 ± 0.03 b.y. (Fig. 10). This confirms the ages of 3.96 to 4.05 b.y. (Fig. 11) reported earlier based on intermediate temperature plateau from samples of crushed matrix material (Stettler et al., 1974).

Nakamura et al. (1976) obtained Rb-Sr and Sm-Nd data (Tables 4 and 5) and internal isochrons of 4.42 ± 0.04 b.y. and 4.37 ± 0.07 b.y. respectively, for the bulk sample 77215,37 (Figs. 12 and 13). This is one of the few pristine samples of the original crust that have been dated!

A thermal event must have heated the noritic breccia at 3.98 b.y. without disturbing the Rb-Sr and Sm-Nd isotopic systems. This could have been the event that intruded the dike material and enclosed the norite clast in the melt sheet represented by the boulder matrix (samples 77115 and 77135), or it could have been mild heating throughout the time span 3.9 to 4.4 b.y.

Nunes et al. (1974) have also reported U-Th-Pb data for 77215 (Table 6). This system has been disturbed.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Stettler et al. (1974) determined an exposure age of 27.2 m.y.

PROCESSING

The initial processing and distribution of 77215 are outlined in Butler and Dealing (1974). It was studied by the international consortium led by E.C.T. Chao (see final report by Minkin et al., 1978). Some notes on the distribution of 77215 are given in the appendix to Chao et al. (1976). Detailed description of the splits is given in open-file report 78-511.

The largest pieces of 77215 that remain unprocessed are: ,18 (103 g); ,17 (101 g); ,21 (69 g); and ,22 (60 g). Twenty-five thin sections have been prepared.

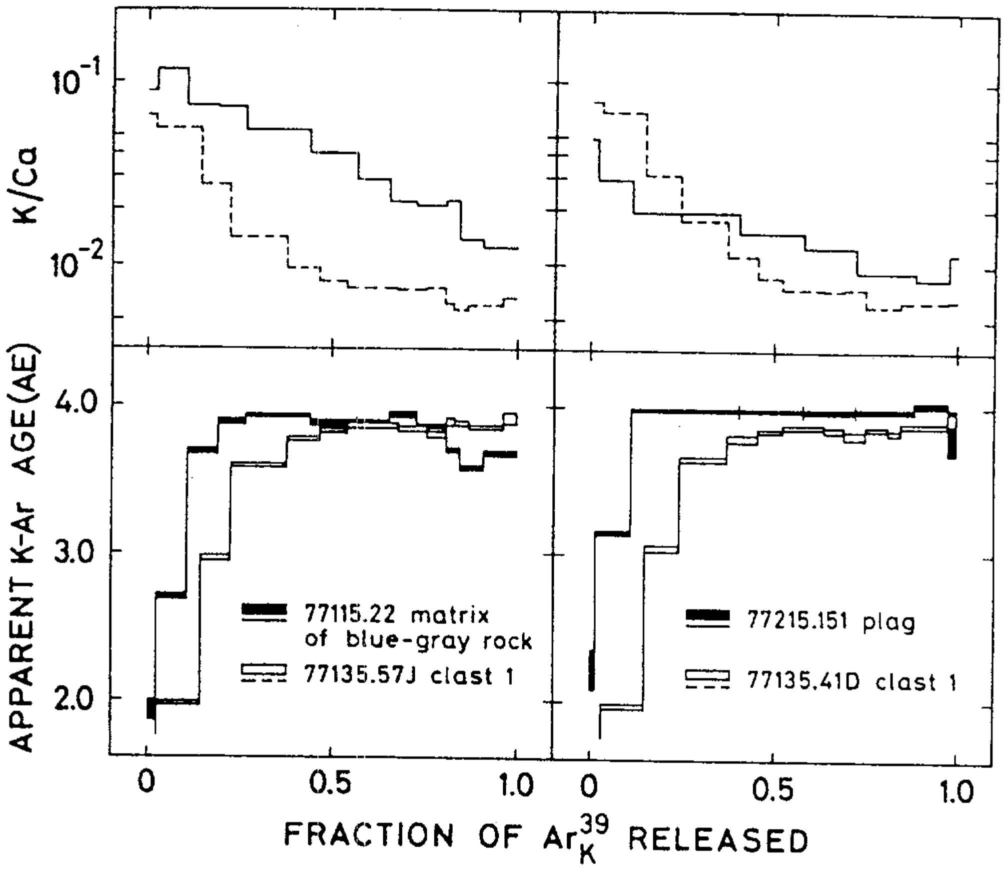


Figure 10: ^{39}Ar-^{40}Ar temperature release pattern for plagioclase from a norite clast in 77215. From Stettler et al. (1978).

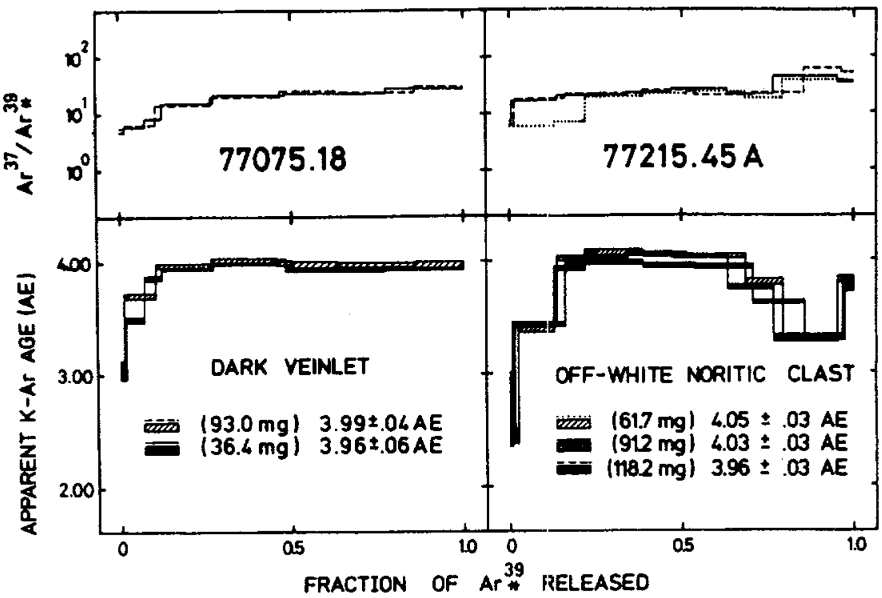


Figure 11: ^{39}Ar-^{40}Ar temperature release pattern for composite noritic material from 77215. From Stettler et al. (1974).

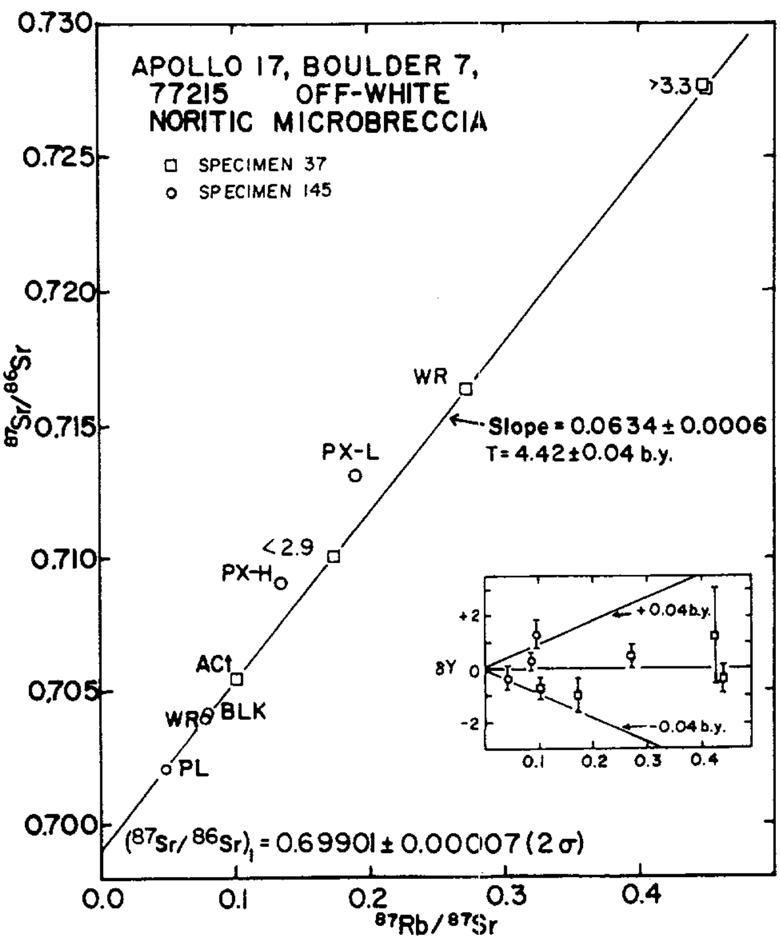


Figure 12: Rb-Sr internal isochron for 77215. From Nakamura et al. (1976).

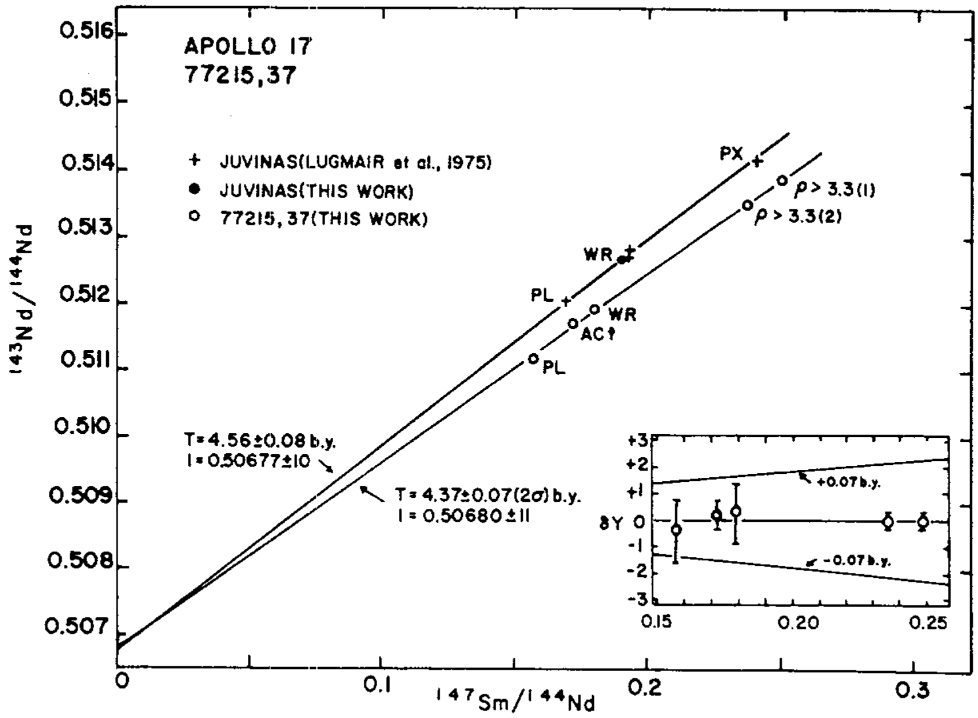


Figure 13: Sm-Nd internal isochron for 77215. From Nakamura et al. (1976).

Table 1: Fragment population of 77215,138.
From Chao et al. (1976).

Fragment type	Vol. %
Norite	8.3
"Anorthosite"	10.2
Gray glass	6.4
Mineral clasts	75.1
Total	100.0

Mineral clasts	>30 µm	<30 µm	Total*	Recalculated to 100%
Orthopyroxene	7.4	23.7	31.0	41.3
Plagioclase	6.3	34.2	40.5	54.0
Troilite	.2	.2	.5	.6
Ilmenite	.1	–	.1	.1
Fe-Co metal	.2	.1	.2	.3
Clinopyroxene	.2	.1	.3	.4
Spinel	.2	–	.2	.2
Silica phase	.04	1.3	1.4	1.8
K-feldspar	.06	.1	.2	.3
Glass-coated clast	.10	.6	.7	1.0
Total	14.8	60.3	75.1	100.0

*Volume percent recalculated from point count 1251 clasts >30 µm and 1370 clasts <30 µm, measured by C. L. Thompson.

Table 2: Whole-rock chemistry of 77215.
a) Winzer et al. (1974); b) Winzer et al. (1977)

Split Technique	,45 (a) AA, IDMS norite	,152 (b) AA, IDMS norite	,115 (b) AA, IDMS black dike	,119 (b) AA, IDMS dike	,121 (b) AA, IDMS dike	,130 (b) AA, IDMS grey glass
SiO_2 (wt%)	51.3	51.1	46.8	47.2	46.0	51.1
TiO_2	0.32	0.30	1.37	1.35	1.32	0.37
Al_2O_3	15.06	13.98	17.44	16.89	17.75	14.32
Cr_2O_3	0.32	0.36	0.19	0.20	0.14	0.36
FeO	10.07	10.38	9.39	9.36	9.04	10.32
MnO	0.16	0.17	0.12	0.12	0.11	0.17
MgO	12.56	14.31	13.16	12.93	12.74	13.23
CaO	8.96	8.65	10.88	10.76	10.94	9.08
Na_2O	0.43	0.39	0.65	0.68	0.68	0.55
K_2O	0.14	0.18	0.24	0.23	0.24	0.15
P_2O_5	0.11	0.14	0.28	0.27	0.26	0.10
Nb (ppm)						
Zr	171	–	419			147
Hf		–				
Sr	105	102	171	169	174	103
Rb	3.54	3.21	6.51	6.48	6.26	
Li	12.3	12.4	21	21.9	26.5	
Ba	166	154	350	349	336	154
La						
Ce	27.2	24.6	84.4	73.3	79.1	29.6
Nd	16.8	15.5	51.9	51.7	50.1	18
Sm	4.68	4.4	14.4	14.5	13.8	5.05
Eu	1.08	1.03	1.93	1.90	1.97	1.01
Gd	6.64	5.21	–			
Dy	7.08	6.64	19.6	19.4	18.4	7.31
Er	4.51	4.57	10	–	10.7	4.44
Yb	4.98	4.88	8.59	10.5	9.94	4.45
Lu	0.766	0.592	1.76		1.68	0.835

Table 3: Trace element data for 77215. Concentrations in ppb.
From Higuchi and Morgan (1975) and Ebihara et al. (1991).

	Sample 77215,35	Sample 77215,37
Ir	2.66	0.0221
Os	3.04	
Re	0.173	0.0047
Au	0.557	0.0108
Pd	1.45	
Ni (ppm)	50	<3
Sb	1.04	0.121
Ge	47.1	14.3
Se	83.2	77
Te	1.92	1
Ag	1.89	0.62
Br		42.4
In	<0.10	
Bi	0.645	0.13
Zn (ppm)	2.95	3
Cd	4.39	4.4
Tl	0.637	0.61
Rb (ppm)	12.3	4.9
Cs	393	180
U	799	920

Table 4: K and Rb-Sr analytical data for 77215.
From Nakamura et al. (1976).

Sample	Weight (mg)	K (%)	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$ [1]	$^{87}Sr/^{86}Sr$ [2]
77215,37 (density separates)						
Acetone float	29.12	0.127	4.933	136.7	0.1044	0.70553 ± 4
ρ>2.9 g/cm^3	29.41	0.387	11.10	184.2	0.1743	0.70990 ± 7
Whole rock	29.67	0.127	6.177	65.46	0.2733	0.71641 ± 12
ρ>3.3 g/cm^3	31.09	0.0081	0.526	3.387	0.4504	0.72738 ± 7
ρ>3.3 g/cm^3	25.13	0.0092	0.611	3.936	0.4499	0.72748 ± 20
77215,145 (hand-picked mineral concentrates)						
Plagioclase	3.33	0.154	3.442	204.1	0.0488	0.70207 ± 3
Whole rock	18.19	0.0842	2.326	86.61	0.0777	0.70397 ± 3
Black material (glass?)	6.24	0.148	2.908	105.2	0.0800	0.70422 ± 5
Pyroxene	7.56	0.0053	0.2303	4.958	0.1344	0.70909 ± 4
Pyroxene (ρ>3.3 g/cm^3)	7.96	0.0063	0.2752	4.187	0.1902	0.71306 ± 7

[1] Uncertainties are estimated to be ≤0.3%.

[2] Uncertainties correspond to last significant figures and are 2σ mean.

Table 5: Sm-Nd analytical data from 77215.
From Nakamura et al. (1976).

Sample	Weight (mg)	Sm (ppm)	Nd[1] (ppm)	$^{147}Sm/^{144}Nd$ [2]	$^{143}Nd/^{144}Nd$ [3]
77215,37					
Plagioclase	9.66	4.084	15.784	0.1564	0.51129 ± 7
Acetone float	129.39	5.516	19.42	0.1717	0.51178 ± 4
Whole rock	21.26	4.372	14.84	0.1780	0.51200 ± 7
Pyroxene (1) (ρ>3.3 g/cm^3)	115.37	2.173	5.329	0.2474	0.51397 ± 2
Pyroxene (2) (ρ>3.3 g/cm^3)	119.01	2.217	5.724	0.2341	0.51359 ± 2
Juvinas					
Whole rock (this study)	92.11	2.021	6.361	0.1920	0.51256 ± 2
Whole rock[4] (La Jolla)				0.1936	0.51264 ± 4

[1] Nd concentrations were calculated using our data normalized to $^{142}Nd/^{146}Nd$ = 1.58170 in Table 3, and $^{148}Nd/^{146}Nd$ = 0.33466 and $^{150}Nd/^{146}Nd$ = 0.32752.
[2] Uncertainties are estimated to be 0.1–0.2%.
[3] Ratios were normalized to $^{142}Nd/^{146}Nd$ = 1.5817. Uncertainties correspond to the last figure and are 2σ mean.
[4] G. W. Lugmair, pers. comm. (1976).

Table 6: U-Th-Pb for 77215.
From Nunes et al. (1974).

Split	77215,37 whole rock	olivine	plagioclase
wt (mg)	158.4	208	194.2
U (ppm)	0.5068	0.7764	0.2390
Th (ppm)	1.993	1.815	1.198
Pb (ppm)	1.079	1.239	0.6817
$^{232}Th/^{238}U$	4.06	2.42	5.18
$^{238}U/^{204}Pb$	1455	479.0	85.4

Rake Fragments from Station 7 Soil Samples

Two soil samples were taken from the regolith surface about 10 meters to the east of the boulder at Station 7 (Fig. 1). Soil 77510 contained rock fragments 77515-77526 and soil 77530 contained rock fragments 77535-77545. Keil et al. (1974) prepared a catalog of these rock fragments.

Meyer (1973) prepared a catalog of additional small "coarse-fine" fragments from these soils.

77515	Poikilitic Impact Melt Breccia
77516	High-Ti Mare Basalt
77517	Unique Fragmental Breccia
77518	Micropoikilitic Impact Melt Breccia
77519	Micropoikilitic Impact Melt Breccia
77525	Impact Melt Breccia
77526	Impact Melt Breccia
77535	High-Ti Mare Basalt
77536	High-Ti Mare Basalt
77537	Impact Melt Breccia
77538	Unusual Fragmental Breccia
77539	Poikilitic Impact Melt Breccia
77545	Poikilitic Impact Melt Breccia

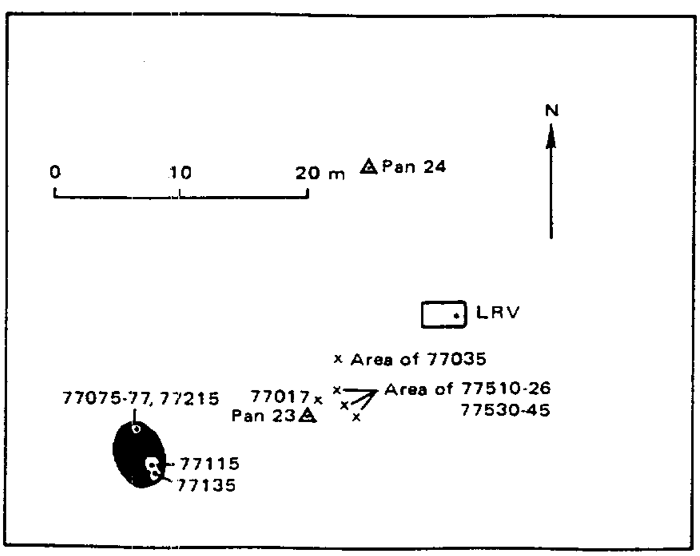


Figure 1: Map of Station 7 at Apollo 17 showing location of rake samples. From Wolfe and others (1980).

77515
Poikilitic Impact Melt Breccia
337.6 g, 7.5 x 6.5 x 5.5 cm

INTRODUCTION

Sample 77515 is a rake sample from soil 77510 at Station 7 (Fig. 1). It is a vesicular impact melt breccia similar in texture and composition to the boulder sample 77135.

PETROGRAPHY

The texture of 77515 is poikiloblastic with irregular pigeonite oikocrysts enclosing abundant euhedral plagioclase laths and tablets and minor rounded olivine grains (Fig. 2). Ilmenite is also poikilitic. Mineral clasts are abundant (mostly plagioclase), but lithic clasts are rare. Warner et al. (1977) give the mineral mode of the matrix 77515 as 52.7% plagioclase, 44.5% pyroxene, and 2% ilmenite.

MINERAL CHEMISTRY

The composition of pyroxene, olivine, ilmenite, and plagioclase is given in Warner et al. (1978) (Fig. 3). Engelhardt (1979) has also studied the ilmenite in 77515.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the chemical composition of 77515 (Table 1 and Fig. 4). 77515 is very similar in composition to the boulders at Apollo 17. Warner et al. (1977) also analyzed the matrix by broad beam electron probe analyses.

SURFACE STUDIES

There are micrometeorite craters on most surfaces.

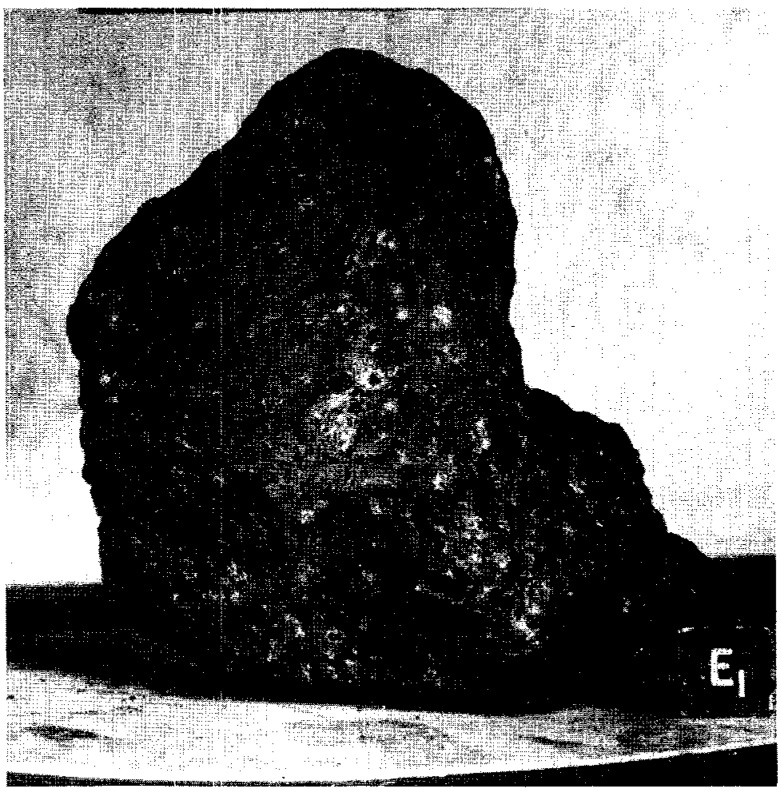


Figure 1: Photograph of 77515. Cube is 1 cm. S73-19416.

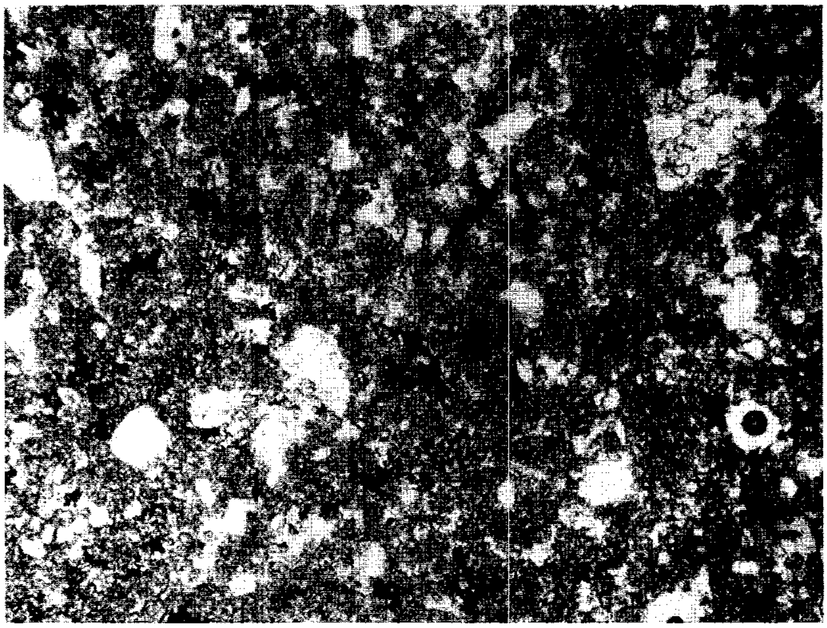


Figure 2: Photomicrograph of matrix for 77515,12. Field of view is 3 x 4 mm.

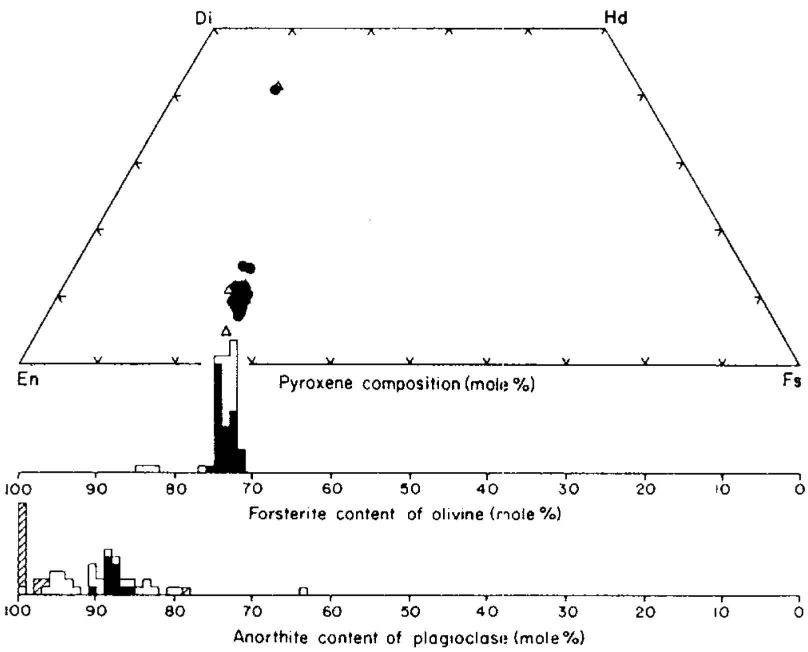


Figure 3: Pyroxene, olivine, and plagioclase composition for 77515. From Warner et al. (1978).

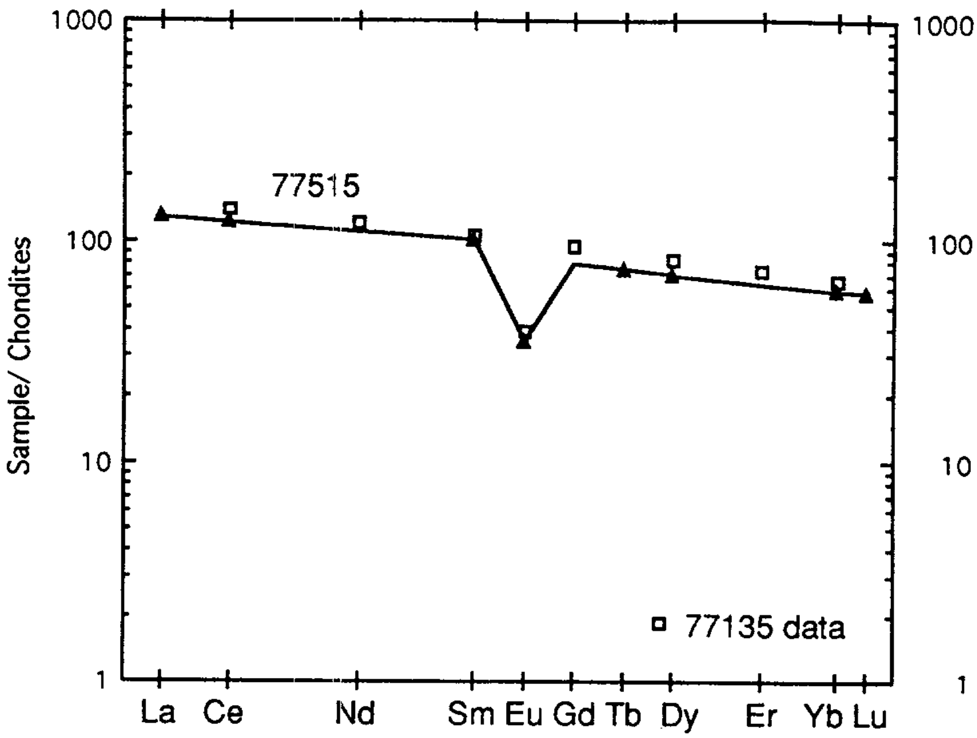


Figure 4: Normalized rare earth element diagram for 77515. Data from Laul and Schmitt (1975). Note the similarity in composition with the Station 7 Boulder sample 77135.

Table 1: Whole-rock chemistry of 77515.
a) Laul and Schmitt (1975); b) Warner et al. (1977)

Split Technique	,3 (a) INAA	(b) BB e-probe
SiO_2 (wt%)	–	48.3
TiO_2	1.4	1.51
Al_2O_3	18.6	18.2
Cr_2O_3	0.17	0.19
FeO	8.4	8.1
MnO	0.099	0.09
MgO	11	11.0
CaO	11.0	11.4
Na_2O	0.68	0.70
K_2O	0.24	0.28
P_2O_5		0.27
Nb (ppm)		
Zr	420	
Hf	9.8	
Ta	1.4	
U	–	
Th	4.1	
Ba	350	
Ni	450	
Co	38.6	
Sc	14	
La	29.8	
Ce	73	
Nd		
Sm	14.7	
Eu	1.93	
Gd		
Tb	2.7	
Dy	17	
Er		
Yb	9.6	
Lu	1.4	
Ge (ppb)		
Ir		
Au		

77516
High-Ti Mare Basalt
103.7 g, 6 x 4 x 2.5 cm

INTRODUCTION

Sample 77516 is a rake sample from soil 77510 at Station 7. It is a medium-grained, high-Ti mare basalt that is similar to other Apollo 17 basalts (Fig. 1).

PETROGRAPHY

Warner et al. (1975) describe this rock as olivine-microporphyritic ilmenite basalt. The texture of the matrix is variolitic, with well-developed sheaves of alternating plagioclase and pyroxene (Fig. 2). Large ilmenite phenocrysts extend up to 5 mm. The mode is 47% pyroxene, 5% olivine, 24% plagioclase, and 19% ilmenite. A silica phase is present.

MINERAL CHEMISTRY

The compositions of the minerals in 77516 are given in Fig. 3 (from Warner et al., 1978).

WHOLE-ROCK CHEMISTRY

Warner et al. (1975) and Laul et al. (1975b) have determined the chemical composition of 77516 (Table 1 and Fig. 4). This basalt has very high TiO_2 content (13.7%).

Classification of Apollo 17 basalts has been discussed by Rhodes et al. (1976), Lindstrom and Haskin (1978), and Pratt et al. (1978) (see appendix). Pratt et al. give it a Type B2 classification.

RADIOGENIC ISOTOPES

Paces et al. (1991) have studied the Rb-Sr and Sm-Nd for whole-rock samples of 77516 and classify it as a Type B2 Apollo 17 mare basalt because the Sr and Nd isotopes do not fall on the whole-rock isochrons for other Apollo 17 mare basalt samples (Table 2). This may indicate a different source region for this basalt sample.

SURFACE STUDIES

There are micrometeorite craters on all surfaces.

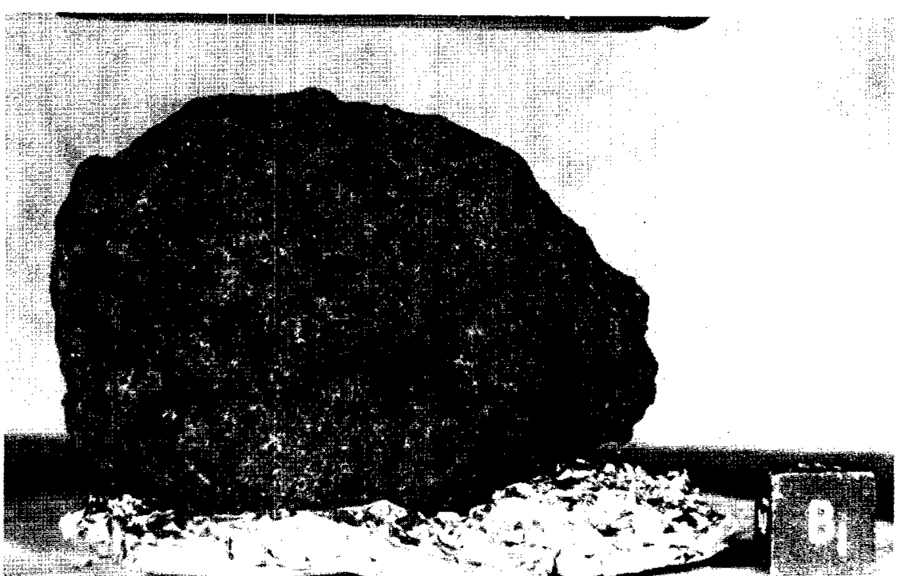


Figure 1: Photograph of 77516. Cube is 1 cm. S73-19409.

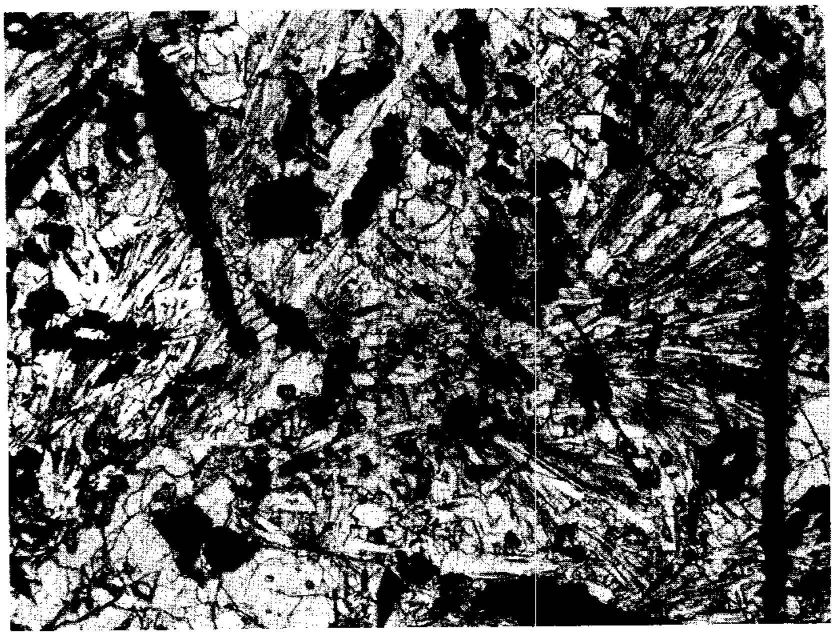


Figure 2: Photomicrograph of thin section 77516,13, showing ilmenite phenocrysts and variolitic texture. Field of view is 3 x 4 mm.

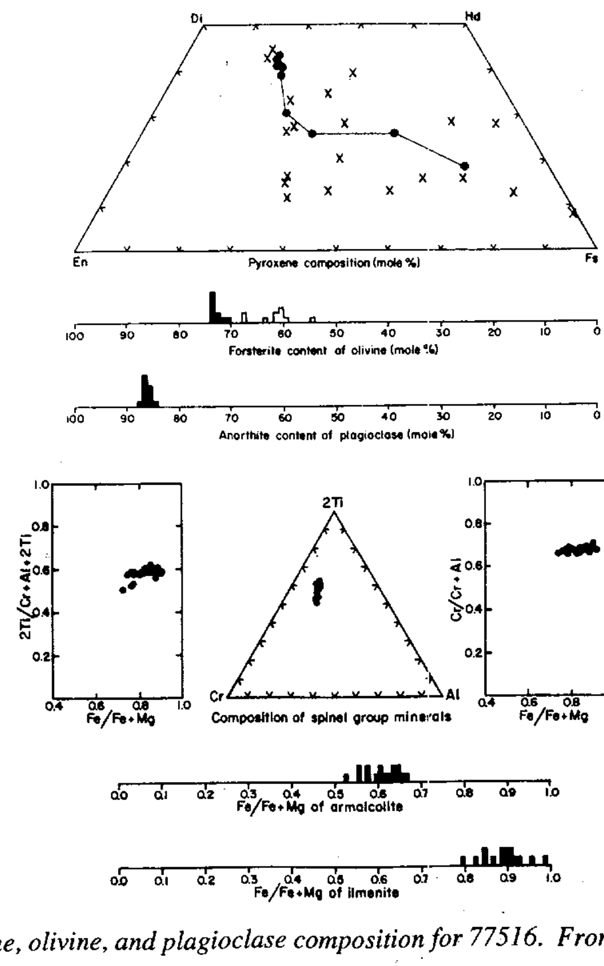


Figure 3: Pyroxene, olivine, and plagioclase composition for 77516. From Warner et al. (1978).

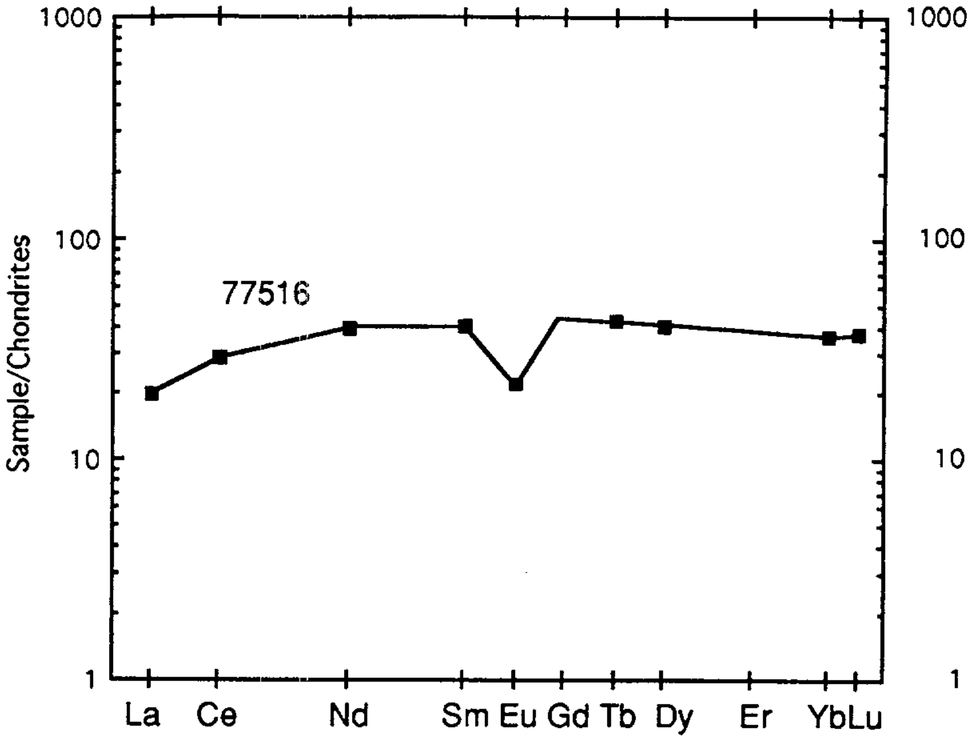


Figure 4: Normalized rare earth element diagram for 77516. Data from Warner et al. (1975).

Table 1: Whole-rock chemistry of 77516.
From Warner et al. (1975).

Split Technique	,2 INAA	Split Technique	,2 INAA
SiO_2 (wt %)	–	La	4.7
TiO_2	13.7	Ce	18
Al_2O_3	7.8	Nd	18
Cr_2O_3	0.48	Sm	6
FeO	20.2	Eu	1.25
MnO	0.25	Gd	
MgO	9.4	Tb	1.6
CaO	9.4	Dy	10
Na_2O	0.33	Er	
K_2O	0.04	Yb	6
Nb (ppm)		Lu	0.91
Hf	6.2	Ge (ppb)	
Ta	1.4	Ir	
Co	24.6	Au	
Sc	80		

Table 2: Rb-Sr and Sm-Nd composition of 77516.
Data from Paces et al. (1991).

Sample	77516,19
wt (mg)	46.77
Rb (ppm)	0.340
Sr (ppm)	110
$^{87}Rb/^{86}Sr$	0.008913 ± 89
$^{87}Sr/^{86}Sr$	0.699619 ± 17
Sm (ppm)	6.39
Nd (ppm)	15.5
$^{147}Sm/^{144}Nd$	0.24944 ± 48
$^{143}Nd/^{144}Nd$	0.514130 ± 60

77517
Unique Fragmental Breccia
45.6 g, 4 x 4 x 3 cm (3 pieces)

INTRODUCTION

Rake sample 77517 is a light grey, fragmental breccia containing clasts of anorthosite, norite, troctolite (and possibly of spinel cataclasite) in a highly porous, poorly sintered matrix that is composed of fine-grained mineral clasts bound together by irregular, wispy overgrowths that form sinuous grain-to-grain contacts (Fig. 1). There is no glass in the matrix (Warner et al., 1978). Sample 77517 is exotic to the Apollo 17 site, containing mineral fragments of pink aluminous spinel, aluminous enstatite, and forsterite.

PETROGRAPHY

Warner et al. (1978) have studied breccia sample 77517. This sample is different from the crystalline matrix breccias. It is clast supported, rather than matrix supported. It is also different from the soil breccias because it does not have glass in the matrix.

Breccia 77517 consists of abundant mineral and lithic clasts in a porous, poorly sintered matrix. The mineral clasts are equant and subrounded (Fig. 2). Grain size is seriate, ranging from 400 to 20 µm. Of the >50 µm mineral clasts, plagioclase is ~55%, mafic minerals are ~40% (with more olivine than pyroxene), and pink spinel is 3 to 4%. Pink spinel grains range in size up to ~400 µm.

Lithic clasts (up to 1 mm) constitute ~20% of the breccia. They include very fine-grained breccia clasts and annealed anorthosite, norite, and troctolite (ANT) clasts. The range of mineral composition in the ANT clasts is plagioclase An_{94-98}, olivine Fo_{72-81}, low-Ca pyroxene $Wo_{3-14}En_{57-82}Fs_{14-22}$, and high-Ca pyroxene $Wo_{34-41}En_{44-50}Fs_{14-17}$. One clast (1.5 mm) has a basaltic texture with intersecting plagioclase laths (0.5 to 1 mm).

Warner et al. (1978) have speculated on the apparent deep-seated origin of the pink spinel-aluminous enstatite, forsterite, and anorthite assemblage. Herzberg (1978) and Baker and Herzberg (1980) have provided thermodynamic calculations to define the temperature and pressure conditions of such a mineral assemblage.

MINERAL CHEMISTRY

The compositions of minerals in 77517 are given in (Fig. 3). Warner et al. (1978) have a table of mineral

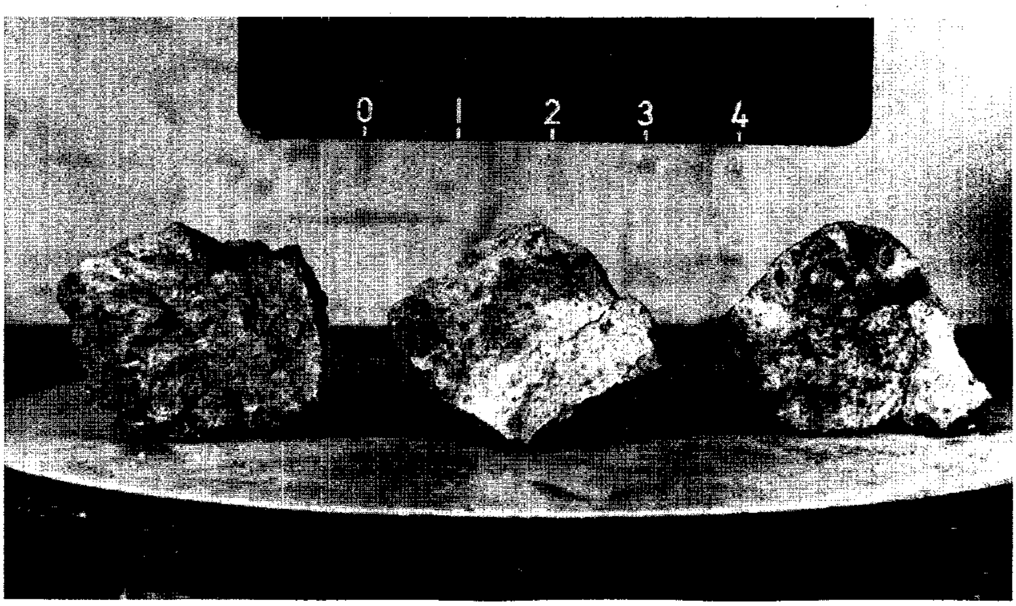


Figure 1: Photograph of 77517. Scale is 1 cm. S73-19404.

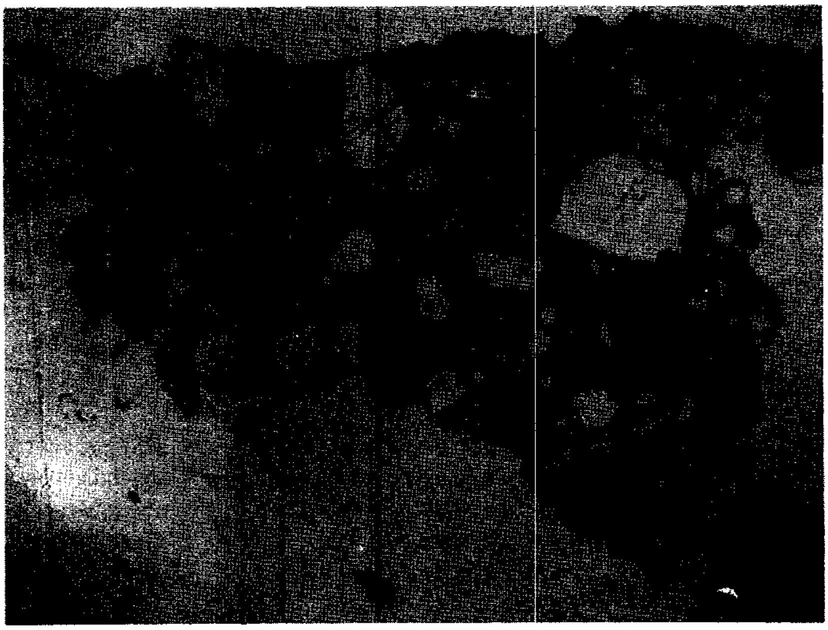


Figure 2: Photomicrograph of thin section 77517,22. Field of view is 3 x 4 mm.

analyses. The range of plagioclase composition is very restricted (An_{96-98}). Olivine mineral clasts range from Fo_{81-90} with the majority being Fo_{81-83}. Most pyroxene is orthopyroxene, ranging from $Wo_{1-5}En_{70-91}Fs_{8-26}$. The most Mg-rich pyroxenes are also Al-rich, and may be related to the abundant Al-rich pink spinel in the same brecciated areas, but this cannot be ascertained because of the extreme brecciation.

WHOLE-ROCK CHEMISTRY

The composition of 77517 has not been determined, probably because individual clasts need to be analyzed separately.

SIGNIFICANT CLASTS

Warner et al. (1978) report a clast assemblage corresponding to spinel cataclasite (i.e., aluminous enstatite + forsterite + plagioclase and aluminous spinel). The brecciated nature of this assemblage raises the question of whether or not it represents an equilibrium assemblage.

One glassy area of 600 µm was found to be ~77 SiO_2, 14% Al_2O_3, and 5% K_2O.

The clasts in this sample deserve more study.

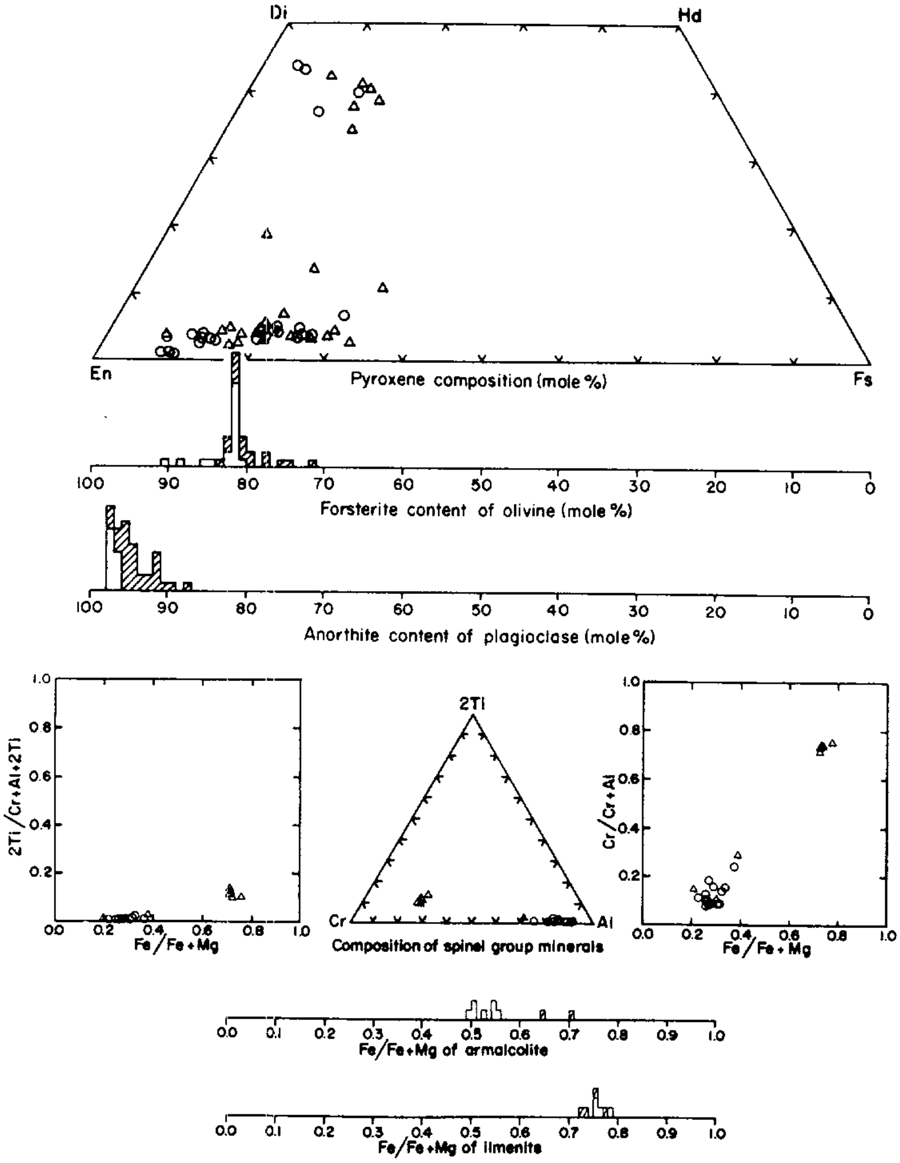


Figure 3: Pyroxene quadrilateral diagram and compositions for minerals in 77517. From Warner et al. (1978)

77518
Micropoikilitic Impact Melt Breccia
42.5 g, 3.5 x 3.5 x 2.5 cm

INTRODUCTION

Sample 77518 is a rake sample from soil 77510 at Station 7 (Fig. 1). It is a vesicular impact melt breccia similar in texture to the boulder sample 77135 and to 77515.

PETROGRAPHY

In thin section, the texture varies from microgranular to micro-poikilitic (Fig. 2). Pigeonite and ilmenite chadocrysts enclose plagioclase and olivine oikocrysts. Warner et al. (1977) give the mineral mode for 77518. The matrix is about 52% plagioclase and 44% low-Ca pyroxene and olivine. One large olivine clast contains symplectite chromite intergrowth. Lithic clasts are rare, mostly recrystallized ANT and feldspathic breccia.

Several pink spinel grains with plagioclase reaction coronas are reported (Warner et al., 1978).

MINERAL CHEMISTRY

The compositions of minerals in 77518 are given in Warner et al. (1978) (Fig. 3). Engelhardt (1979) has also studied the ilmenite in 77518.

WHOLE-ROCK CHEMISTRY

The chemical composition of 77518 (Table 1) has been determined only by "broad beam microprobe analyses" (Warner et al., 1977). These analyses also indicate that this sample is typical of impact melt rocks at Station 7.

SIGNIFICANT CLASTS

Warner et al. (1978) report that one edge of the chip that they studied had an area of Si-Al-K-rich glass (80% SiO_2, 12% Al_2O_3, and 8% K_2O) with a gradational boundary with the breccia matrix.

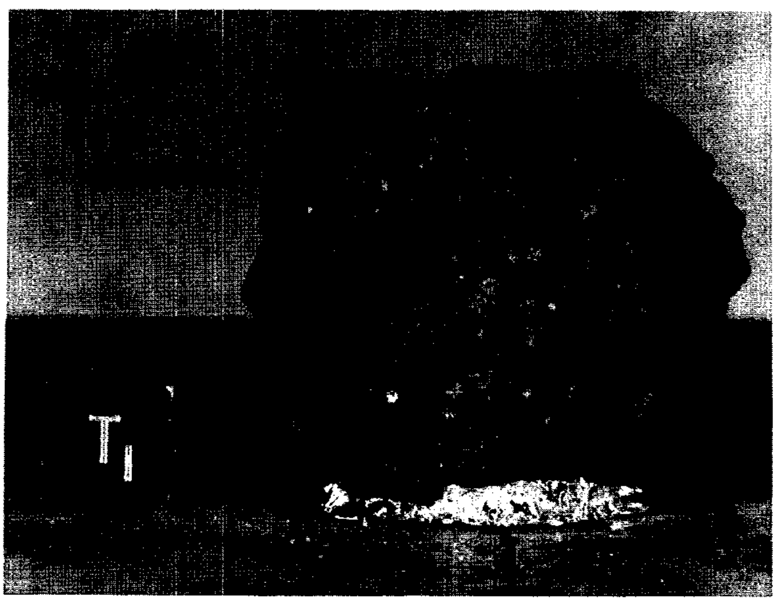


Figure 1: Photograph of 77518. Cube is 1 cm. S73-19143.

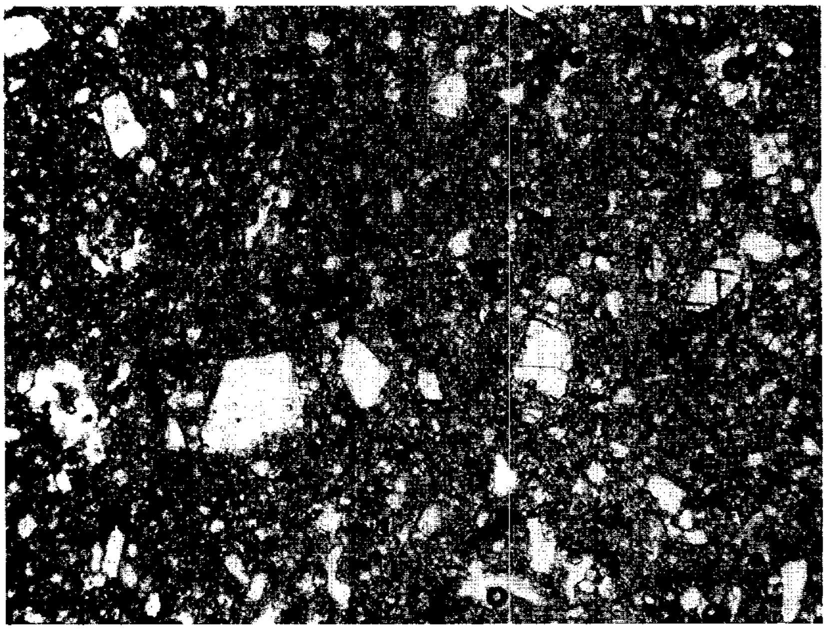


Figure 2: Photomicrograph of thin section 77518,12. Field of view is 3 x 4 mm.

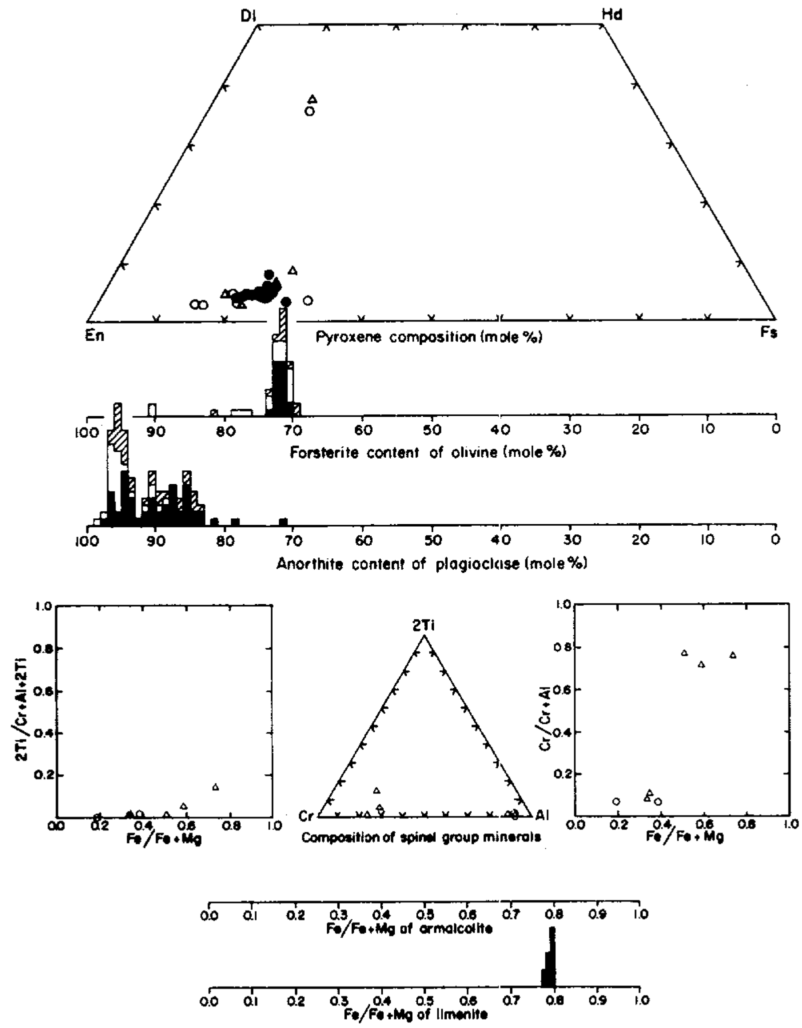


Figure 3: Mineral compositions of 77518. From Warner et al. (1978).

Table 1: Whole-rock chemistry of 77518.
From Warner et al. (1977).

Split **Technique**	**matrix** **BB e-probe**
SiO_2 (wt%)	47.1
TiO_2	1.25
Al_2O_3	19.7
Cr_2O_3	0.15
FeO	7.8
MnO	0.12
MgO	10.5
CaO	11.7
Na_2O	0.72
K_2O	0.42
P_2O_5	0.31

77519
Micropoikilitic Impact Melt Breccia
27.4 g, 3.5 x 2.5 x 1.2 cm

INTRODUCTION

Sample 77519 is a rake sample from soil 77510 at Station 7 (Fig. 1).

PETROGRAPHY

Sample 77519 is an aphanitic, dark grey, coherent, nonvesicular impact melt rock (Fig. 1). There is no thin section, and the chemical composition has not been determined.

Figure 1: Photograph of 77519. Cube is 1 cm. S73-19134.

77525
Impact Melt Breccia
1.19 g, 1 x 1 x 0.5 cm

INTRODUCTION

Sample 77525 is a light grey chip of impact melt breccia (Fig. 1). It is angular and aphanitic and appears to resemble sample 77217.

PETROGRAPHY

There are no thin sections of 77525.

WHOLE-ROCK CHEMISTRY

The chemical composition has not been determined.

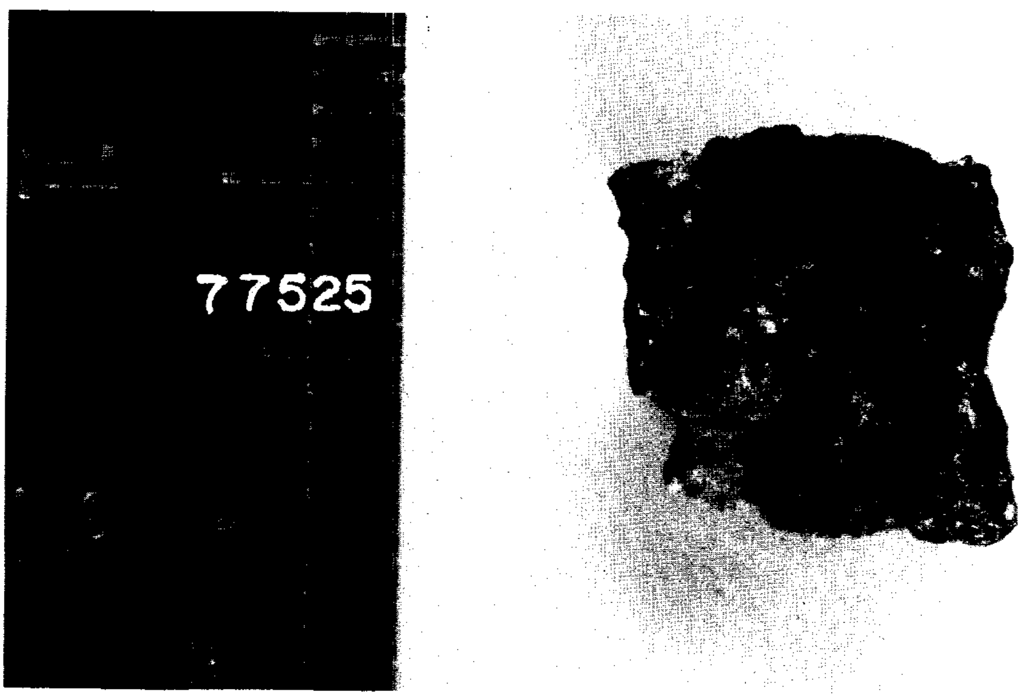


Figure 1: Photograph of 77525. Scale is 1 cm. S73-19379.

77526
Impact Melt Breccia
1.07 g, 1.5 x 1 x 0.5 cm

INTRODUCTION

Sample 77526 is a light grey chip of impact melt breccia (Fig. 1). It is angular, aphanitic, and resembles sample 77517 in overall appearance.

PETROGRAPHY

Approximately half of this chip appears to be a clast of cryptocrystalline microbreccia. There are no thin sections of 77526.

WHOLE-ROCK CHEMISTRY

The chemical composition has not been determined.

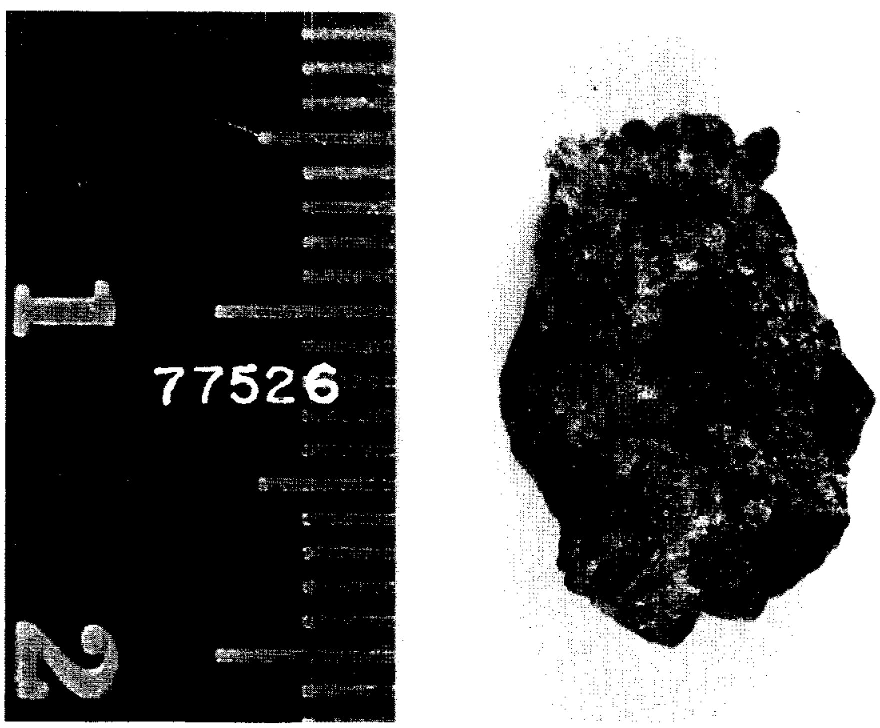


Figure 1: Photograph of 77526. Scale is 1 cm. S73-19380.

77535
High-Ti Mare Basalt
577.8 g, 10.5 x 8.5 x 3.5 cm

INTRODUCTION

Sample 77535 is a rake sample from soil 77530 at Station 7. It is a coarse-grained, high-Ti mare basalt that is similar to other Apollo 17 basalts (Fig. 1).

PETROGRAPHY

Warner et al. (1978) classify 77535 as a coarse-grained, plagioclase-poikilitic ilmenite basalt (Fig. 2). They give the mode as 48% plagioclase, 31% pyroxene, 17% ilmenite, with only trace olivine. They report ~3% silica and trace zirconolite and armalcolite.

77535 has about 1% vugs and cavities with projecting pyroxene and opaque crystals. It has zap pits on all surfaces.

MINERAL CHEMISTRY

The compositions of the minerals in 77535 are given in Fig. 3 (from Warren et al., 1978).

WHOLE-ROCK CHEMISTRY

Rhodes et al. (1976) and Laul et al. (1975b) have determined the chemical composition of 77535 (Table 1 and Fig. 4). Gibson et al. (1976) determined the sulfur content of 77535.

Classification of Apollo 17 basalts has been discussed by Rhodes et al. (1976), Lindstrom and Haskin (1978), and Pratt et al. (1978) (see appendix). Lindstrom and Haskin designate 77535 as a Type U basalt, while Pratt et al. call it a Type B3.

RADIOGENIC ISOTOPES

Nyquist et al. (1976) have reported Rb-Sr data for the whole rock (Table 2).

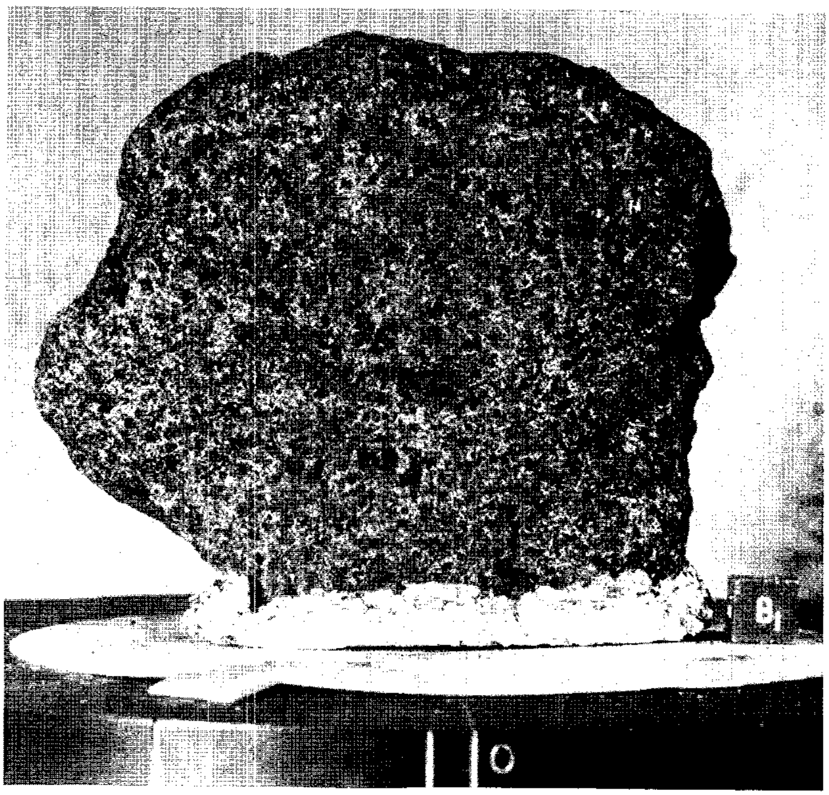


Figure 1: Photograph of 77535. Cube is 1 cm. S73-19122.

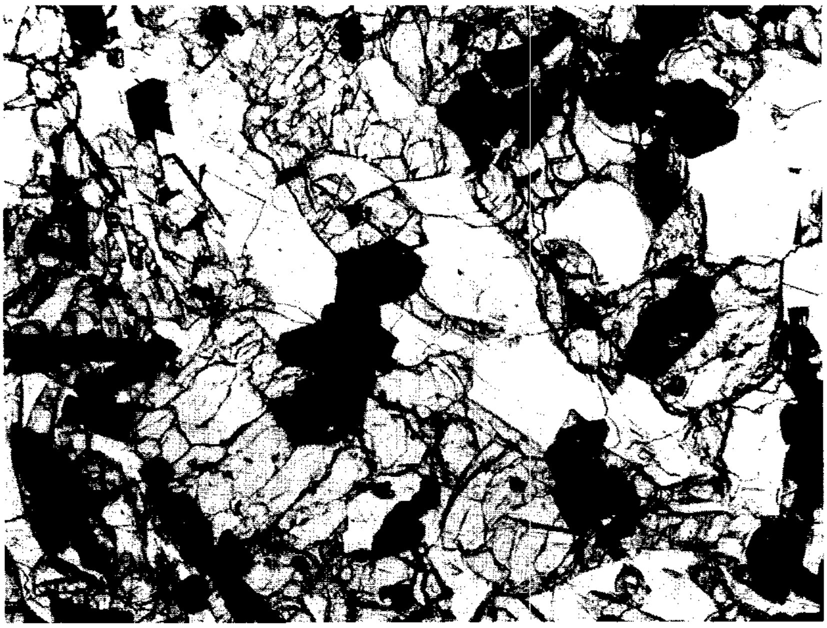


Figure 2: Photomicrograph of thin section 77535,11. Field of view is 3 x 4 mm.

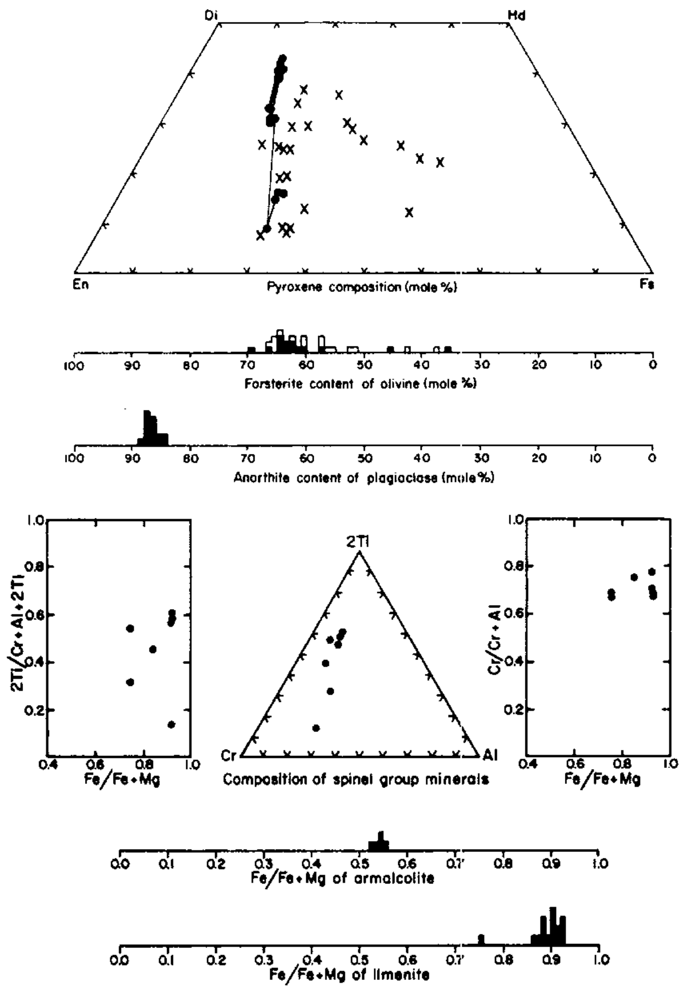


Figure 3: Compositions of minerals in 77535. From Warner et al. (1978).

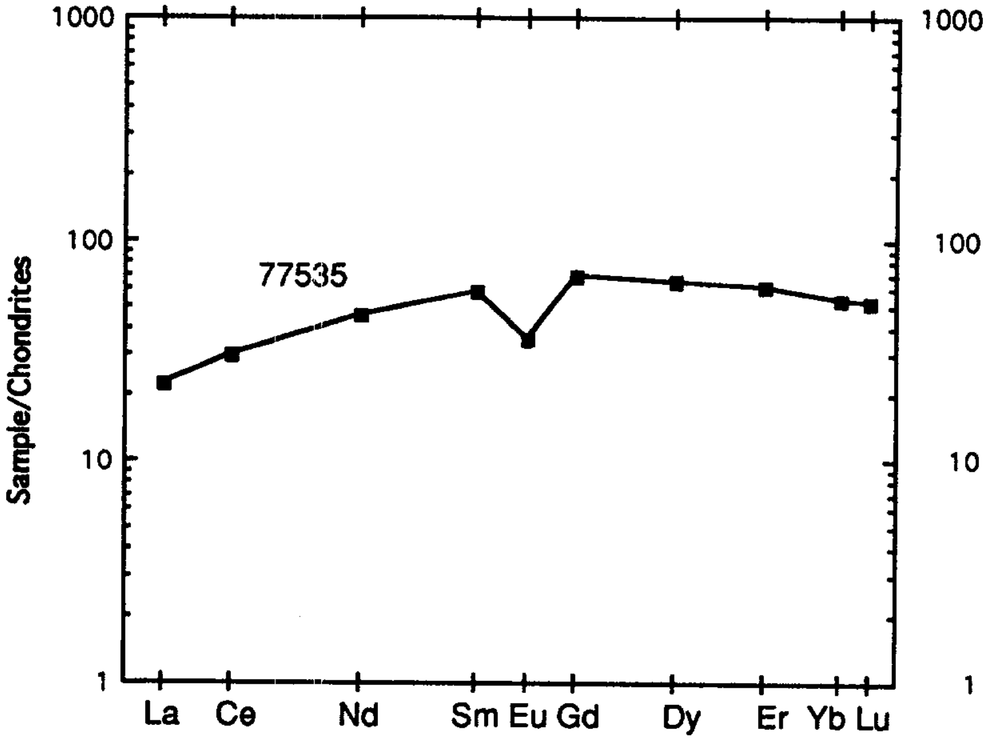


Figure 4: Normalized rare earth element diagram for 77535. Data from Rhodes et al. (1976).

Table 1: Whole-rock chemistry of 77535.
a) Laul et al. (1975); b) Rhodes et al. (1976)

Split **Technique**	**,1 (a)** **INAA**	**,6 (b)** **XRF, IDMS, *INAA***
SiO_2 (wt%)	–	38.57
TiO_2	12.1	12.39
Al_2O_3	8.6	8.95
Cr_2O_3	0.485	0.43
FeO	19.5	18.53
MnO	0.239	0.27
MgO	8.7	8.85
CaO	9.8	10.66
Na_2O	0.36	0.39
K_2O	0.066	0.05
P_2O_5		0.04
S		0.16
Nb (ppm)		
Hf	8.6	*8.6*
Ta	1.6	
Sr		184
Rb		0.55
Li		9.7
Ba		70.7
Co	20.5	*20.4*
Sc	79	*80*
La	5.7	5.24
Ce	23	18.3
Nd	22	20.7
Sm	8.8	8.7
Eu	1.94	1.98
Gd		13.6
Tb	2.4	
Dy	15	15.8
Er		9.84
Yb	8.1	8.91
Lu	1.3	*1.29*
Ge (ppb)		
Ir		
Au		

Table 2: Rb-Sr composition of 77535.
Data from Nyquist et al. (1976).

Sample	**77535,6**
wt (mg)	51
Rb (ppm)	0.547
Sr (ppm)	184
$^{87}Rb/^{86}Sr$	0.0086 ± 3
$^{87}Sr/^{86}Sr$	0.69961 ± 8
T_B	4.14 ± 0.80
T_L	4.70 ± 0.80

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

77536
High-Ti Mare Basalt
355.3 g, 11 x 7.0 x 3.5 cm

INTRODUCTION

Sample 77536 is a rake sample from soil 77530 at Station 7. It is a coarse-grained, high-Ti mare basalt that is similar to other Apollo 17 basalts (Fig. 1). It has a very high TiO_2 content (14.5%).

PETROGRAPHY

Warner et al. (1978) classify 77536 as a coarse-grained, plagioclase-poikilitic ilmenite basalt (Fig. 2). They give the mode as 50% plagioclase, 27% pyroxene, 19% ilmenite, with ~1% olivine. They report ~1.6% silica and trace armalcolite, zirconolite, and baddeleyite.

Sample 77536 has about 1% vugs with projecting pyroxenes and ilmenite crystals. One side has a partial glass coating. All sides have micrometeorite craters. One plagioclase crystal is 3 mm long (Fig. 2).

MINERAL CHEMISTRY

The compositions of the minerals in 77536 are given in Fig. 3 (from Warner et al., 1978). Note that some of the olivine is Fe rich.

WHOLE-ROCK CHEMISTRY

Warner et al. (1975) have reported the chemical composition of 77536 (Table 1 and Fig. 4). The rare earth pattern is identical to other Apollo 17 samples, including 77535.

Classification of Apollo 17 basalts has been discussed by Rhodes et al. (1976), Lindstrom and Haskin (1978), and Pratt et al. (1978) (see appendix). Lindstrom and Haskin designate 77536 as a Type U basalt, while Pratt et al. call it a Type B3.

The sample has very high TiO_2 (14.5%) and Cr_2O_3 (0.56%).

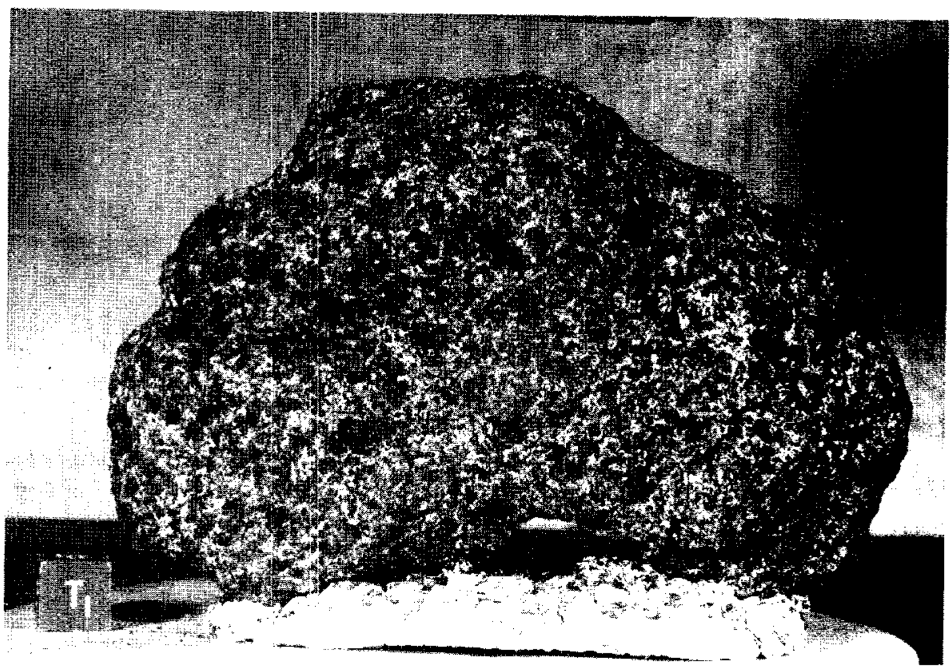


Figure 1: Photograph of 77536. Scale is 1 cm. S73-19154.

Figure 2: Photomicrograph of thin section 77536,8. Field of view is 3 x 4 mm.

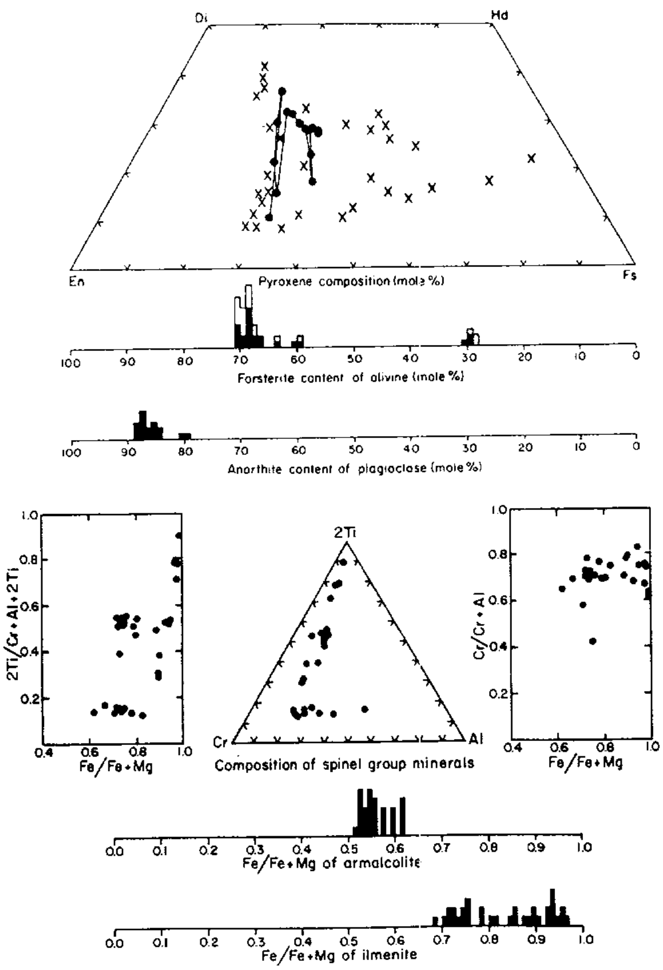


Figure 3: Mineral compositions of 77536. From Warner et al. (1978).

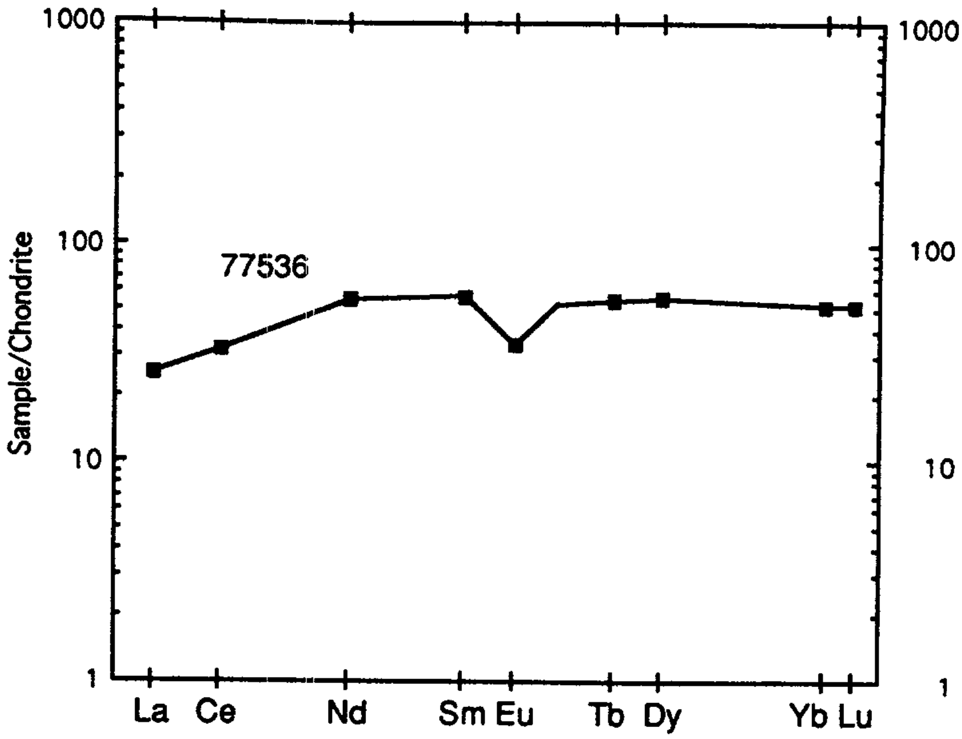


Figure 4: Normalized rare earth element diagram for 77536. Data from Warner et al. (1975).

Table 1: Whole-rock chemistry of 77536.
From Warner et al. (1975).

Split Technique	,2 INAA
SiO_2 (wt%)	--
TiO_2	14.5
Al_2O_3	8.0
Cr_2O_3	0.56
FeO	18.8
MnO	0.23
MgO	9.2
CaO	10.2
Na_2O	0.33
K_2O	0.07
Nb (ppm)	
Hf	8.8
Ta	2
Co	17.8
Sc	78
La	6.1
Ce	20
Nd	25
Sm	8.5
Eu	1.94
Gd	
Tb	2.0
Dy	14
Er	
Yb	8.5
Lu	1.3
Ge (ppb)	
Ir	
Au	

77537
Impact Melt Breccia
71.7 g, 5 x 4.5 x 3 cm

INTRODUCTION

Sample 77537 is a rake sample from soil 77530 at Station 7 (Fig. 1). It is a dark grey, vesicular impact melt breccia.

PETROGRAPHY

Keil et al. (1974) provided a brief description of 77537. It is coherent without fractures and has about 10-20% vesicles ranging in size from <1 mm to more than 15 mm. Some of the small vesicles are in the walls of the large ones. The large cavities have a preferred orientation.

Clasts in 77537 are difficult to discern and are welded into the matrix.

No thin sections of 77537 have been prepared.

WHOLE-ROCK CHEMISTRY

The chemical composition of 77537 has not been determined.

Sample 77537 has micrometeorite craters on all sides.

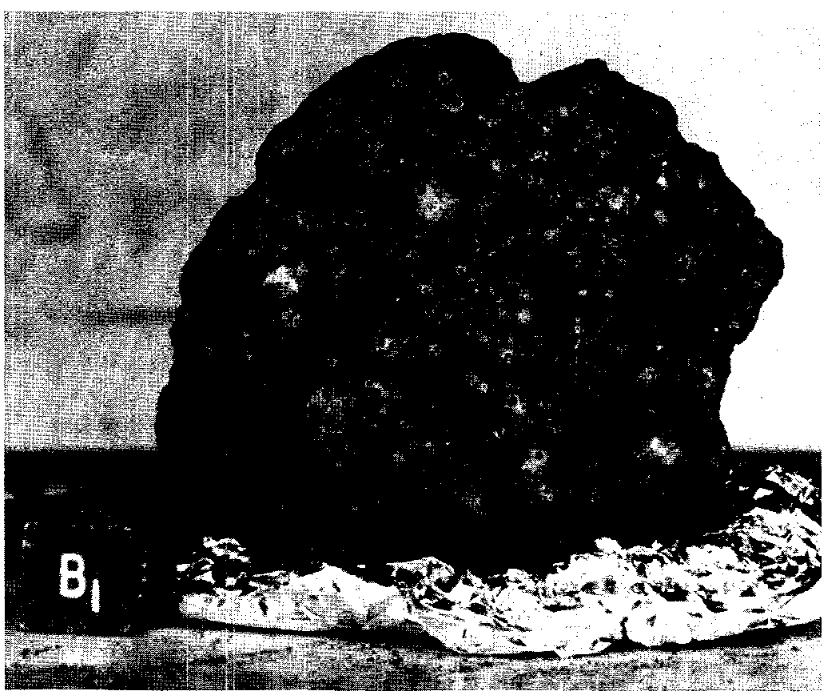


Figure 1: Photograph of 77537. Scale is 1 cm. S73-19145.

77538
Unusual Fragmental Breccia
47.2 g, 4 x 3.5 x 3 cm

INTRODUCTION

Rake sample 77538 is a light grey, fragmental breccia that is composed of abundant mineral and lithic clasts set in a porous, poorly sintered matrix (Fig. 1). It has a very high, KREEP-like trace element content.

An important feature of this unusual breccia is the occurrence of both high-Si, high-K clasts along with high-Fe lithic clasts whose compositions resemble those of immiscible-melts produced during late-stage magmatic crystallization via apparent silicate liquid immiscibility.

PETROGRAPHY

Warner et al. (1978) have described 77538 as a clast-rich, friable breccia with abundant mineral and lithic clasts in a poorly sintered matrix. Mineral clasts are generally subequant and subangular, with the majority being about 100 μm. Lithic clasts range up to 1 mm. Fig. 2 illustrates a granitic clast in the ground-up matrix of 77538.

The collection of mm-sized clasts of high-Fe and high-K, high-Si composition in 77538 probably represents the best example that silicate liquid immiscibility took place on a scale larger than the glassy mesostasis in lunar basalts (Warner et al., 1978; Taylor et al., 1980).

MINERAL CHEMISTRY

The compositions of minerals in 77538 are given in Fig. 3 (from Warner et al., 1978). Note the Fe-rich olivine in this rock.

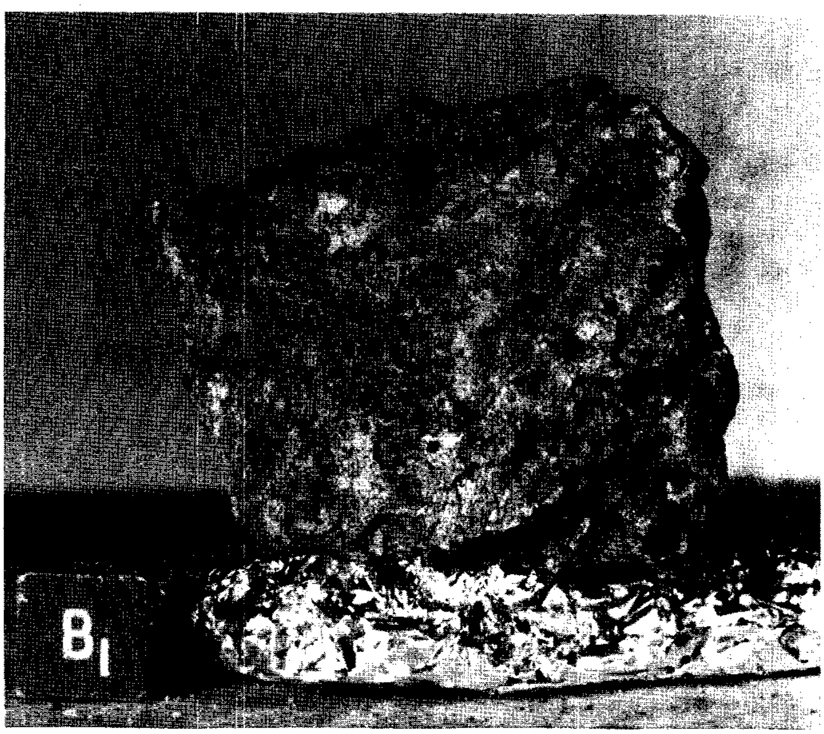


Figure 1: Photograph of 77538. Scale is 1 cm. S73-19064.

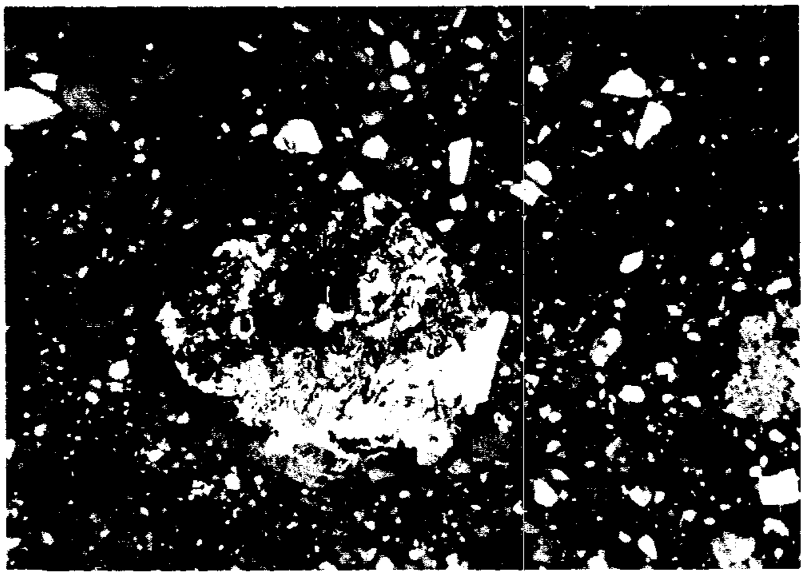


Figure 2: Photomicrograph of 77538 illustrating one of the granitic clasts in the porous breccia matrix. Field of view is 2 x 3 mm. From Warner et al. (1978).

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the chemical composition of 77538 (Table 1 and Fig. 4). This sample has a very high trace element content.

SIGNIFICANT CLASTS

Both graphic-textured high-K, high-Si clasts and high-Fe clasts are present as small patches that have been analyzed by broad-beam electron microprobe analyses (Warner et al., 1978).

The high-Si clasts consist mostly of silica and K-feldspar ($An_{1-4}Ab_{4-5}Or_{88-93}$), frequently intergrown in a barred texture, with small amounts of sodic plagioclase (~$An_{68}Ab_{30}Or_{3}$), fayalitic olivine (Fo_{4-13}), ferroaugite ($Wo_{40-44}En_{6-9}Fs_{48-51}$), ilmenite, metal, troilite, and a Ca-rich phosphate mineral.

The high-Fe clasts are mainly ferroaugite ($Wo_{32-40}En_{15-22}Fs_{42-48}$) and ferropigeonite ($Wo_{14-15}En_{30-36}Fs_{49-56}$) that enclose blebs of silica and fayalitic olivine (Fo_{12-17}), troilite, metal, and ilmenite.

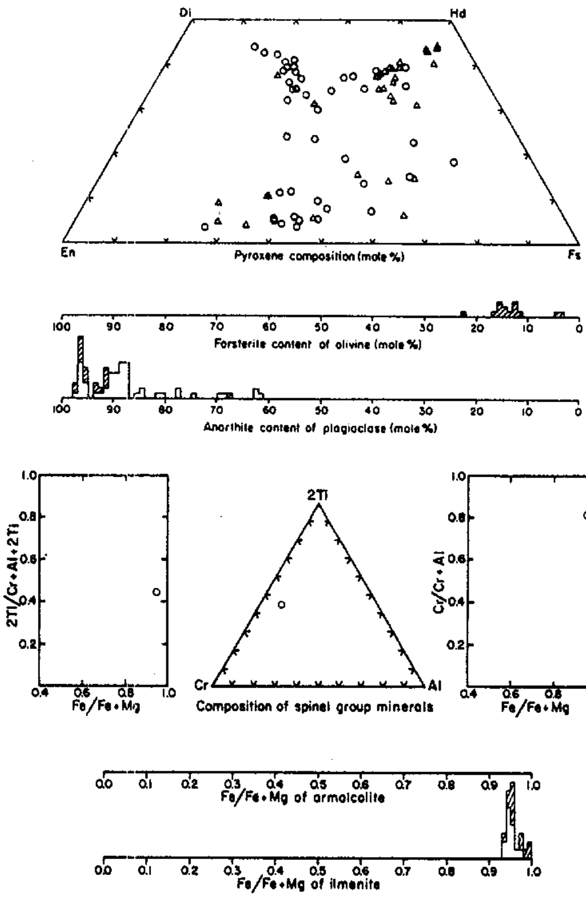


Figure 3: Pyroxene, olivine, and plagioclase composition of 77538. From Warner et al. (1978).

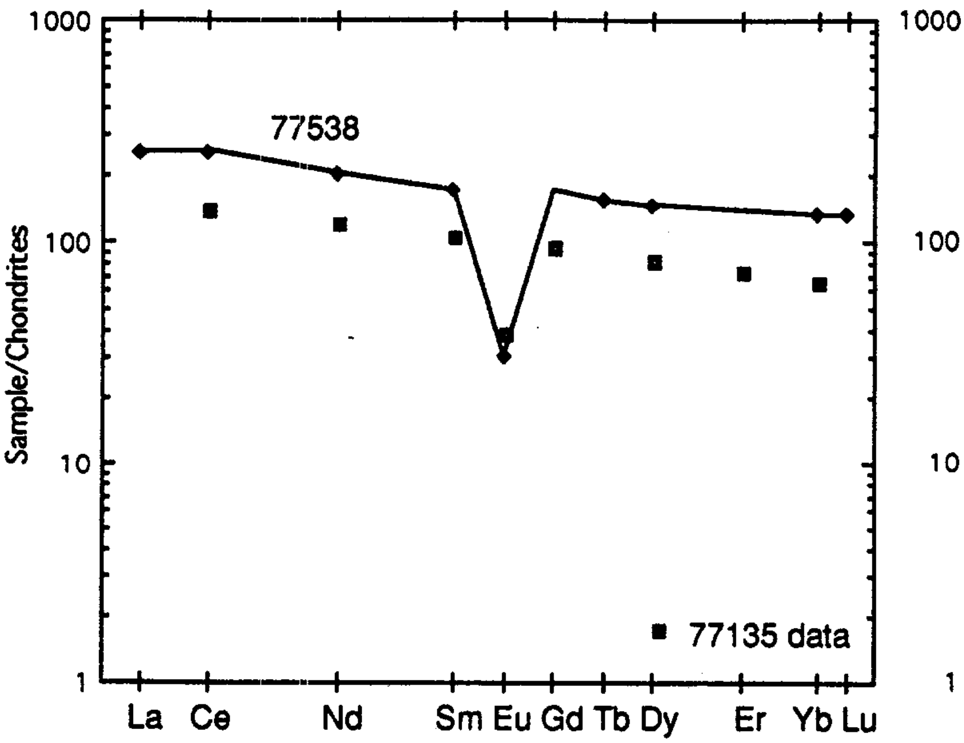


Figure 4: Normalized rare earth element diagram for 77538 compared with 77135. Data from Laul and Schmitt (1975).

Table 1: Whole-rock chemistry of 77538.
a) Laul and Schmitt (1975); b) Warner et al. (1978)

Split Technique	,2 (a) INAA whole rock	average (b) BB e-probe 5 clasts	average (b) BB e-probe 4 clasts
SiO_2 (wt%)	–	74.0	50.3
TiO_2	1.2	0.54	2.82
Al_2O_3	14.5	12.5	0.96
Cr_2O_3	0.24	<0.01	0.17
FeO	10.6	2.21	**31.3**
MnO	0.15	–	–
MgO	5.0	0.08	4.3
CaO	10.3	1.86	9.8
Na_2O	0.75	0.90	0.12
K_2O	**1.04**	**7.6**	0.29
P_2O_5		0.07	0.28
Nb (ppm)			
Zr	730		
Hf	21.5		
Ta	3.3		
U	4.2		
Th	**16**		
Ba	700		
Ni	–		
Co	13.5		
Sc	22		
La	59		
Ce	150		
Nd	90		
Sm	25.1		
Eu	1.7		
Gd			
Tb	5.5		
Dy	35		
Er			
Yb	21.7		
Lu	3.2		
Ge (ppb)			
Ir			
Au			

77539
Poikilitic Impact Melt Breccia
39.6 g, 5 x 3 x 2 cm

INTRODUCTION

Sample 77539 is a rake sample from soil 77530 at Station 7 (Fig. 1). It is a vesicular impact melt breccia that is similar in texture to the matrix of boulder sample 77135. Sample 77539 contains a quasipristine "anorthosite" clast (Warren, 1993).

PETROGRAPHY

The texture of 77539 is poikiloblastic, with irregular pigeonite oikocrysts enclosing abundant euhedral plagioclase laths and tablets and minor rounded olivine grains (Fig. 2). Ilmenite is also poikilitic. Mineral clasts are abundant (mostly plagioclase), but lithic clasts are rare. Warner et al. (1977) give the mineral mode of the matrix of 77539 as 50.8% plagioclase, 45.2% pyroxene, and 2.2% ilmenite.

MINERAL CHEMISTRY

The compositions of minerals in 77539 are given in Fig. 3 (Warner et al., 1978). Engelhardt (1979) has studied the ilmenite in 77539.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the composition of 77539 (Table 1 and Fig. 4). The analysis of Laul and Schmitt indicates that their piece had an excess of plagioclase. Warner et al. (1977) analyzed the matrix by broad-beam electron probe analyses and reported a composition more typical of impact melts (Table 1).

SIGNIFICANT CLASTS

Keil et al. (1974) reported that 77539 contained a large white clast (30% of sample?) that is very fine sugary material with patches of "yellow-green" mineral up to 2 mm. Warren et al. (1991) found that this clast is a pristine "anorthosite." This clast is reported as having an extremely fine-grained granulitic texture. A bulk analysis of this clast is given in Table 1. Warren (1993) reports that this clast is ~99% plagioclase ($An_{94.5-96.3}$), and ~1% olivine (Fo_{72}) and pyroxene ($Wo_9En_{64}Fs_{27}$). Metal grains found included in this clast are low in Ni and Co. Although this clast has very low Ir, Warren (1993) lists it as only "quasipristine."

Figure 1: Photograph of 77539. Cube is 1 cm. S73-19062.

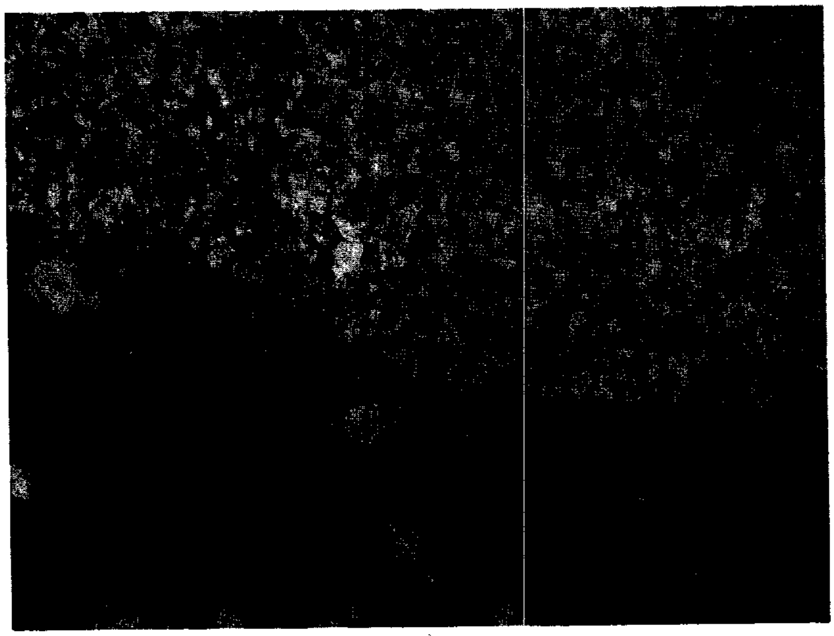


Figure 2: Photomicrograph (partially crossed polarizers) of thin section 77539,13, showing poikiloblastic matrix and part of a large clast (6 mm) of shocked and recrystallized anorthite. Field of view is 3 x 4 mm.

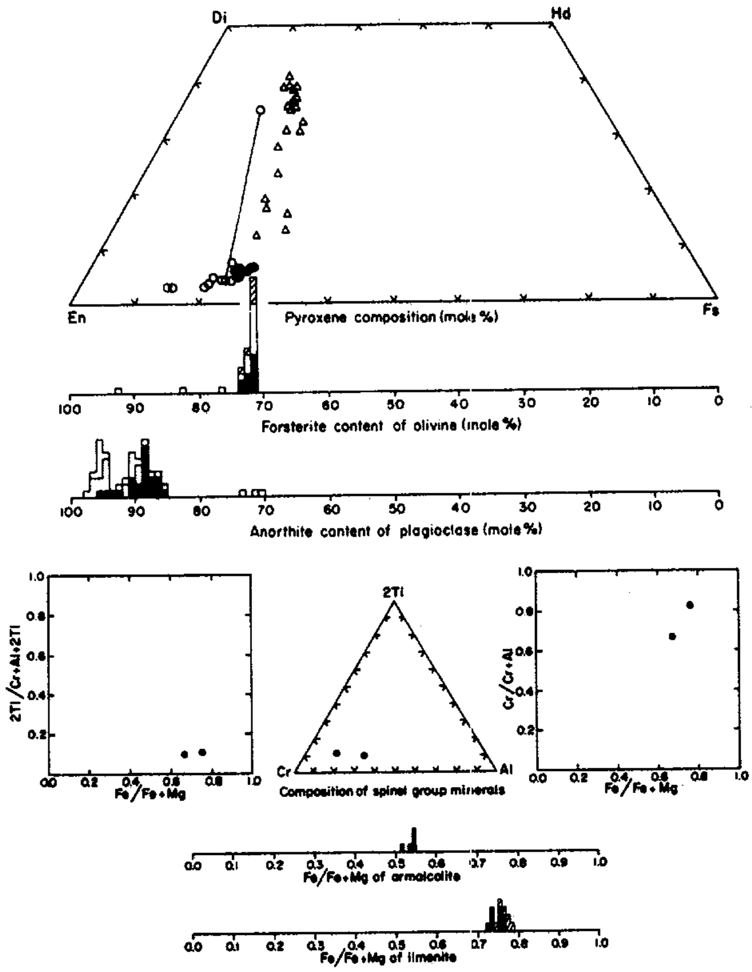


Figure 3: Compositions of minerals from 77539. From Warner et al. (1978).

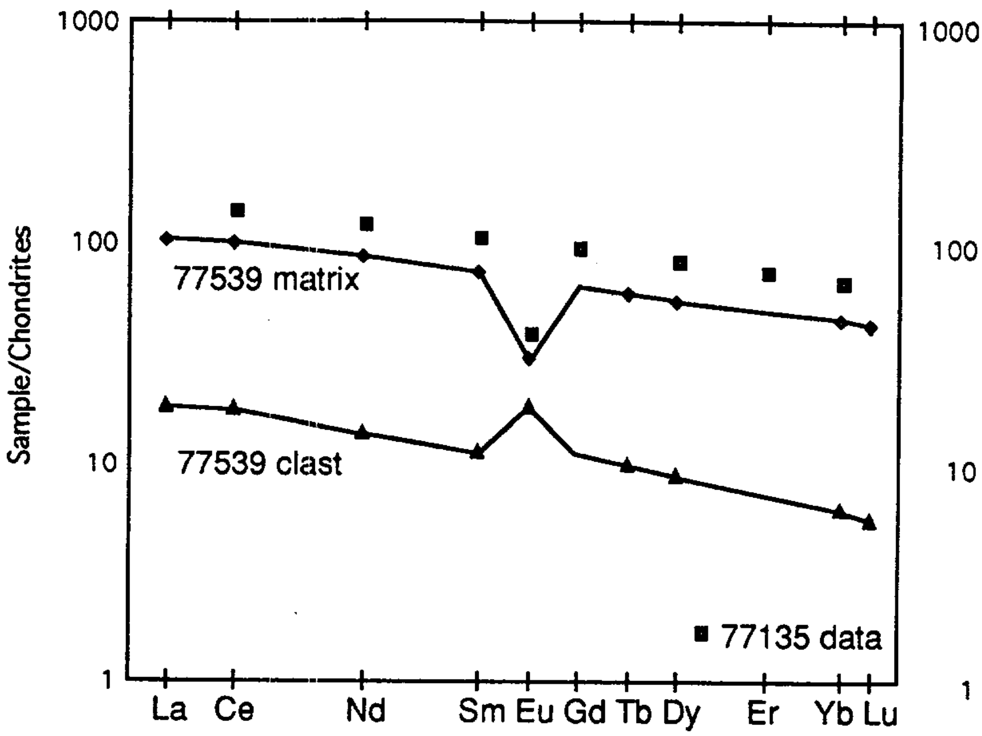


Figure 4. Normalized rare earth element diagram for 77539 matrix and "anorthosite clast" compared with data from 77135. Data from Laul and Schmitt (1975) and Warren (1991).

Table 1: Whole-rock chemistry of 77539.
a) Laul and Schmitt (1975); b) Warner et al. (1977); c) Warren et al. (1991)

Split Technique	,8 (a) INAA	matrix (b) BB e-probe matrix	,15 (c) INAA clast
SiO_2 (wt%)	–	48.1	44.08
TiO_2	1.1	0.84	0.11
Al_2O_3	22	17.7	34.2
Cr_2O_3	0.136	0.16	0.02
FeO	6.9	7.8	0.67
MnO	0.082	0.11	0.012
MgO	8	11.3	0.896
CaO	12.5	11.1	18.9
Na_2O	0.56	0.73	0.45
K_2O	0.2	0.27	0.047
Nb (ppm)			
Zr	300		46
Hf	8.4		0.94
Ta	1.1		0.106
U	1.2		0.161
Th	3.2		0.62
Ba	240		57
Ni	300		3.0
Co	28		1.18
Sc	11		2.58
La	23.5		4.2
Ce	58		10.4
Nd	38		6.1
Sm	10.5		1.65
Eu	1.65		0.99
Gd			
Tb	2.1		0.35
Dy	13		2.12
Er			
Yb	7.1		0.99
Lu	1		0.132
Ge (ppb)			16
Ir	7		0.012
Au	2		0.028

77545

Poikilitic Impact Melt Breccia
29.5 g, 3.5 x 3 x 2.5 cm

INTRODUCTION

Sample 77545 is a rake sample from soil 77530 at Station 7 (Fig. 1). It is a vesicular impact melt breccia similar in texture and composition to the boulder sample 77135.

PETROGRAPHY

The texture of 77545 is poikiloblastic, with irregular pigeonite oikocrysts enclosing abundant euhedral plagioclase laths and tablets and minor rounded olivine grains (Fig. 2). Ilmenite is also poikilitic. Mineral clasts are abundant (mostly plagioclase), but lithic clasts are rare. Warner et al. (1977) give the mineral mode of the matrix of 77545 as 53.2% plagioclase, 44% pyroxene/olivine, and 1.6% ilmenite.

Pigeonite oikocrysts in the matrix of 77545 are large (up to 1 mm) and form an interlocking network throughout the matrix.

MINERAL CHEMISTRY

The composition of pyroxene, olivine, ilmenite, and plagioclase is given in Warner et al. (1978) (Fig. 3). Engelhardt (1979) has also studied the ilmenite in 77545.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the composition of 77545 (Table 1). The major element analyses of the sample studied by Laul and Schmitt do not agree with those of Warner et al. (1977) for the matrix. Wasson et al. (1977) repeated the analyses and found that 77545 was typical of the Apollo 17 impact melt rocks (Fig. 4).

SIGNIFICANT CLASTS

Warner et al. (1977) studied a large (6 x 6 mm) angular dunite clast in 77545. The clast has a coarse granoblastic texture, with 0.5 to 1 mm size olivine grains intersecting at near 120 deg triple junctions. The clast has been shocked, resulting in undulous extinction of the olivine grains and minor recrystallization along fractures. The olivine is Fo_{89} with minor amounts of chromite located along the olivine-olivine grain boundaries. This clast has not been analyzed.

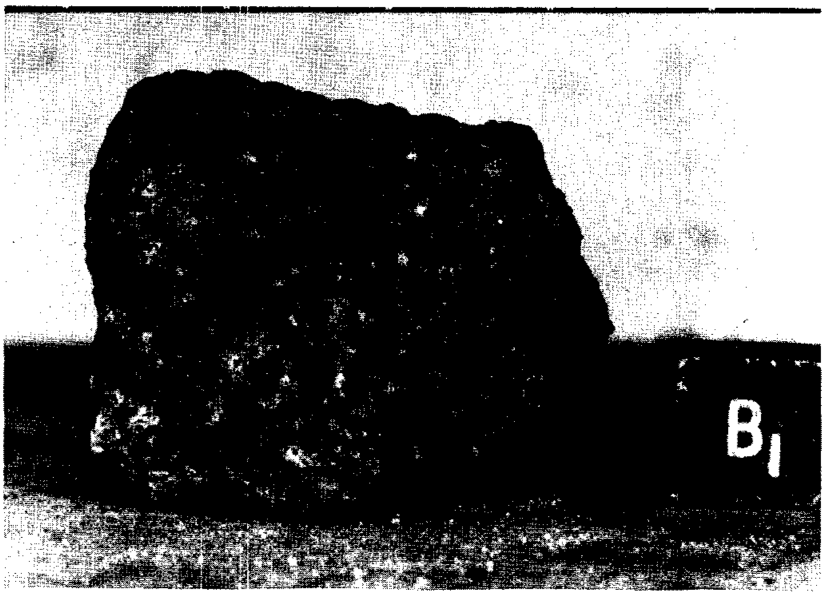


Figure 1: Photograph of 77545. Cube is 1 mm. S73-19128.

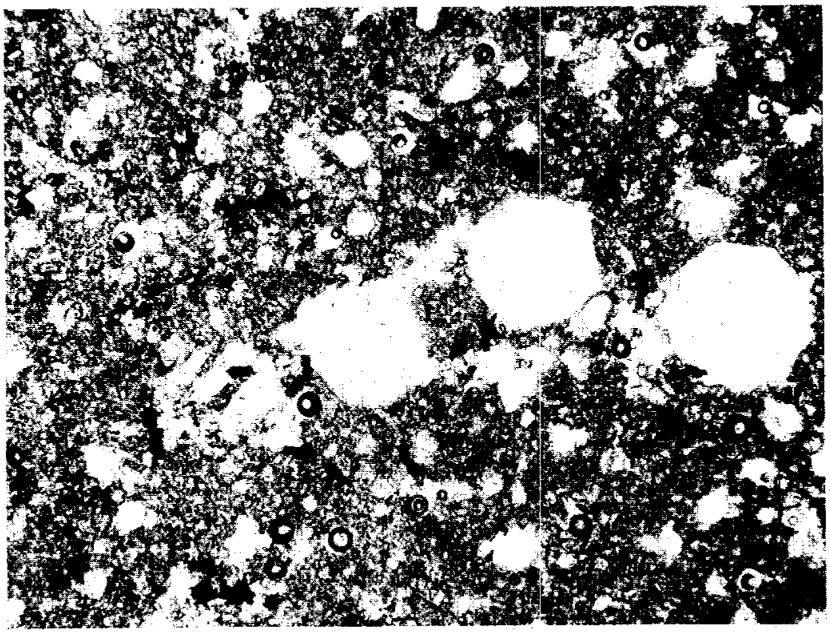


Figure 2: Photomicrograph of thin section 77545,8, showing poikilitic matrix and large vesicles. Field of view is 3 x 4 mm.

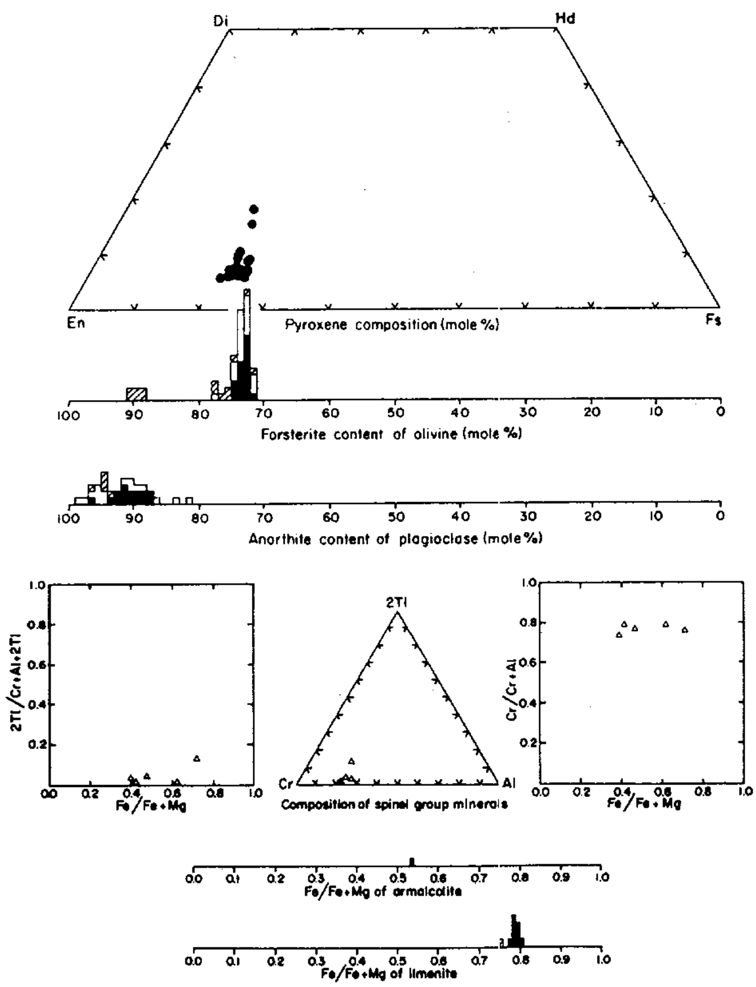


Figure 3: Compositions of minerals in 77545. From Warner et al. (1978).

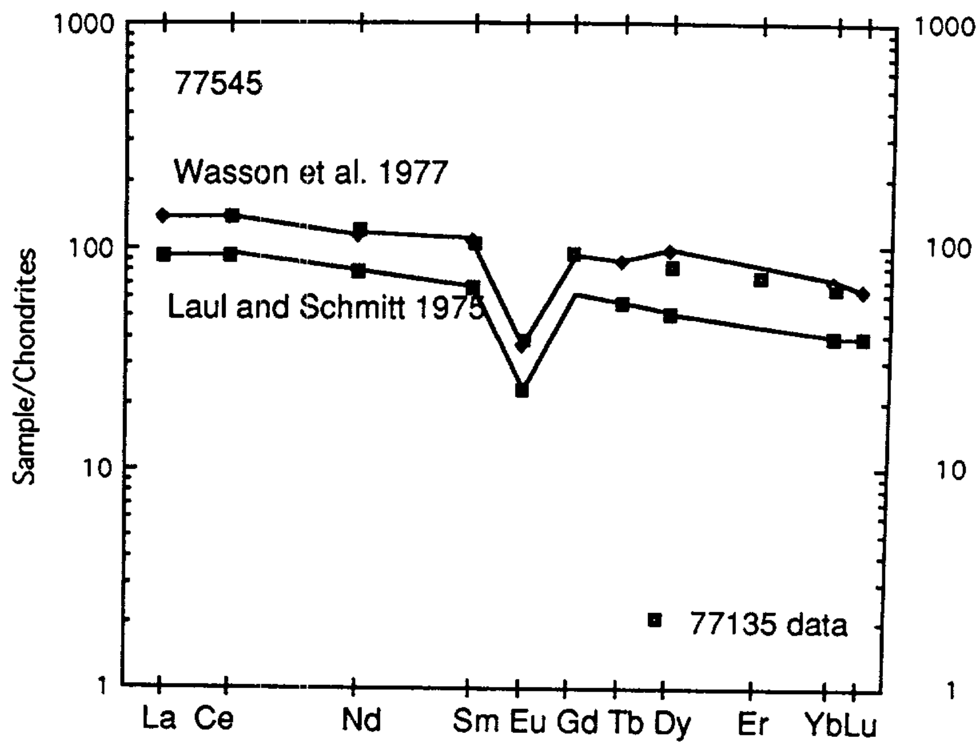


Figure 4: Normalized rare earth element diagram for 77545 with 77135 data for comparison. The data of Laul and Schmitt (1975) do not agree with those of Wasson et al. (1977).

Table 1: Whole-rock chemistry of 77545.
a) Laul and Schmitt (1975); b) Warner et al. (1977); c) Wasson et al. (1977)

Split Technique	,1 (a) INAA	matrix (b) BB e-probe	,3 (c) INAA
SiO_2 (wt%)	–	49.6	–
TiO_2	1.2	0.77	1.52
Al_2O_3	10.9	17.7	18.7
Cr_2O_3	0.52	0.19	0.20
FeO	10.3	7.4	8.89
MnO	0.11	0.11	–
MgO	10	11.5	12.9
CaO	6.6	11.4	11.06
Na_2O	0.47	0.72	0.71
K_2O	0.14	0.21	0.24
Nb (ppm)			
Zr	240		560
Hf	8.2		11.8
Ta	1		1.4
U	0.9		1.4
Th	3.2		5.4
Ba	220		340
Ni	600		60
Co	67		13.5
Sc	11		17
La	21.5		32.2
Ce	55		82
Nd	35		51
Sm	9.8		15.4
Eu	1.3		2.00
Gd			
Tb	2		3.1
Dy	12		23
Er			
Yb	6.3		11
Lu	0.94		1.52
Ge (ppb)			
Ir	7		1.0
Au	2		0.8

78135
High-Ti Mare Basalt
133.9 g, 5 x 4 x 3 cm

INTRODUCTION

Sample 78135 is a medium-grained, ilmenite-rich mare basalt collected from the regolith at Station 8 (Fig. 1).

PETROGRAPHY

Brown et al. (1975a) gives the modal mineralogy of 78135 as 0.4% olivine, 24.4% opaques, 20.6% plagioclase, 50.7% pyroxene, and 4% silica. Plagioclase and pyroxene are intergrown in a variolitic texture (Fig. 2).

MINERAL CHEMISTRY

Brown et al. (1975a) report a "new" Zr-rich mineral in 78135 that is closely related in composition to terrestrial zirkelite.

WHOLE-ROCK CHEMISTRY

Rhodes et al. (1976a) measured the chemical composition of 78135 (Table 1 and Fig. 3). Gibson et al. (1976) determined the sulfur content. Keith et al. (1974) and Fruchter et al. (1975) determined the K, U, and Th contents of Apollo 17 samples, including 78135 (Table 2).

Rhodes et al. classify 78135 as a Type U basalt, but the trace element data indicate that it may be Type A (see appendix).

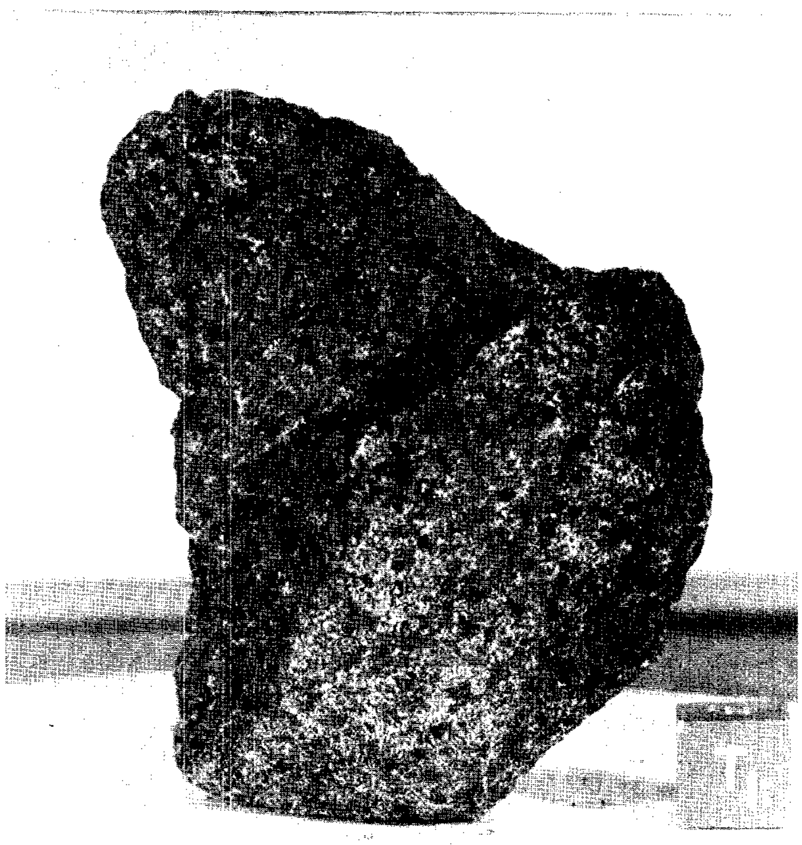


Figure 1: Photograph of 78135. Scale is 1 cm. S73-15003.

RADIOGENIC ISOTOPES

Nyquist et al. (1976) have reported Rb-Sr data for the whole rock (Table 3).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Some of the Apollo 17 samples (including 78135) provided a unique opportunity to study the energy spectrum (and potential angular anisotropy) of the incident proton flux from the August 1972 solar flare (Rancitelli et al., 1974; Keith et al., 1974). Table 2 compares the induced activity of 78135 with other samples of Apollo 17 (see also table in 76215).

Drozd et al. (1977) have determined an exposure age of 126 m.y. for 78135 using the ^{81}Kr-Kr method.

SURFACE

Part of the surface of 78135 is covered with a thin film of dark glass.

PROCESSING

The largest remaining piece of 78135 weighs 83 g. There are only three thin sections.

Figure 2: Photomicrograph of thin section 78135,27. Field of view is 3 x 5 mm.

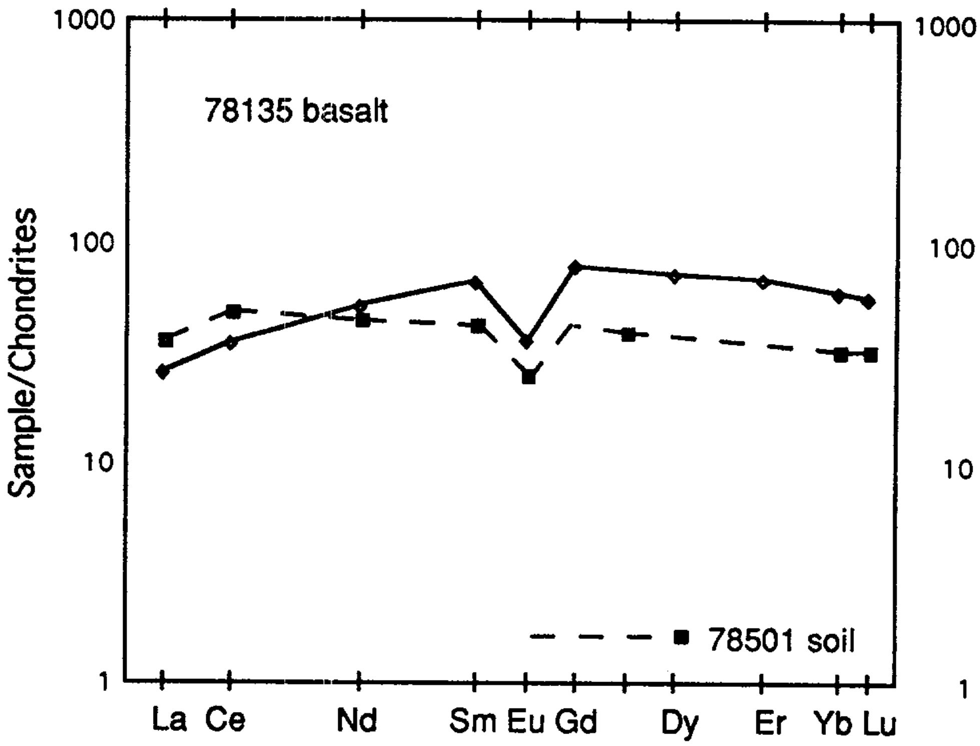


Figure 3: Normalized rare earth element diagram for 78135 basalt compared with 78501 soil. Data from Rhodes et al. (1976a).

Table 1: Whole-rock chemistry of 78135.
From Rhodes et al. (1976a).

Split **Technique**	**,5** **XRF, IDMS, *INAA***
SiO_2 (wt%)	37.98
TiO_2	12.89
Al_2O_3	8.38
Cr_2O_3	0.45
FeO	19.05
MnO	0.27
MgO	8.69
CaO	10.71
Na_2O	0.36
K_2O	0.05
P_2O_5	0.04
S	0.18
Nb (ppm)	
Hf	*9.3*
Sr	174
Rb	0.58
Li	9.2
Ba	74.1
Ni	
Co	*18.4*
Sc	*84*
La	5.8
Ce	20.2
Nd	22.4
Sm	9.43
Eu	1.93
Gd	14.9
Tb	
Dy	17
Er	10.5
Yb	9.21
Lu	*1.33*
Ge (ppb)	
Ir	
Au	

Table 2: Solar flare induced activity from large solar flare, August 1972.
From Keith et al. (1974).

	Sample 78135	Sample 78235	Sample 78255
dpm/Kg			
^{26}Al	42 ± 4	77 ± 7	65 ± 6
^{22}Na	74 ± 5	111 ± 8	50 ± 5
^{54}Mn	180 ± 20	55 ± 8	10 ± 5
^{56}Co	240 ± 20	52 ± 9	30 ± 20
^{46}Sc	76 ± 5	1.4 ± .9	<15
^{48}V	18 ± 5	<12	
Th (ppm)	.26	.59	.83
U (ppm)	.107	.196	.227
K (%)	.0525	.049	.059

Table 3: Rb-Sr composition of 78135.
Data from Nyquist et al. (1976).

Sample	78135,5
wt (mg)	50
Rb (ppm)	0.584
Sr (ppm)	174
$^{87}Rb/^{86}Sr$	0.0097 ± 3
$^{87}Sr/^{86}Sr$	0.69969 ± 6
T_B	4.25 ± 0.56
T_L	4.74 ± 0.56

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

78155
Feldspathic Granulitic Impactite
401.1 g, largest piece 6.5 x 4.5 x 3.0 cm

INTRODUCTION

Sample 78155 is a friable white cataclasite that was found in a small "pit crater" (1 meter) in the wall of a 15-meter crater at Station 8. The sample itself may have been the projectile that made the small "pit crater." It appears to be exotic to the site because other pieces of it were not found in the nearby rake sample. The transcript shows that the astronauts originally collected "one big and several small in bag 567" and recognized that it was very friable. The big piece apparently broke up along the arduous way to Houston (Fig. 1)!

Sample 78155 is important because its clast population reveals the nature of rocks that resided at or near the lunar surface before 4.2 b.y. (Bickel, 1977, and Warner et al., 1977).

PETROGRAPHY

Bickel (1977) describes 78155 as a holocrystalline, weakly coherent polymict breccia that has been thermally metamorphosed at a high temperature (1100 °C). Warner et al. (1977) group it with other rocks from the early lunar crust as "feldspathic granulitic impactites." Lindstrom and Lindstrom (1986) have also discussed the polymict nature of 78155.

Table 1, from Bickel (1977), shows the complexity of 78155 based on his study of a number of thin sections. Roughly 65% of the rock is granoblastic matrix with another 20% "crushed material." The mineralogical mode of the matrix is ~75% plagioclase (An_{95}), and ~25% mafic silicates (mostly pigeonite $Wo_{10}En_{62}Fs_{18}$) with trace olivine ($Fo_{60\text{-}65}$), augite, and opaques. Figs. 2 and 3 illustrate the granoblastic matrix next to a polygonal anorthosite clast.

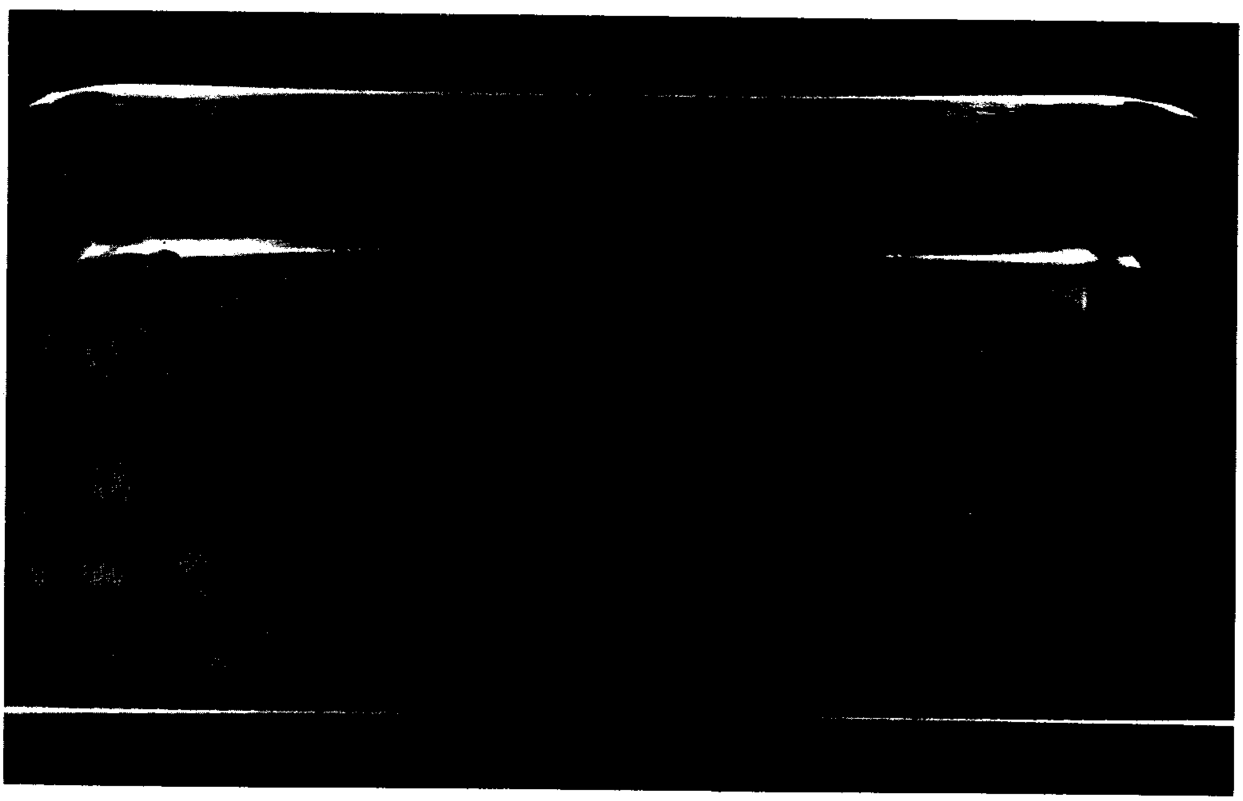


Figure 1: Photograph of 78155. The largest sample is about 6.6 cm. S73-15408.

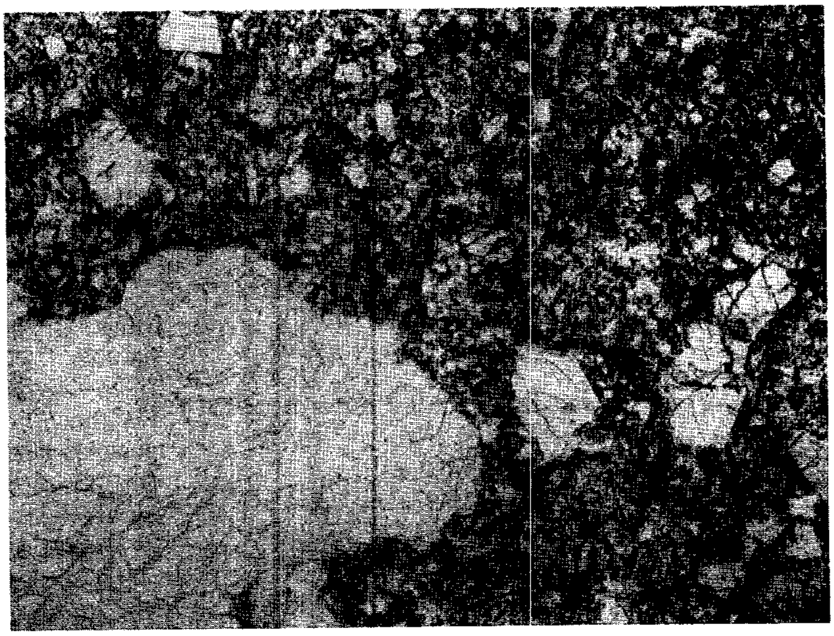


Figure 2: Photomicrograph of thin section 78155,48. Field of view is 3 x 4 mm.

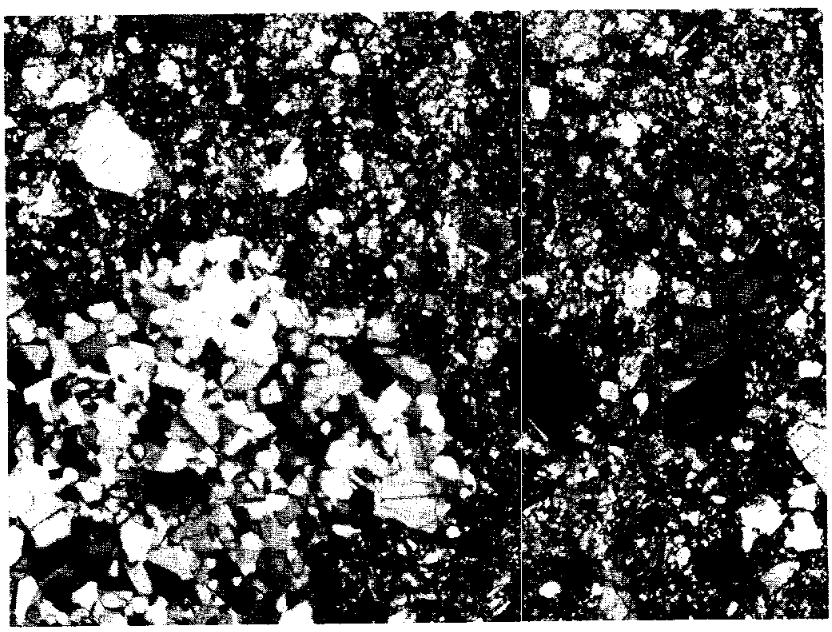


Figure 3: Same area of thin section as Fig. 2, but with partially crossed polarizers showing the granoblastic texture of the matrix and the polygonal texture of the plagioclase clast.

A variety of lithic clasts from the highlands are described by Bickel (1977). Most of the lithic clasts have mineral compositions like those of the matrix (relatively Fe-rich pyroxene), but a few clasts have more Mg-rich pyroxene (Fig. 4). Type I clasts are fine-grained anorthosites with a felty texture in which the interstices between tabular plagioclase are occupied by crystals of pigeonite and olivine. Type II lithic clasts in 78155 are coarse grained and display a range in composition (40-80% plagioclase; the major mafic mineral is olivine in some, low-Ca pyroxene in others, and augite in one) and texture (subophitic, poikiloblastic, and granoblastic).

Evidence of temperatures in excess of 1100 °C during the metamorphism of breccia 78155 are inferred from coexisting uninverted pigeonite and low-Ca augite (Bickel, 1977) and equilibrated olivine and ilmenite (Anderson and Lindsley, 1979).

MINERAL CHEMISTRY

Mineral compositions are given in Bickel (1977). The average plagioclase composition in 78155 is $Or_{0.8}Ab_{4.7}An_{94.5}$, with a narrow range from An_{91} to An_{97} (Fig. 5). Average pyroxene is $Wo_{10}En_{61}Fs_{29}$ (Fig. 4). Note that pyroxene with less than Wo_5 is exceedingly rare in this piece of the early lunar crust (although it is common in impact melt breccias from the 3.9 b.y. event). Olivine also has a limited range of composition (Fo_{62-65}). Engelhardt (1979) has studied the ilmenite in 78155.

Hewins and Goldstein (1975) studied the provenance of iron metal in 78155 (Fig. 6). They found that the Ni and Co contents were intermediate between those of the coarse-grained lunar anorthosites and anorthositic "remelts." Again, there is a rather narrow range in metal composition.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1973), Hubbard et al. (1974), Wanke et al. (1976), and Lindstrom and Lindstrom (1986) have analyzed 78155 (Table 2 and Fig. 7). Moore et al. (1974) and Gibson and Moore (1974) reported sulfur abundance and Brett (1976) discussed reduction by sulfur loss.

Morgan et al. (1974) have determined the trace siderophile and volatile elements (Table 3). Morgan et al., Wanke et al., and Lindstrom and Lindstrom have all found high Ir (3, 4, and 8 ppb, respectively), indicating that this rock is not pristine. This is consistent with the relatively high Ni content of the metal.

SIGNIFICANT CLASTS

So far, clast studies have been limited to small clasts in thin sections.

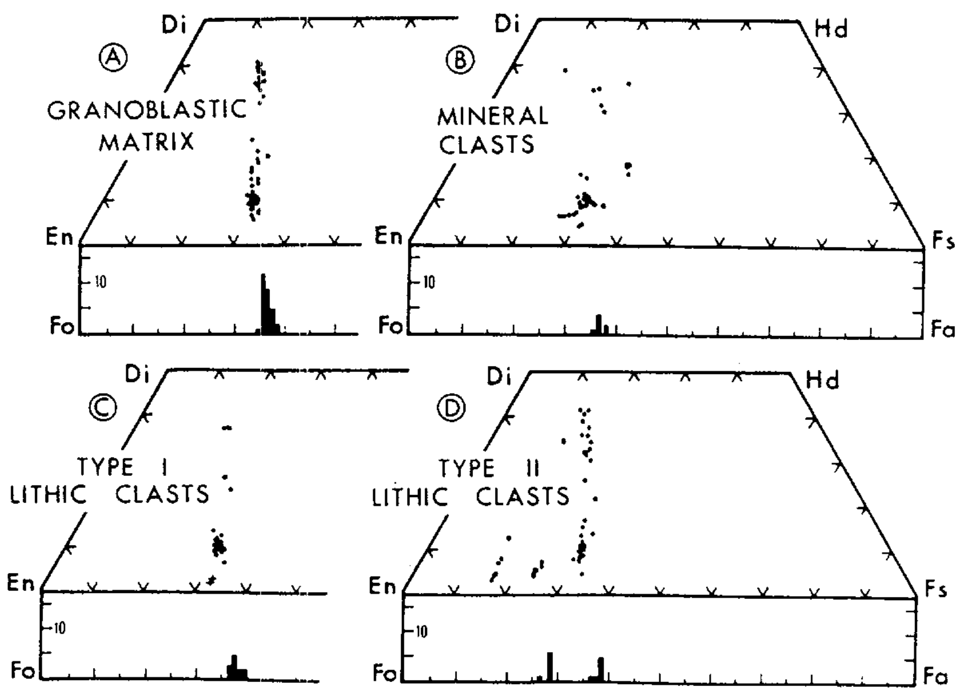


Figure 4: Pyroxene compositions in matrix and in clasts in 78155. From Bickel (1977).

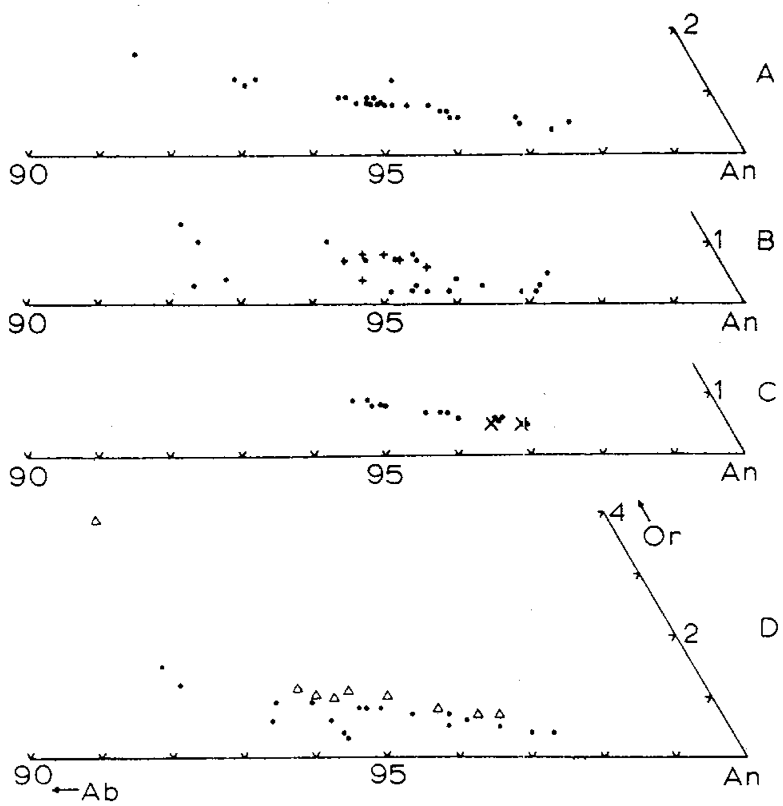


Figure 5: Plagioclase composition in 78155. A is plagioclase in the matrix, B is small plagioclase clasts, C is Type I lithic clasts, and D is Type II lithic clasts. From Bickel (1977).

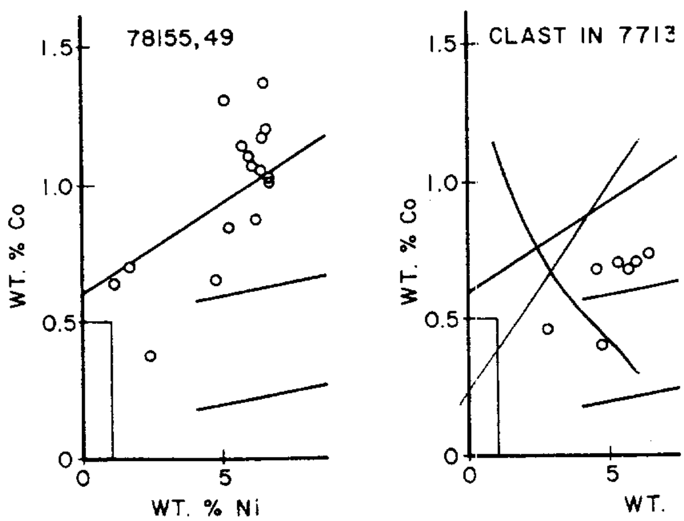


Figure 6: Composition of metal grains in 78155. From Hewins and Goldstein (1975).

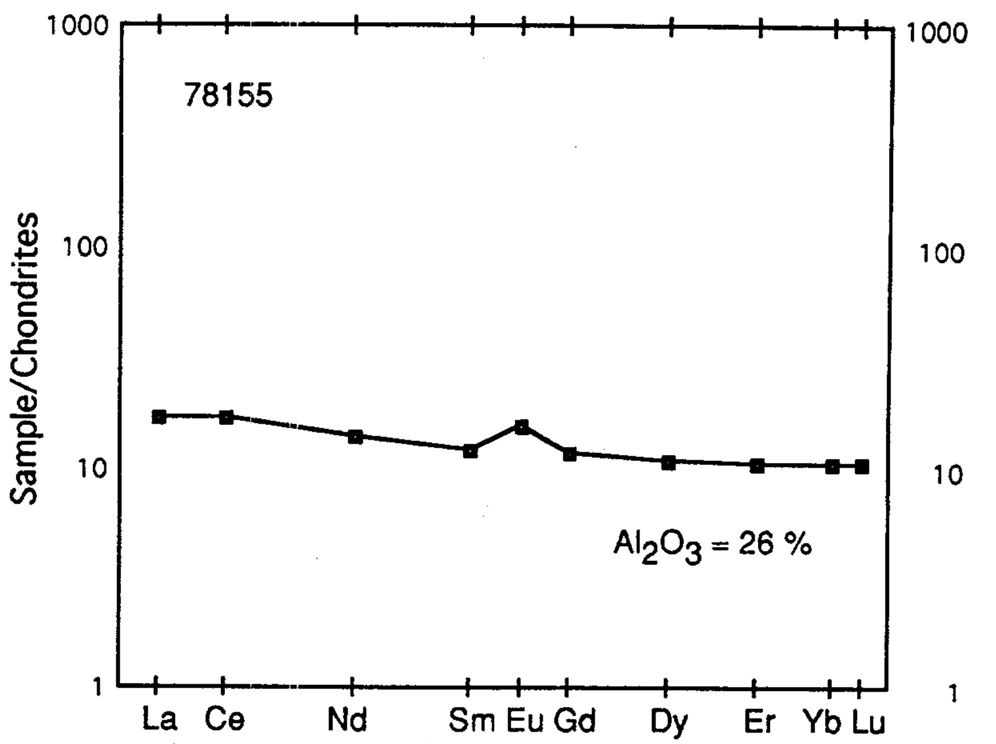


Figure 7: Normalized rare earth element diagram for 78155. Data from Hubbard et al. (1974).

COMETS ?

Sill et al. (1974) studied the carbon content of 78155 with the hope of finding evidence of a cometary contribution to breccia 78155. They found that 78155 was the most volatile-rich of all samples studied. The CO_2, CO, and CH_4 content represented 267 ppm carbon. Hydrocarbons (exclusive of CH_4) were present in approximately 60 ppm quantity; the most abundant ion was m/e = 43. This sample also outgassed hydrogen cyanide (~5 ppm) and hydrogen sulfide (~6 ppm).

RADIOGENIC ISOTOPES

Turner and Cadogan (1975a) determined a ^{39}Ar-^{40}Ar plateau age of 4.22 ± 0.04 b.y., identical to its total Ar age (Fig. 8). Oberli et al. (1979) confirmed this Ar age with a plateau of their own at 4.17 ± 0.03 b.y. (Fig. 9). Using acid-leaching experiments, Oberli et al. were also able to obtain a $^{207}Pb/^{206}Pb$ age of 4.17 ± 0.02 b.y. (Fig. 10). Nunes et al. (1974 and 1975) also studied the U-Pb systematics of 78155 (Table 4), but there were too many different Pb components and Pb loss events to obtain a unique U/Pb age. However, there is evidence from these studies that the early Moon had a high U/Pb ratio.

Nyquist et al. (1974) (Table 5), Murthy and Coscio (1977), and Murthy (1978) have determined the Rb/Sr ratio and Sr isotopes in 78155. These studies did not yield Rb/Sr ages, but they did set limits on the initial Sr isotopic ratio for the Moon.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Drozd et al. (1977) have determined an exposure age of 22 m.y. for 78155 using the ^{81}Kr-Kr method, and Turner and Cadogan (1975) determined an exposure age of 30 m.y. by the Ar exposure age technique.

MAGNETIC STUDIES

Nagata et al. (1974 and 1975) reported the intensity of saturation magnetization for 78155. Hargraves and Dorety (1975) have also attempted to study the remanent magnetism of 78155.

SURFACE STUDIES

Adams and Charette (1975) have determined the reflectance spectra of 78155 (Fig. 11). Note the deep pyroxene absorption band at 0.91 μm. This absorption band appears deeper than for rocks with high contents of pyroxene!

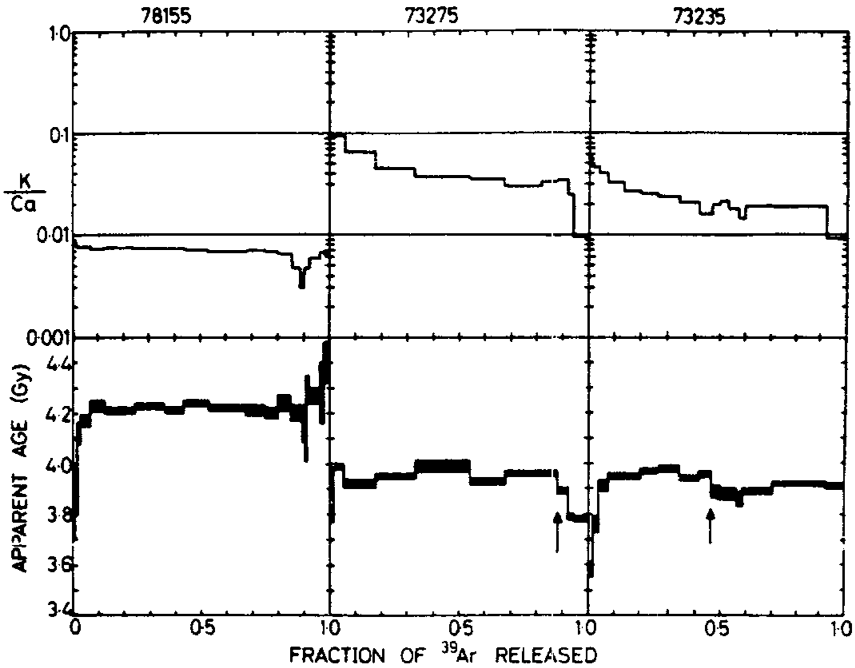


Figure 8: ^{39}Ar-^{40}Ar plateau age of 78155 (4.22 ±0.04 b.y.). Note the flat pattern for all temperatures. From Turner and Cadogan (1975a).

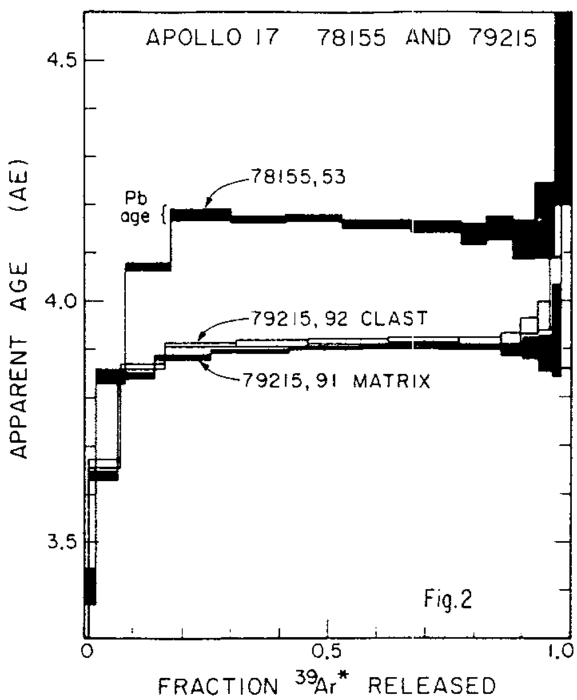


Figure 9: ^{39}Ar-^{40}Ar plateau age of 78155 (4.17 ±0.03 b.y.). Note the agreement with Turner and Cadogan. From Oberli et al. (1979).

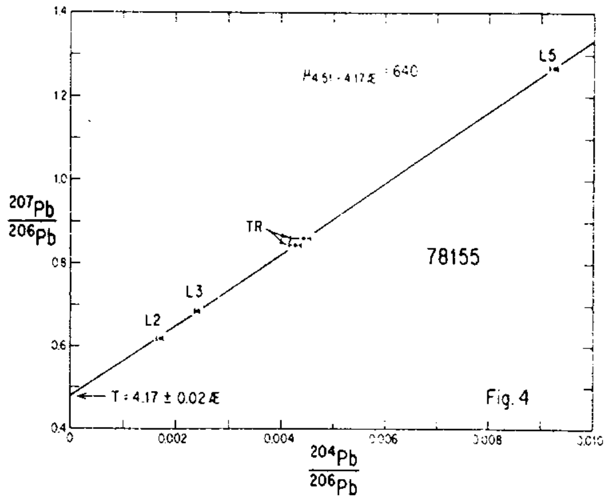


Figure 10: $^{207}Pb/^{206}Pb$ diagram for 78155. Note the age of 4.17 ±0.02. From Oberli et al. (1979).

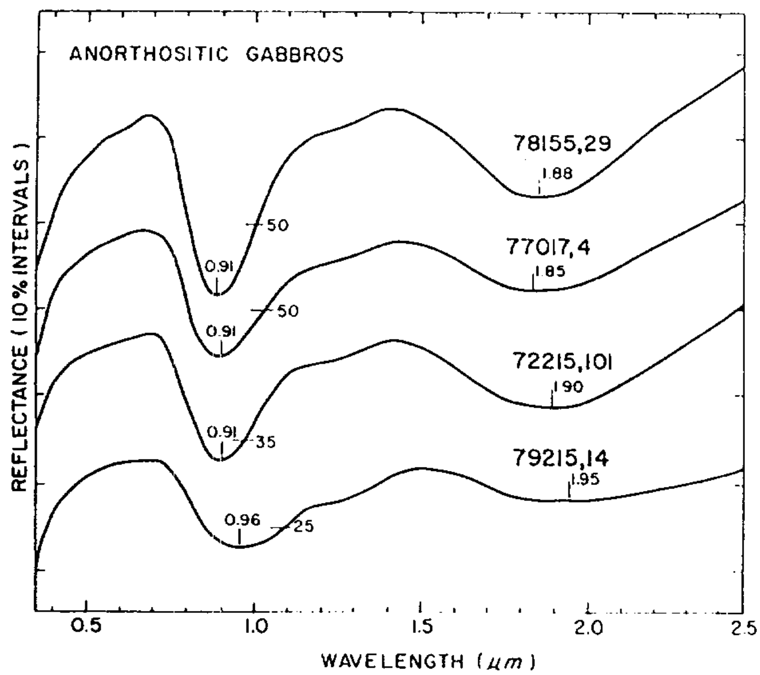


Figure 11: Reflectance spectra of 78155. From Adams and Charette (1975).

Table 1: Lithology of 78155.
From Bickel (1977).

Lithology	Approximate % of rock*	Maximum size of fragment or clast (mm)#	Grain size (μm)
Granoblastic matrix	65	4.6 x 3.0	Anorthite: 20-100, mafic silicates: 2-40, oxides: 0.5-75
Mineral clasts			
Anorthite	10	3 x 2	–
Pyroxene †	3	0.8 x 0.6	–
Olivine	< 1	0.6 x 0.2	–
Polymineralic lithic clasts			
Fine-grained, felty textured anorthosite (Type I)	1-2	2.8 x 1.0	Finer grained: Anorthite: 8 x 40 to 16 x 80; mafic silicates: 8 x 12 Coarser grained: Anorthite: 20 x 160 to 30 x 200; mafic silicates: 15 x 25, wedge shaped up to 60 μm long
Annealed Type I	1-2	1.2 x 0.8	Same as Type I, but with greater range in sizes of mafic silicates
Medium and coarse grained (Type II)	< 1	1.5 x 1.0	See Table 3
Crushed material	20	0.1	Angular fragments ≤ 100 μm across

*Mode based on visual estimates and limited point counting.
#All the constituents are seriate in size.
†Pigeonite is much more abundant than augite.

Table 2: Chemical composition of 78155.
a) LSPET; b) Wiesmann and Hubbard (1975); c) Hubbard et al. (1974); d) Laul and Schmitt (1973); e) Wanke et al. (1976); f) Lindstrom and Lindstrom (1986)

Split Technique	,2 (a, b, c) XRF, IDMS	,57 (d) INAA	,127 (e) INAA	,137 (f) INAA
SiO_2 (wt%)	45.57	–	45.35	–
TiO_2	0.27	0.22	0.29	0.32
Al_2O_3	25.94	26.2	25.34	26.0
Cr_2O_3	0.14	0.12	0.14	0.14
FeO	5.82	5.3	5.63	5.62
MnO	0.10	0.076	0.085	–
MgO	6.33	6.2	6.42	6.2
CaO	15.18	15.2	15.19	15.2
Na_2O	0.33	0.39	0.38	0.39
K_2O	0.08	0.07	0.073	–
P_2O_5	0.04	–		
S	0.04	–		
Nb (ppm)	4.8		2	
Zr	59	–	54	48
Hf		1.4	1.49	1.42
Ta		0.23	0.25	0.22
U	0.28	0.4	0.24	0.25
Th	1.01	0.9	0.84	0.86
W			0.104	
Y	16		16	
Sr	147		141	165
Rb	2.061		2.01	–
Li	5.2		4.8	
Ba	58.8	50	63.6	61
Cs			0.11	0.103
Zn	4		4.13	
Cu			4.52	
Ni	53	90	80	100
Co		14	14.3	15.8
Sc		11	13.3	12.9
La	4.02	4.3	4.28	3.98
Ce	10.2	12	11.3	9.9
Nd	6.29	8	7.3	5.7
Sm	1.81	1.9	1.69	1.74
Eu	0.874	0.9	0.862	0.835
Gd	2.32		2.3	

Table 2: (Concluded).

Split Technique	,2 (a, b, c) XRF, IDMS	,57 (d) INAA	,127 (e) INAA	,137 (f) INAA
Tb		0.35	0.39	0.41
Dy	2.64	2.3	2.63	
Er	1.69		1.90	
Yb	1.73	1.7	1.83	1.57
Lu	0.259	0.23	0.271	0.244
Ga			2.91	
F			15	
Cl			6.9	
Re (ppb)			0.24	
Ir		–	3.9	8
Au		–	0.68	

Table 3: Trace element data for 78155.
a) Morgan et al. (1974); b) Wanke et al. (1976)

	Sample 78155,30 (a)	Sample 78155,127 (b)
Ir (ppb)	3.32	3.9
Os (ppb)		
Re (ppb)	0.278	0.24
Au (ppb)	0.66	0.68
Ni (ppm)	68	80
Sb (ppb)	20.4	
Ge (ppb)	27	
Se (ppb)	49	60
Te (ppb)	3.2	
Ag (ppb)	1	
Br (ppb)	65	68
Bi (ppb)	0.29	
Zn (ppm)	2.3	4.13
Cd (ppb)	63	
Tl (ppb)	5.9	
Rb (ppm)	1.76	2.01
Cs (ppb)	84	110
U (ppb)	250	240

Table 4: U-Th-Pb composition of 78155.
From Nunes et al. (1974).

Split	78155
wt (mg)	112.1
U (ppm)	0.2683
Th (ppm)	0.9352
Pb (ppm)	0.8513
$^{232}Th/^{238}U$	3.60
$^{238}U/^{204}Pb$	165

Table 5: Rb-Sr composition of 78155.
Data from Nyquist et al. (1974).

Sample	78155,2
wt (mg)	51.6
Rb (ppm)	2.06
Sr (ppm)	146.7
$^{87}Rb/^{86}Sr$	0.0406 ± 4
$^{87}Sr/^{86}Sr$	0.70164 ± 6
T_B	4.37 ± 0.14
T_L	4.48 ± 0.14

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

Station 8 Boulder

Station 8 at Apollo 17 was located at the base of the Sculptured Hills, although it was located only about 20 meters above the valley floor and within the zone mapped as dark mantle in detailed pre-mission maps (Jackson et al., 1975). The small boulder at Station 8 was selected for sampling because it was perched on the surface. However, it had no boulder track leading up the mountain, and its glass coating may mean that it was delivered to the location as a "bomb" (Wolfe and others, 1981). Fig. 1 is a planimetric map of Station 8 showing the location of the samples collected.

The boulder dimensions are about 30 x 55 x 55 cm (Fig. 2). The astronauts rolled the Station 8 Boulder completely over and then chipped samples of the original top surface to get pieces 78235, 78236, 78237, and 78238. These fell in the dirt, where they were collected along with some soil (78230). Samples 78235 and 78237 were found to fit together, so were combined. 78236 was located a few centimeters away from where 78235 was chipped. Samples 78255 and 78256 were taken from the original bottom surface of the boulder after it had been rolled further and were also collected with dirt. In the laboratory, 78255 and 78256 were found to fit together, so 78256 was relabeled as a part of 78255. 78255 had a lower solar flare–cosmic ray induced activity, as would be expected because of the shielding by the boulder from the solar flare. However, the glass coating on 78255 had numerous micrometeorite craters (Butler, 1973), indicating that it had been on top at one time. The astronauts noted how easy it was to roll the boulder on the slope where it was located.

All of the samples from the boulder have the same norite lithology, although the 78255 sample may have more plagioclase. The boulder is coarse grained (~5-10 mm) with about 50% yellow-tan orthopyroxene and 50% blue-grey plagioclase. Distinct structural features such as foliations and fracture planes, as well as branching glass veins, are conspicuous features of the boulder and the samples taken from it (Jackson et al., 1975).

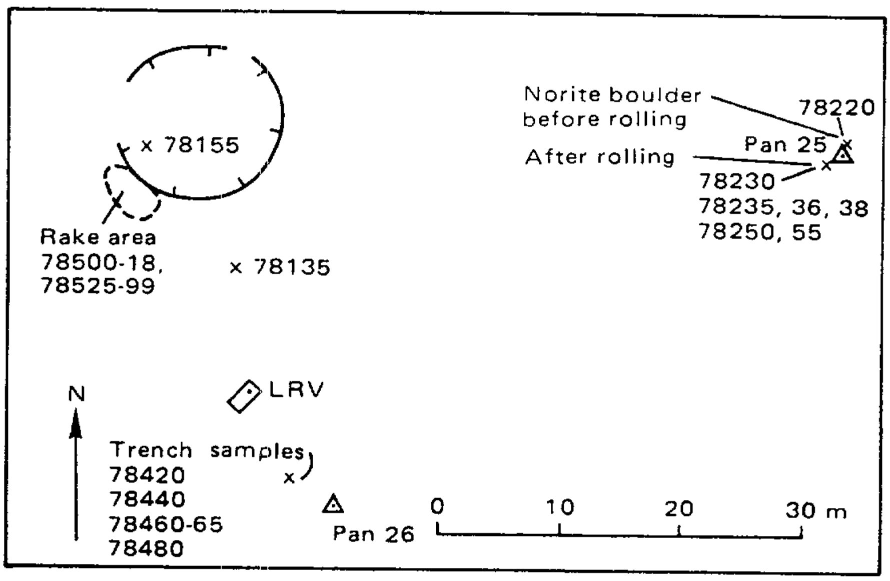


Figure 1: Planimetric map of Station 8. From Wolfe and others (1981).

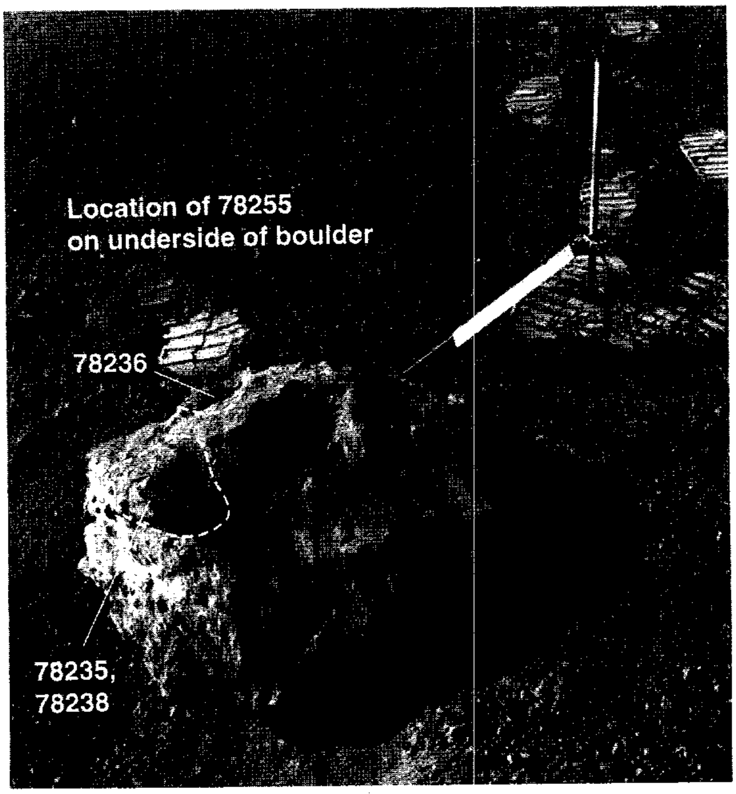


Figure 2: Photograph of the Station 8 Boulder showing location of samples. AS17-146-22370.

This boulder is one of the oldest samples from the Moon. Its original crystallization age is about 4.4 b.y. The following summary of the crystallization ages for samples of this rock is from Nyquist and Shih (1992).

Summary of Age Determinations

	^{39}Ar-^{40}Ar	Rb-Sr	Sm-Nd	U-Pb
78235				4.426 ± 0.065 (a)
78236	4.39 (b)	4.38 ± 0.02 (b)	4.43 ± 0.05 (b)	
	4.11 ± 0.02 (d)		4.34 ± 0.04 (c)	

(a) Premo and Tatsumoto (1991); (b) Nyquist et al. (1981); (c) Carlson and Lugmair (1981);
(d) Aeschlimann et al. (1982)

The chemical composition of the norite boulder has been difficult to determine precisely because of the coarse grain size and the small sample allocations (~100 mg) that have been made for chemical analysis. The Al_2O_3 contents reported range from 14 to 27%, indicating variable amounts of plagioclase in the analyzed splits. This is also seen in the range of Eu contents. The low Ir in samples 78235 (Higuchi and Morgan, 1975) and 78255 (Warren and Wasson, 1978) shows that the rock is free of meteorite contamination and is chemically "pristine." The lack of meteorite signature is also indicated by the low Ni in the metallic iron particles in the norite.

Summary of Compositional Data

	Al_2O_3 (wt. %)	Th (ppm)	Ce (ppm)	Eu (ppm)	Reference
78234	14.36	0.62	8.6	0.7	Warren et al. (1987)
78235	20.87		9.2	1.03	Winzer et al. (1975)
		0.59			Keith et al. (1974)
78236	17.66	0.6	12.8	0.82	Blanchard and McKay (1981)
78255	27.40	0.44	7.8	1.21	Warren and Wasson (1979)
		0.83			Keith et al. (1974)

BOULDER HISTORY

Jackson et al. (1975) wrote a suggested history of the norite boulder.

1) Crystallization from a magma, with plagioclase and orthopyroxene on the liquidus. The grain size and texture argue that the depth of crystallization was at least 8 km, and perhaps as much as 30 km.

2) Settling of the plagioclase and orthopyroxene crystals onto a floored chamber under the influence of lunar gravity.

3) Folding of the planer lamination by unknown process, possibly an irregular magma chamber floor.

4) Shock metamorphism, producing maskelynite and fractures.

5) Shock metamorphism, possibly during excavation or possibly during the same event, producing additional fractures and veins.

6) At rest at an unknown location for about 0.75 m.y. with its bottom up, receiving micrometeorite craters on its glass coating.

7) Movement to its discovery site at Station 8, where it rested, with top side up, for an amount of time approximately equal to that at its former site.

8) Rolling and sampling by the Apollo 17 crew. Return to earth. Preliminary examination.

9) Cutting, distribution, dissolution, irradiation, and vaporization. Use for education of students.

FIELD GEOLOGY

Note: During collection of the samples from the Station 8 Boulder by the astronauts, many observations about the lithology of this coarse-grained sample were correctly made, proving that field geology could be done on the Moon—by humans at least. Obvious excitement was noted in their voices.

06 20 20+ CDR "I think I'll get one more swap off there. Well, that disappeared. Get it this way. That disappeared, too? That probably went into orbit. Boy, is that pretty inside. Whoo! We haven't seen anything like this. I haven't. Unless you've been holding out on me."

LMP "No, this is a nice crystalline rock. This is about a 50-50 mixture of what looks like maskelynite or at least blue-grey plagioclase, and a very—let's say light yellow-tan mineral, probably orthopyroxene. It's fairly coarsely crystalline. By coarsely crystalline, probably, the average grain size will turn out to be about 3 or 4 millimeters, maybe half a centimeter."

78235

Shocked Norite

199 g; 4.0 x 5.0 x 5.5 cm, 3.5 x 4.0 x 5.0 cm (2 pieces)

INTRODUCTION

Samples 78235-238 were chipped off the top of the Station 8 Boulder after it had been rolled over completely *(see section on the Station 8 Boulder)*. The chips fell in the dirt, from which they were then collected. The sample bag also included more than 200 g of dirt that may include additional fragments of this important rock. Sample 78237 was combined with 78235 because these two pieces were found to fit together. Samples 78236 and 78238 are also from the top surface of the boulder; 78255 is from the bottom. These samples are all very similar.

Sample 78235 is a heavily shocked plutonic norite of cumulate origin with a glass coating and glass veins (Fig. 1). Some of the glass veins are continuous with the glass coating. The degree of shock was sufficient to convert some of the plagioclase to maskelynite. Except for the glass and the shock features, this rock is a coarse-grained (5-10 mm), pristine, igneous lunar norite (about half plagioclase and half orthopyroxene). It has an initial crystallization age of about 4.4 b.y., making it one of the oldest lunar rocks sampled during the Apollo missions.

PETROGRAPHY

Dymek et al. (1975), McCallum and Mathez (1975), Jackson et al. (1975), Sclar and Bauer (1975 and 1976), Steele (1975), and the astronauts have all described 78235 as a shocked norite. James and Flohr (1983) consider it the best example of the Mg suite of lunar norites (Fig. 2).

78235 has a well-preserved, coarse-grained (5-10 mm) cumulus texture where cumulus plagioclase (~50%) and cumulus orthopyroxene (~50%) form distinct layers (Jackson et al., 1975; McCallum and Mathez, 1975).

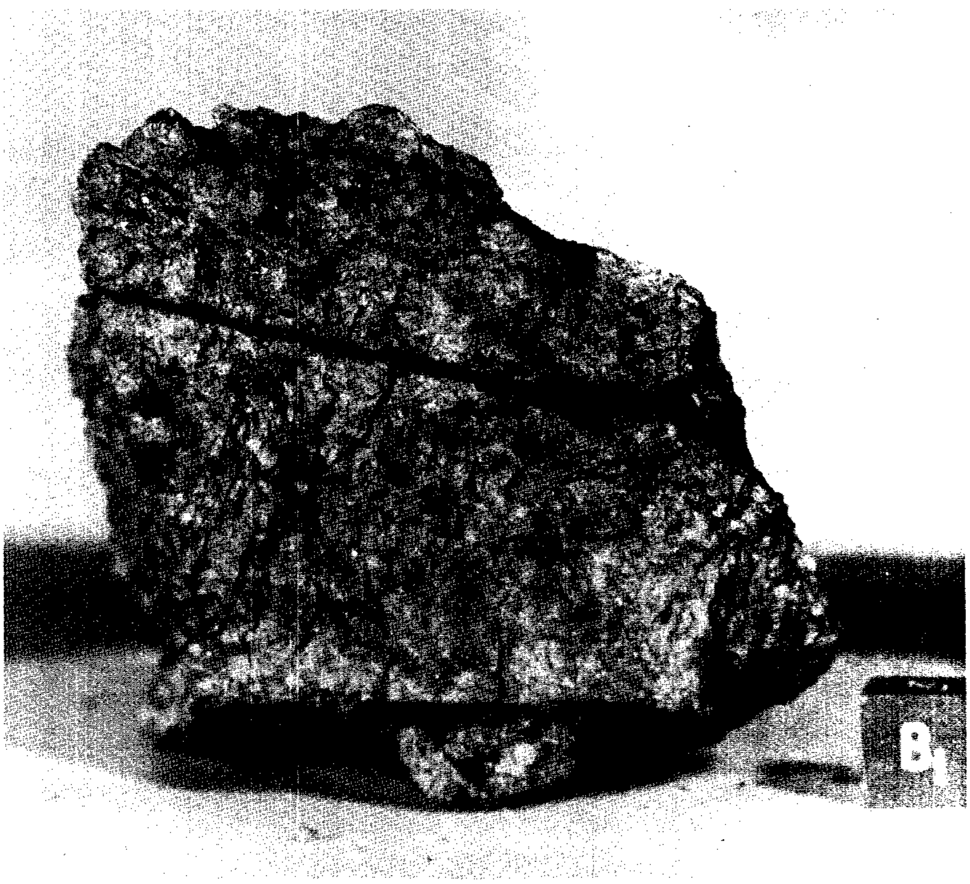


Figure 1: Photograph of 78235. Cube is 1 cm. S73-15180.

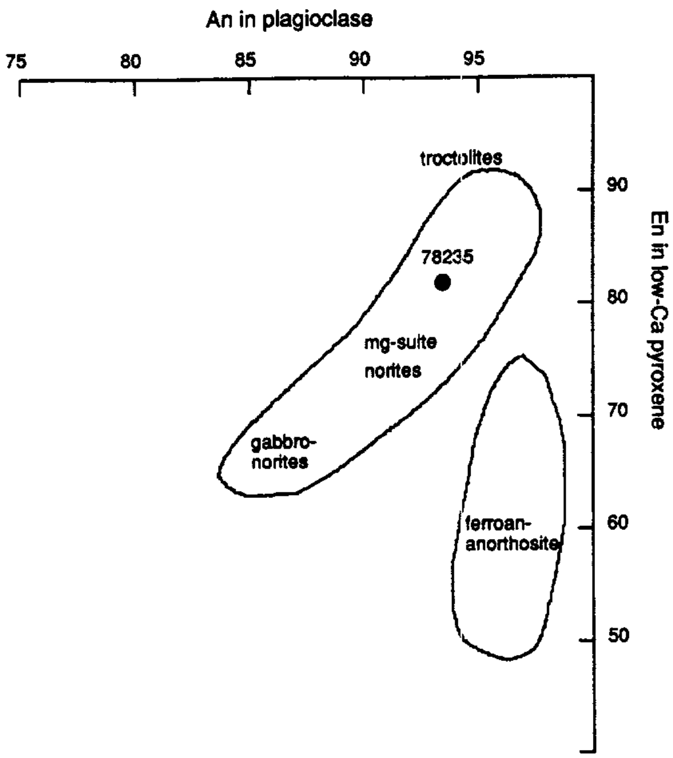


Figure 2: Plagioclase-pyroxene compositional diagram for 78235. 78235 is one of the best examples of the Mg-suite norites. Fields from James and Flohr (1983).

Postcumulus enlargement of these minerals eliminated all but a few percent of the intercumulus liquid. Plagioclase (An_{93-95}) and orthopyroxene ($Wo_3En_{78}Fs_{19}$) are homogeneous, with no compositional variation among cores, rims, and interstitial grains. Interstitial zones contain a remarkable suite of accessory minerals formed at a late stage from a fractionated, trapped liquid. In decreasing order of abundance they are silica, apatite, REE-rich whitlockite, Fe-Ni-Co alloy (Co = 2.6%, Ni = 2.4%), diopside, chromite, troilite, niobian rutile, zircon, and baddeleyite.

Sporadically distributed through the orthopyroxene and localized in the pyroxene at specific sites along orthopyroxene-plagioclase interfaces are ameboid patches and veinlets. These consist of the four-phase assemblage iron-chromite-diopside-silica (Sclar and Bauer, 1975 and 1976). This mineral assemblage is probably just part of the mesostasis of the cumulate (McCallum and Mathez; ElGoresy et al., 1976), but Sclar and Bauer argued that it had a shock origin.

The rock has been heavily shocked, resulting in partial destruction of the original cumulus texture in some areas. Plagioclase has been partially maskelynitized and locally even melted, while the orthopyroxene shows undulatory extinction, cracking, and mosaicism. Some of the cracking of the pyroxene is obviously due to the expansion of the partially maskelynitized plagioclase (Fig. 3). A brown, vesicular, partially devitrified glass fills fractures in the rock. Flow banding in the glass is defined by crystallites of metal and troilite. Spherical globules (~20 μm) of metal and metal plus troilite in the glass have compositions within the meteorite range, indicating meteoritic contamination of the glass.

Sclar and Bauer (1975 and 1976) have studied the shock features in 78235. The presence of maskelynite indicates that the shock pressure was between 300 and 400 kbar, and the occurrence of glass veins may mean that the rock experienced pressures in excess of 500 kbar. Sclar and Bauer (1976) have speculated that fine oriented rods of metallic iron in the plagioclase and maskelynite are due to subsolidus reduction of iron during shock.

MINERAL CHEMISTRY

McCallum and Mathez (1975) and Dymek et al. (1975) have analyzed the minerals in 78235. Pyroxene and

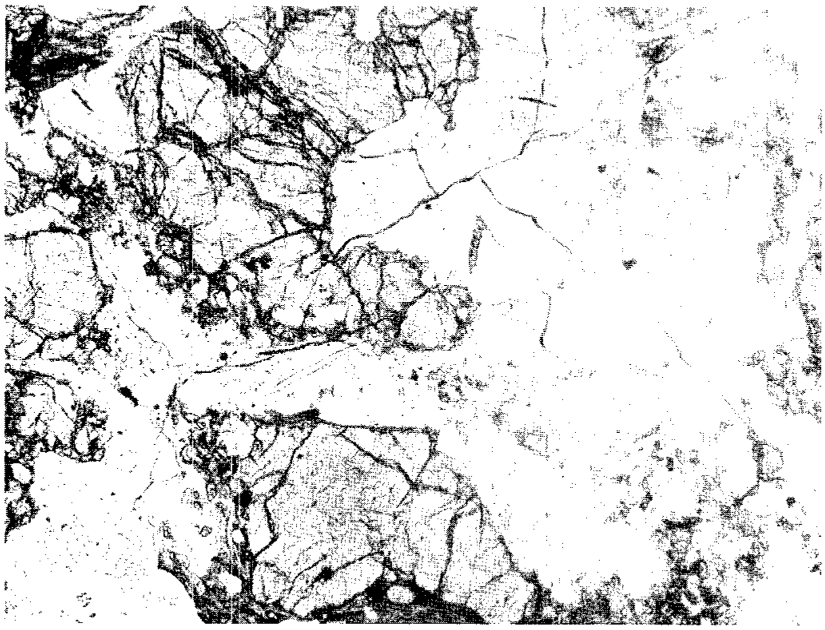


Figure 3: Photomicrograph of thin section 78235,41. Field of view is 3 x 4 mm.

plagioclase are uniform in composition (Figs. 4 and 5). Dymek et al. report high Al, Ti, and Cr in small diopside grains in 78235 ($Wo_{47}En_{45}Fs_8$; Al_2O_3 = 2.86, TiO_2 = 1.01, and Cr_2O_3 = 1.11%). McCallum and Mathez have used the compositions of the pyroxenes to estimate a temperature of equilibration of ~800 °C.

McCallum and Mathez (1975) and Steele (1975) report analyses for whitlockite, apatite, chromite, rutile, and baddeleyite. The Nb content of the rutile is extremely high (~14% by Steele and ~5% by McCallum and Mathez). About 10% of the REE in the rock are tied up in the whitlockite. Nyquist et al. (1981) report a few grains of K-feldspar ($Or_{90.8}Ab_{2.1}An_{7.1}$).

Bersch et al. (1991) precisely determined the composition of the pyroxene. Hansen et al. (1979) and Steele et al. (1980) measured the trace element contents of the plagioclase. Hinthorne et al. (1977), Steele et al. (1980), and Papike et al. (1994) determined the trace elements in plagioclase and pyroxene by ion microprobe analysis. Winzer et al. (1975) measured the compositions of plagioclase and orthopyroxene separates by isotope dilution mass spectroscopy (Fig. 6). Delaney and Sutton (1991) attempted to determine the Fe/Mn ratio in plagioclase in 78235 using the new synchrotron x-ray technique. Palme et al. (1984) discussed trace elements in plagioclase.

McCallum and Mathez, Hewins and Goldstein (1975), and Mehta and Goldstein (1980) have studied the provenance of iron metal in 78235 (Fig. 7; also see figure in section on 78238).

Steele (1975) has shown that orthopyroxene with space group $P2_1ca$ in 78235 means that this rock is of plutonic origin. Takeda et al. (1982) studied the orthopyroxene ($Wo_3En_{76}Fs_{21}$) in 78236 by combined single crystal x-ray diffraction and TEM techniques and showed that there was no augite exsolution with (100) in common. They found abundant Guinier-Preston zones, several unit cells wide, in the pyroxene. Takeda's microstructural data favor Nyquist's thermal model for cooling of 78236 because formation at 4.4 b.y. may have produced exsolution lamellae in the orthopyroxene during cooling below 1000 °C in the lunar crust. Takeda proposed that 78236 was excavated when this rock reached about 1000 °C and then cooled more slowly at moderate temperatures to produce the Guinier-Preston zones.

Irving et al. (1974) also studied orthopyroxene with associated diopside from coarse fines in the soils adjacent to 78235.

WHOLE-ROCK CHEMISTRY

It should be remembered that 78235 is a coarse-grained rock, and that small sample splits of a coarse-grained rock may not represent the whole rock. Winzer et al. (1975) have determined the major element and rare earth element content of the whole rock: glass, pyroxene, and plagioclase separates form their small sample split of 78235 (Table 1, Fig. 8). Blanchard and McKay (1981) have determined the

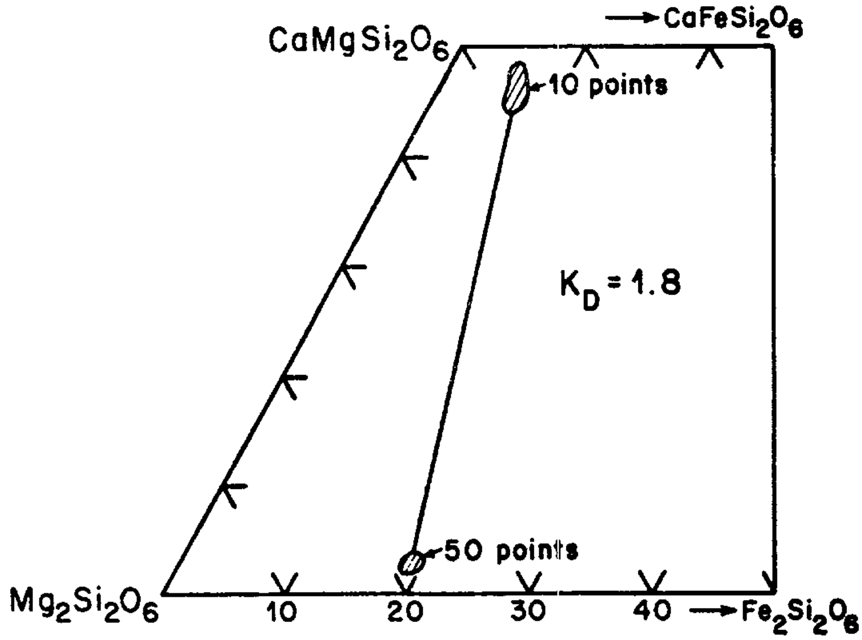


Figure 4: Pyroxene quadrilateral. From McCallum and Mathez (1975).

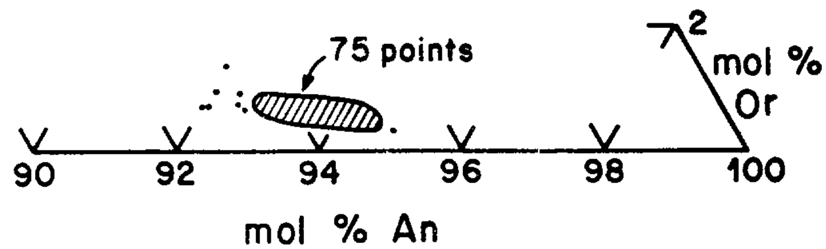


Figure 5: Plagioclase composition diagram. From McCallum and Mathez (1975).

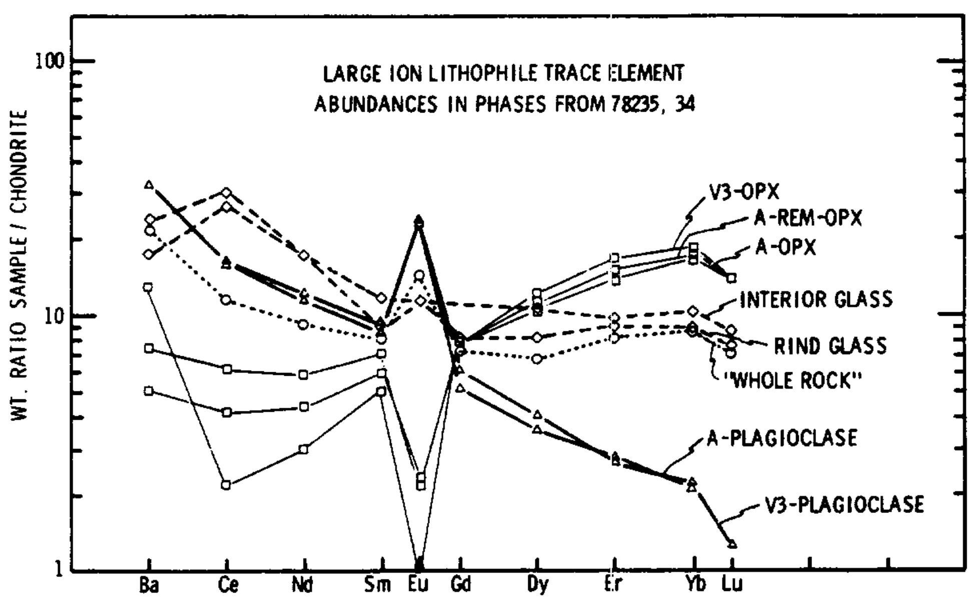


Figure 6: Normalized rare earth element diagram for mineral separates from 78235. From Winzer et al. (1975).

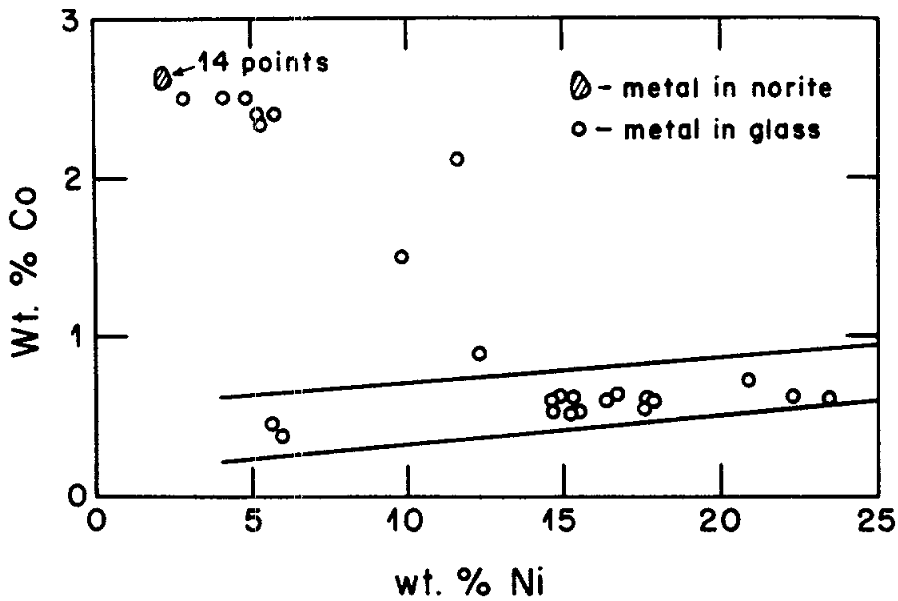


Figure 7: Ni and Co concentrations of metal particles in 78235. The metal grains in the pristine part of the rock have low and uniform Ni contents, while the metal grains in the glass are high in Ni, indicating two different origins for metal in the rock. Data from McCallum and Mathez (1975).

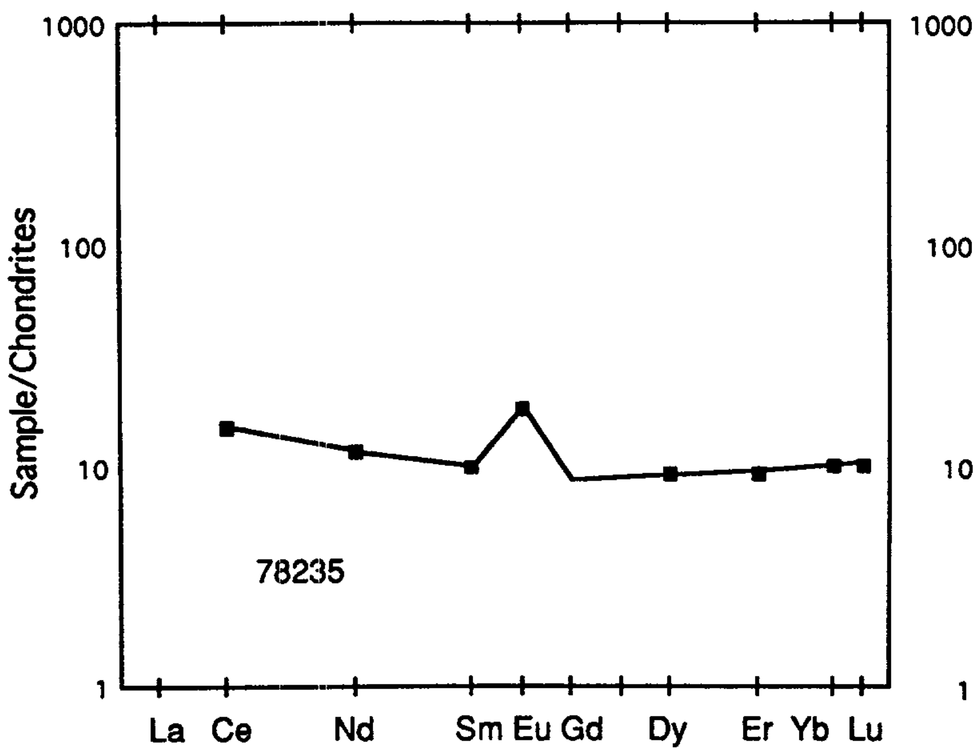


Figure 8: Normalized rare earth element diagram for 78235. Data from Winzer et al. (1975).

composition of 78236, which is in reality another piece of 78235. Warren and Wasson (1978) have analyzed 78255. Warren et al. (1987) analyzed "coarse-fines" sample 78234,5, which they believe to be another piece of 78235-78255. This analysis is included in Table 1 for comparison.

Higuchi and Morgan (1975) reported the trace siderophile and volatile elements in 78235 (Table 2). James (1994) reviewed the siderophile and volatile element composition.

Keith et al. (1974) have analyzed large pieces of 78235 and 78255 and found that the Th, U, and K contents were slightly different in the two samples (Table 3).

The glass coating and glass veins in samples 78235-78255 also give an indication of the bulk composition of this sample. Winzer et al., Sclar and Bauer (1975), Steele, McCallum and Mathez, and Dymek et al. have all analyzed the glass (Table 4).

Glass veins and coating (rind) plot halfway along the tie line from plagioclase to pyroxene (Fig. 9). The glass appears to be formed by *in situ* melting of the rock without the addition of other rock components. A meteoritic component is indicated by the very high Ni and Ir in the glass.

STABLE ISOTOPES

Mayeda et al. (1975) report typical lunar delta ^{18}O (o/oo) values of 5.67 (plagioclase) and 5.41 (pyroxene) for this pristine lunar rock.

RADIOGENIC ISOTOPES

Hinthorne et al. (1977) dated 78235 by the Pb-Pb ion probe method. Ages from three baddeleyites and one zircon in thin section 78235,49 were all consistent at 4.25 ± 0.09 b.y. These data required correction for unspecified molecular ion interferences. It is also difficult to understand how the U-Pb system in the minor phases could not have been affected by the shock melting that is evident in this rock. For these reasons this Pb-Pb age is generally not accepted—although it has generally been confirmed by more recent work.

Premo and Tatsumoto (1991 and 1992) have studied the U-Th-Pb isotopic systematics of 78235 (Table 5) and determined a crystallization age of 4.426 ± 0.065 b.y. with a disturbance at 3.93 ± 0.21 b.y. (Fig. 10). Their work also shows that the Moon had a high U/Pb ratio—about 508. There is also a hint of a mild event (shock?) at about 900 m.y. in their data.

Nyquist et al. (1981), Aeschlimann et al. (1982), and Carlson and Lugmair (1982) have precisely dated 78236 by ^{39}Ar-^{40}Ar, Rb-Sr and Sm-Nd methods (see section on 78236).

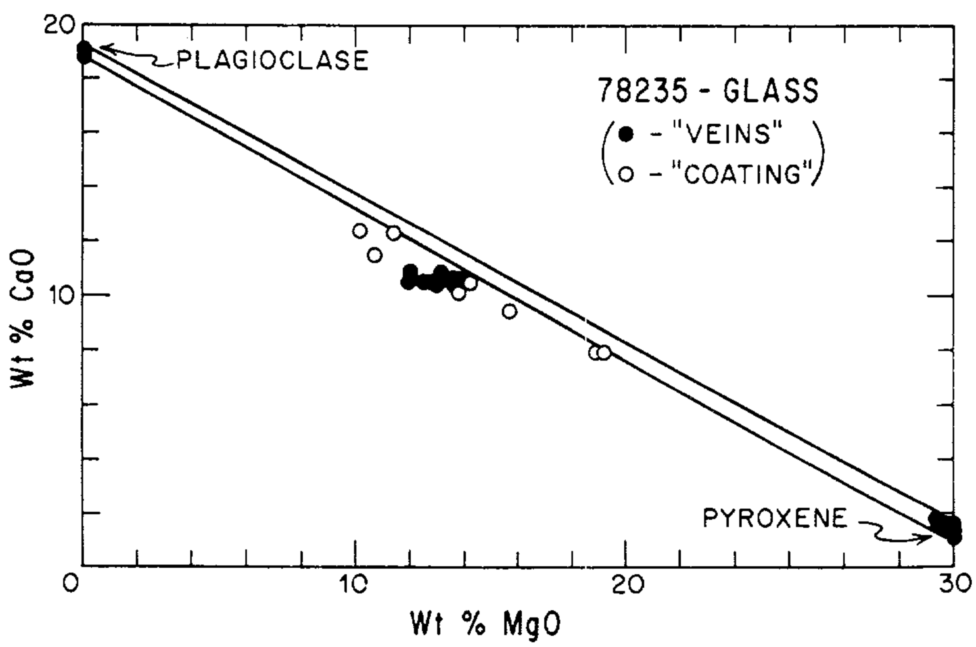


Figure 9: Composition of glass veins in and glass coating on 78235. From Dymek et al. (1975).

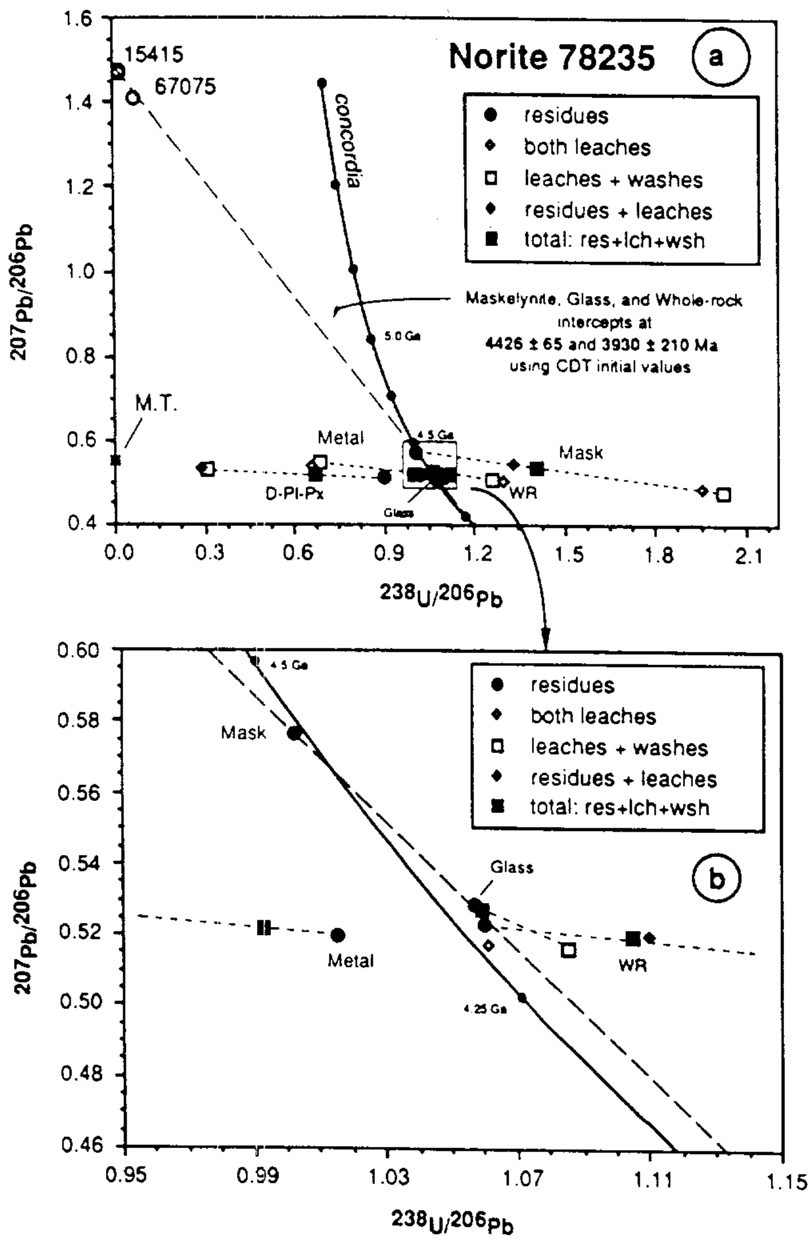


Figure 10: U-Pb Concordia diagrams for 78235 from Premo and Tatsumoto (1991), illustrating the U-Pb behavior of leaches + washes (open squares), both leaches (open diamonds) and residues (solid circles) of mineral separates. Total U-Pb for each separate (combining residue + leaches + wash) is shown as a solid square, and the position of each along a tie line (residue to leaches + wash; short-dashed lines) shows the effect of the leaching procedure on the U-Pb systematics of each separate.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Some of the Apollo 17 samples (including 78235) provided a unique opportunity to study the energy spectrum (and potential angular anisotropy) of the incident proton flux from the August 1972 solar flare (Rancitelli et al., 1974; Keith et al., 1974). Table 3 compares the induced activity of 78235 with 78255, from the underside of the boulder.

Drozd et al. (1977) have determined an exposure age of 292 ± 14 m.y. for 78235 using the ^{81}Kr-Kr method. Aeschlimann et al. (1982) reported an Ar exposure age of 300 m.y. for 78236.

SURFACE STUDIES

The original catalog (Butler, 1973) notes that the glass coating on 78235 is pitted and in places cracked by spalls from micrometeorite craters. Larger pits have penetrated the glass to the crystalline rock beneath.

PROCESSING AND DISTRIBUTION

The largest piece remaining of 78235 weighs 112 g. Thin sections of sample 78235 have been widely distributed to undergraduate students as part of the JSC educational thin section set (Meyer, 1987).

Table 1: Whole-rock chemistry of 78235.
a) Winzer et al. (1975b); b) Warren et al. (1987); c) Dymek et al. (1975)

Split Technique	,34 (a) INAA	78234 (b)* INAA	78235 (c) calculated
SiO_2 (wt%)	49.5	50.93	49.8
TiO_2	0.16	0.25	0.08
Al_2O_3	20.87	14.36	18.4
Cr_2O_3	0.23	0.40	0.31
FeO	5.05	7.33	6.02
MnO	0.08	0.126	0.10
MgO	11.76	16.43	14.5
CaO	11.71	9.24	10.5
Na_2O	0.35	0.25	0.3
K_2O	0.061	0.055	0.05
P_2O_5	0.04		
Nb (ppm)			
Zr		29	
Hf		1.66	
Ta		0.25	
U		0.22	
Th		0.62	
Sr		107	
Rb		–	
Ba	79.6	53	
Ni		11.5	
Co		29.3	
Sc		13	
La		3.3	
Ce	9.16	8.6	
Nd	5.4	4.5	
Sm	1.49	1.49	
Eu	1.03	0.7	
Tb		0.38	
Dy	2.26	2.73	
Er	1.47		
Yb	1.64	2.33	
Lu	0.241	0.35	

Table 1: (Concluded).

Split Technique	,34 (a) INAA	78234 (b)* INAA	78235 (c) calculated
Ga		2.9	
Ge (ppb)			
Ir		<15	
Au		15	

*78234 is a "coarse-fine" fragment from the same sample bag as 78235 (see text).

Table 2: Data for 78235.
From Higuchi and Morgan (1975).

	Sample 78235,31	Sample black glass
Ir (ppb)	0.135	25.9
Os (ppb)		
Re (ppb)	0.0117	1.66
Au (ppb)	0.421	5.08
Ni (ppm)	12	450
Sb (ppb)	0.079	1.1
Ge (ppb)	18.9	131
Se (ppb)	7.5	176
Te (ppb)	<0.8	3.5
Ag (ppb)	0.4	0.96
Br (ppb)	6.4	6.7
Bi (ppb)	0.05	0.41
Zn (ppm)	1.5	2
Cd (ppb)	2.9	5.4
Tl (ppb)	0.023	0.038
Rb (ppm)	0.922	1.1
Cs (ppb)	64.3	80.3
U (ppb)	360	200

Table 3: Solar flare induced activity from large solar flare, August 1972.
From Keith et al. (1974).

	Sample 78135	Sample 78235	Sample 78255
dpm/Kg			
^{26}Al	42 ± 4	77 ± 7	65 ± 6
^{22}Na	74 ± 5	111 ± 8	50 ± 5
^{54}Mn	180 ± 20	55 ± 8	10 ± 5
^{56}Co	240 ± 20	52 ± 9	30 ± 20
^{46}Sc	76 ± 5	1.4 ± .9	<15
^{48}V	18 ± 5	<12	
Th (ppm)	.26	.59	.83
U (ppm)	.107	.196	.227
K (%)	.0525	.049	.059

Table 4: Glass chemistry of 78235.
a) Winzer et al. (1975b); b) McCallum and Mathez (1975); c) Dymek et al. (1975)

	(a) vein	(a) rind	(b) brown	(c) rind	(c) vein
SiO_2 (wt%)	49.8	49.7	49.32	49.42	48.41
TiO_2	0.19	0.16	0.16	0.16	0.15
Al_2O_3	17.15	17.58	18.64	17.86	18.52
Cr_2O_3	0.35	0.33	0.33	0.35	0.34
FeO	7.52	7.39	7.53	6.97	7.67
MnO	0.12	0.11	0.12	0.10	0.12
MgO	14.98	14.51	13.43	14.25	12.96
CaO	9.92	9.86	10.48	10.24	10.52
Na_2O	0.35	0.34	0.39	0.25	0.39
K_2O	0.06	0.058	0.07	0.06	0.08
P_2O_5	0.08	0.07	0.05	0.05	0.10
S			0.20		
Ba (ppm)	62.5	87.3			
Ce	20.5	23.2			
Nd	9.52	9.48			
Sm	2.04	1.52			
Eu	0.815	0.819			
Dy	2.97	2.34			
Er	1.77	1.66			
Yb	1.91	1.63			
Lu	0.297	0.258			

Table 5: U-Th-Pb analytical data for 78235.
From Premo and Tatsumoto (1991).
(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	67.3	0.30	468	295	363	2862	0.000270	0.5252	0.4185	3913	1.27
						(0.31)§	(8.7)	(0.06)	(0.15)	(8.7)	
D-Pl-Px	110.0	0.43	196	99.0	63.3	5399	0.000064	0.5188	0.5250	13880	0.661
						(2.6)	(57)	(0.06)	(0.18)	(30)	
Mask	52.5	3.1	210	108	253	634.3	0.000643	0.5801	0.6522	1550	2.41
						(0.29)	(44)	(0.25)	(1.5)	(45)	
Glass	22.4	0.72	396	197	667	1146	0.000634	0.5322	0.9162	1657	3.50
						(0.10)	(11)	(0.09)	(0.10)	(11)	
Metal	0.12	11	4220	1880	3790	77.83	0.009667	0.5730	0.8161	95.6	2.08
						(0.11)	(11)	(1.1)	(1.0)	(13)	
Dilute HNO_3 (1N) leaches											
A2-WR	—	1.5	56.5	6.73	123	95.91	0.009911	0.5929	1.379	31.0	18.9
						(0.12)	(1.5)	(0.15)	(0.30)	(2.0)	
A2-D-Pl-Px	—	2.8	18.3	1.88	27.8	598.1	0.000600	0.5482	1.240	412	15.3
						(0.08)	(54)	(0.35)	(0.75)	(55)	
A2-mask	—	4.7	19.2	5.93	38.4	406.7	0.000731	0.6062	1.093	984	6.69
						(0.34)	(73)	(0.40)	(0.82)	(74)	
A2-glass	—	24	8.63	2.37	16.7	86.02	0.002377	0.5635	1.219	278	7.27
						(0.14)	(145)	(3.3)	(4.7)	(150)	
A2-metal	—	67	247	53.4	211	22.59	0.02966	0.6499	1.414	19.2	4.07
						(0.26)	(7.7)	(26)	(35)	(204)	
Dilute HBr (0.1 N) leaches											
A1-WR	—	0.71	152	85.6	638	103.1	0.009424	0.5464	1.585	162	7.70
						(0.69)	(1.1)	(0.11)	(0.33)	(1.3)	
A1-D-Pl-Px	—	0.45	153	17.0	164	1804	0.000373	0.5374	1.465	772	9.95
						(0.50)	(15)	(0.08)	(0.31)	(15)	
A1-mask	—	1.2	103	86.7	601	817.5	0.000748	0.4649	1.541	2940	7.16
						(0.24)	(19)	(0.22)	(0.62)	(19)	
A1-glass	—	11	28.5	11.9	105	175.5	0.000854	0.5097	1.790	1390	9.16
						(0.22)	(190)	(2.0)	(2.6)	(191)	
A1-metal	—	65	342	27.1	369	19.20	0.04959	0.8480	1.986	5.40	14.1
						(0.02)	(11)	(5.1)	(5.5)	(189)	
Water Washes											
W-WR	70.8¶	2.7	25.1	4.63	22.2	29.33	0.03354	0.7157	1.662	16.2	4.95
						(0.12)	(0.46)	(0.13)	(0.19)	(1.5)	
W-D-Pl-Px	113	6.6	6.25	2.08	7.66	99.20	0.007910	0.5664	1.154	98.8	3.81
						(0.21)	(8.5)	(0.70)	(1.5)	(10)	
W-mask	63.5	3.0	25.7	24.4	137	106.7	0.008455	0.5155	1.056	250	5.81
						(0.13)	(3.2)	(0.38)	(1.0)	(3.9)	
W-glass	22.4	23	7.63	3.05	18.6	45.10	0.01506	0.5967	1.403	69.2	6.29
						(0.64)	(18)	(2.8)	(3.1)	(27)	
W-metal	0.12	83	83.3	11.3	30.6	18.52	0.05650	0.8774	1.961	8.10	2.80
						(0.11)	(29)	(25)	(27)	(570)	

* Concentrations 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 *Ludwig* (1980, 1985a).
§ Numbers in parentheses are 2-sigma errors given in percent for the values just above them.
¶ Original weights before washing and leaching procedure.

78236
Shocked Norite
93.06 g, 7.5 x 5.5 x 2.0 cm

INTRODUCTION

Sample 78236 is a piece of the same norite as 78235 *(see section on the boulder at Station 8)*. It is a heavily shocked, coarse-grained, plutonic norite of cumulate origin. One side of this piece has a thick coating of black glass (Fig. 1), and the other side shows a coarse-grained igneous texture (Fig. 2).

78236 has been used extensively for age dating studies.

PETROGRAPHY

Nyquist et al. (1981) have discussed the petrography of 78236. Modal analysis and the mineralogy of their thin section of 78236 agreed with previous descriptions of 78235 and 78238. All minerals in 78236 have been shocked to a moderate degree (~30 GPa), with local areas of more intense shock (up to ~50 GPa). Veins of solidified melt have been developed *in situ.*

Carlson and Lugmair (1982) and Nyquist et al. have pointed out the importance of the minor phases to age dating studies. An important part of the Sm and Nd must be tied up in the whitlockite, and Rb must be present in the K-feldspar inclusions (Nyquist et al., 1981). Partially devitrified dark brown mesostasis occurs interstitially—mostly intergranular between pyroxene grains—and contains tiny clinopyroxene and opaque crystals. The shock event(s) that have

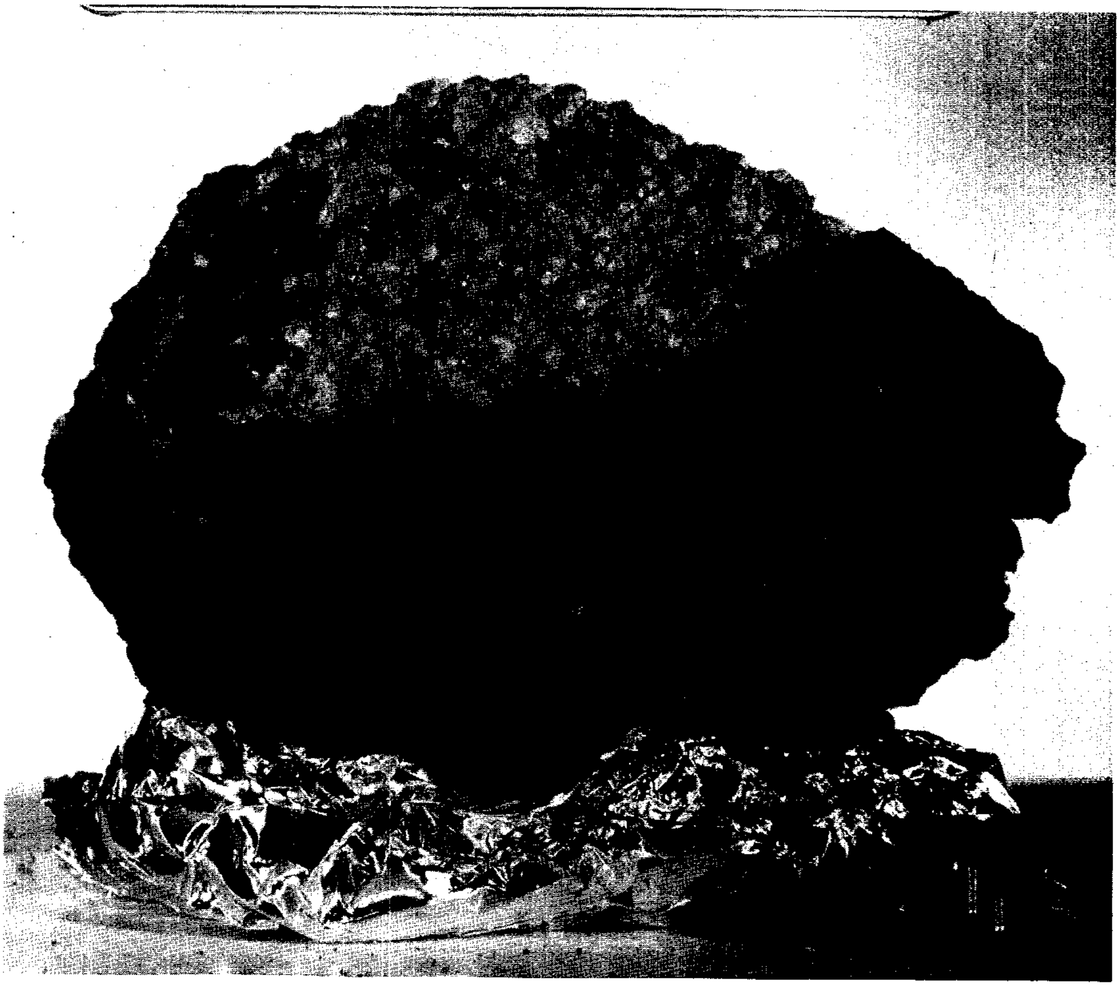


Figure 1: Photograph of 78236. Cube is 1 cm. S73-15394.

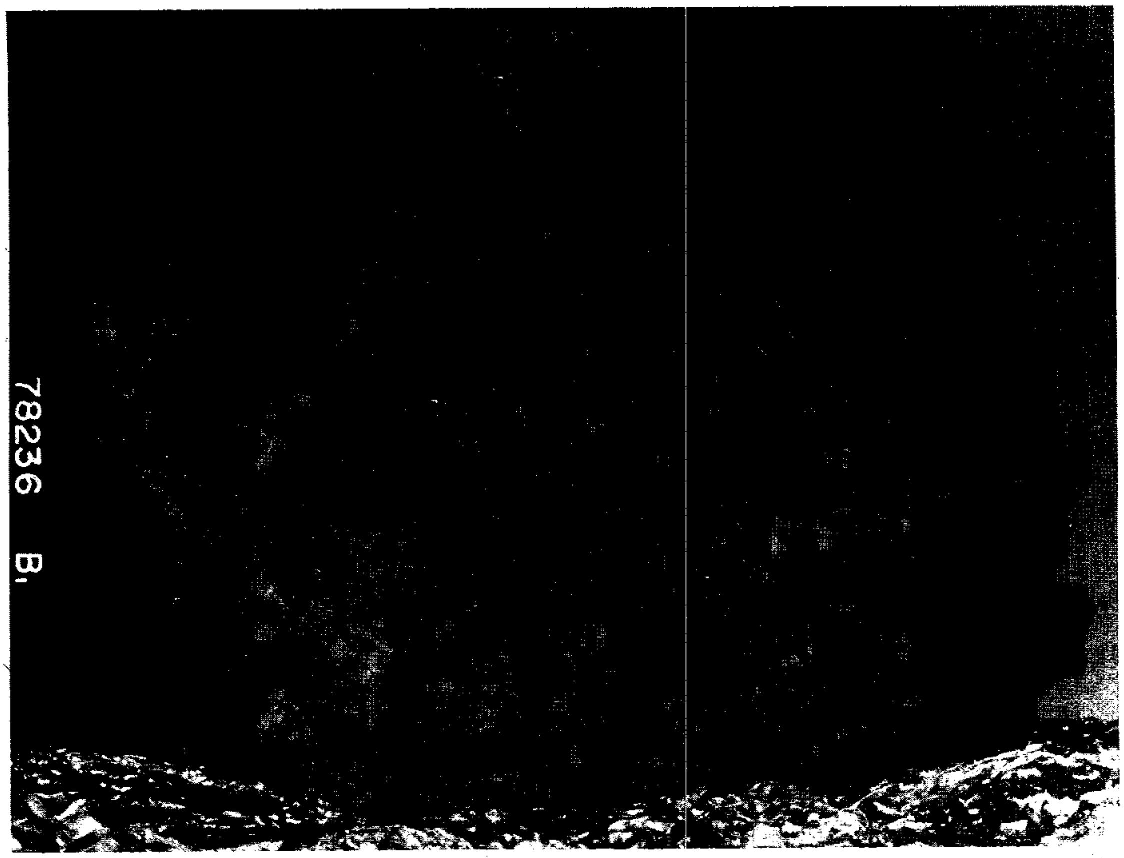


Figure 2: Photograph of 78236. Field of view is 5 x 7 cm. S73-17813.

partially altered the texture of this rock must have at least partially remobilized the radiogenic pairs in these minor phases. Some of the plagioclase has lost Ar while being converted to maskelynite.

WHOLE-ROCK CHEMISTRY

Blanchard and McKay (1981) have determined the major and trace element content of 78236 and found it to be the "same" as that of 78235 (Table 1 and Fig. 3).

RADIOGENIC ISOTOPES

Sample 78236 was used for age dating studies of the norite boulder. Aeschlimann et al. (1982) dated the plagioclase in 78236 by the ^{39}Ar-^{40}Ar plateau technique at 4.11 ± 0.02 (Fig. 4). Nyquist et al. (1981) also dated 78236 by the ^{39}Ar-^{40}Ar plateau method, but they obtained an age of 4.39 for a sample of the whole rock (Fig. 5). The Ar released during the low temperatures has a younger age.

Carlson and Lugmair (1981) dated 78236 by the Sm-Nd internal isochron method (Table 2). A crystallization age of 4.34 ± 0.05 is indicated by a best fit isochron (Fig. 6). However, one of the hand-picked plagioclase and one of the pyroxene separates were outside of the ± 50 m.y. error envelope, and evidence of isotopic resetting was noted.

Nyquist et al. (1981) also dated 78236 by the Rb-Sr (Table 3) and Sm-Nd methods (Table 4). The Rb-Sr and Sm-Nd ages determined by the most retentive samples are 4.38 ± 0.02 b.y. (Fig. 7) and 4.43 ± 0.05 b.y. (Fig. 8), respectively. Nyquist et al. note that all of the isotopic systems in 78236 have been reset to some degree. They discuss this from two points of view—shock effects and slow cooling of the rock after crystallization.

Jost and Marti (1982) and Marti (1983) have recognized a low temperature release pattern of spallation Xe in plagioclase separates from 78236 that is different from the high temperature release pattern, possibly due to recoil events from adjacent mineral phases.

Sample 78235 has been dated by the U-Pb method (see section of 78235).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Aeschlimann et al. (1982) report an Ar exposure age of 300 m.y. Drozd et al. (1977) have determined an exposure age of 292 ± 14 m.y. for 78235 using the ^{81}Kr-Kr method.

SURFACE STUDIES

The original catalog (Butler, 1973) notes that the glass coating on 78236 has been pitted by micrometeorites. The largest spall is 6 mm; the average pit size is reported to be 0.5 mm.

PROCESSING

The largest piece of 78236 remaining weighs 79 g. There are only two thin sections, but there are numerous sections of 78235.

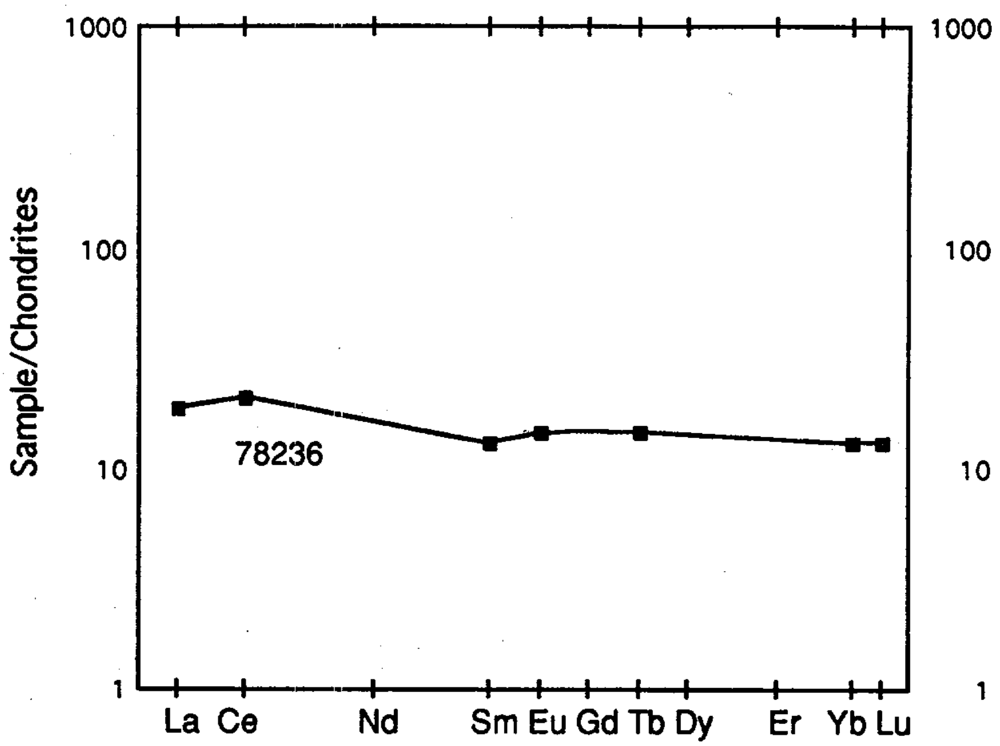


Figure 3: Normalized rare earth element diagram for 78236. Data from Blanchard and McKay (1981).

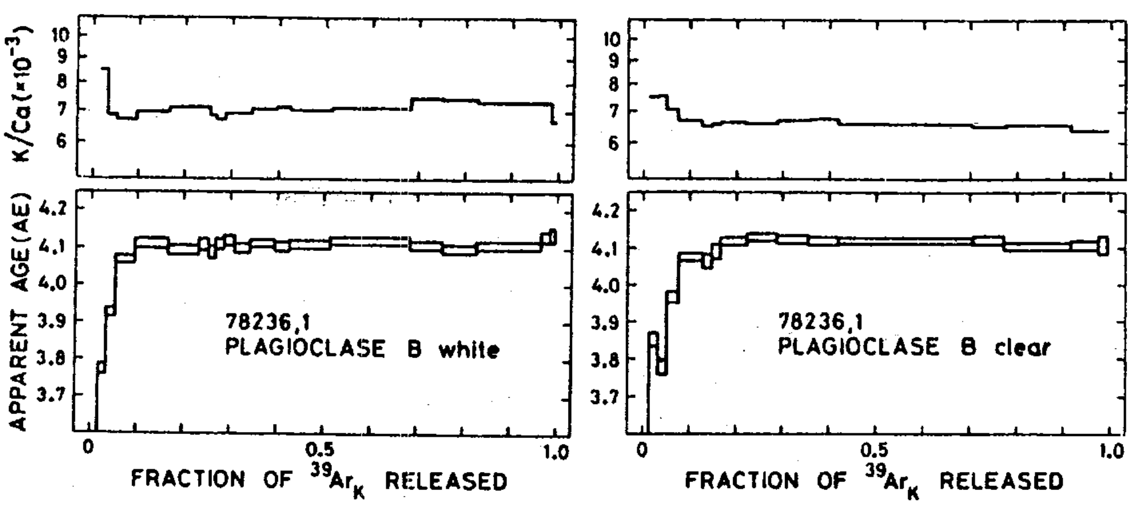


Figure 4: Temperature release data from the ^{39}Ar-^{40}Ar plateau age dating technique for plagioclase from 78236. From Aeschlimann et al. (1982).

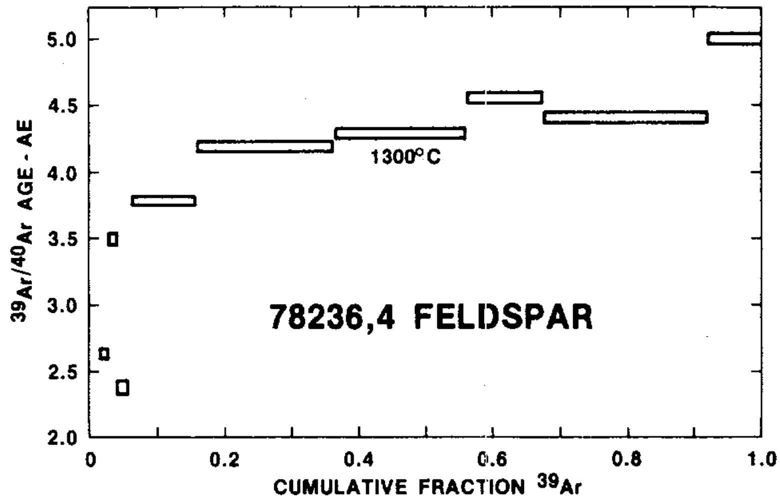


Figure 5: Data from ^{39}Ar-^{40}Ar plateau technique for 78236 feldspar. From Nyquist et al. (1981).

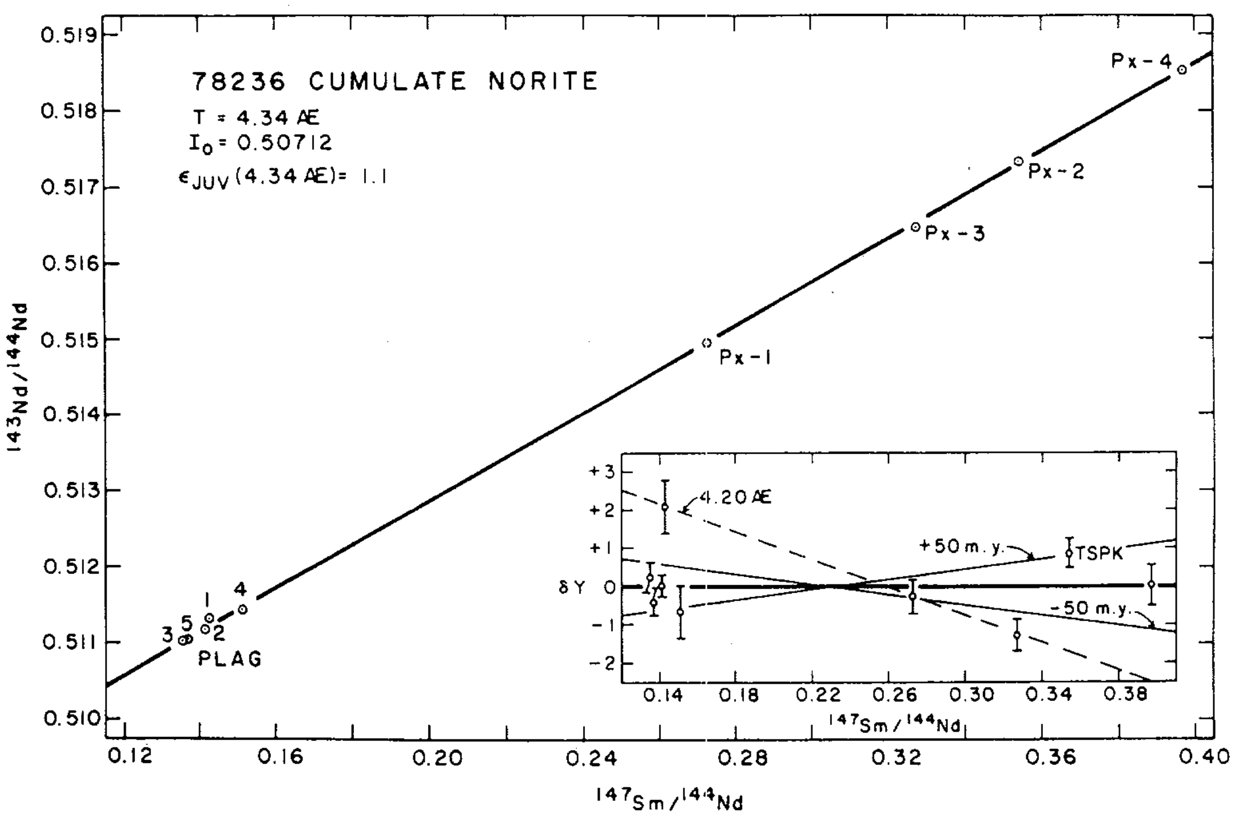


Figure 6: Sm-Nd internal isochron for 78236. From Carlson and Lugmair (1981).

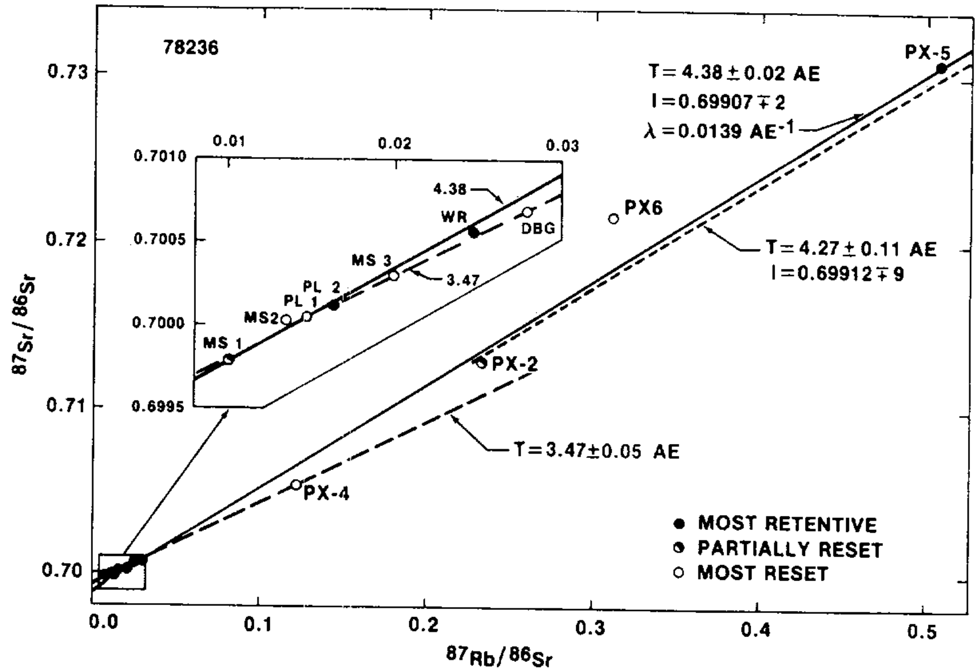


Figure 7: Rb-Sr internal isochron for mineral separates from 78236. From Nyquist et al. (1981).

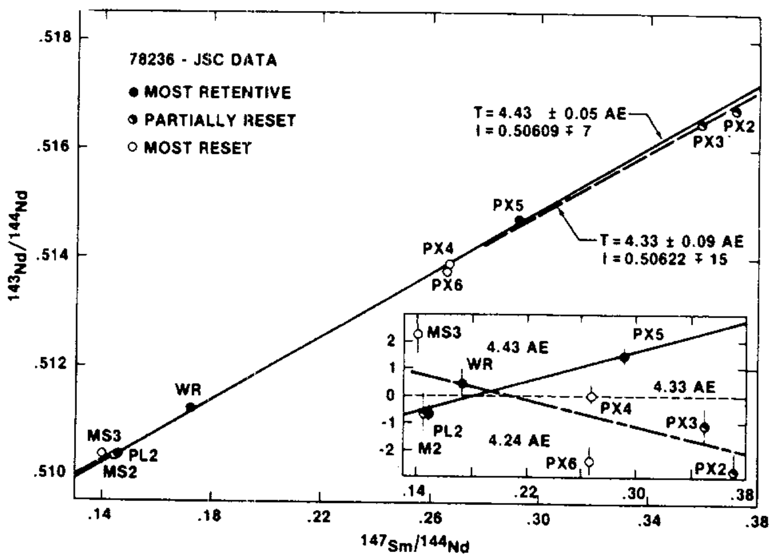


Figure 8: Sm-Nd internal isochron for mineral separates from 78236. From Nyquist et al. (1981).

Table 1: Whole-rock chemistry of 78236.
a) Blanchard and McKay (1981); b) Dymek et al. (1975)

Split Technique	,3 (a) XRF, INAA	78235 (b) calculated
SiO_2 (wt%)	50.15	49.8
TiO_2	0.18	0.08
Al_2O_3	17.66	18.4
Cr_2O_3	0.31	0.31
FeO	6.49	6.02
MnO	0.12	0.10
MgO	14.28	14.5
CaO	10.12	10.5
Na_2O	0.31	0.30
K_2O	0.04	0.05
P_2O_5	0.08	
S	0.02	
Nb (ppm)		
Zr		
Hf	1.7	
Ta	0.2	
U		
Th	0.6	
Ni		
Co	28.2	
Sc	11.2	
La	4.47	
Ce	12.8	
Nd		
Sm	1.93	
Eu	0.82	
Gd		
Tb	0.53	
Dy		
Er		
Yb	2.12	
Lu	0.32	
Ge (ppb)		
Ir		
Au		

Table 2: Sm-Nd analytical data for 78236.
From Carlson and Lugmair (1981).

Separate	Weight (mg)	[Sm] (ppm)	[Nd] (ppm)	$^{147}Sm/^{144}Nd$ [a]	$^{143}Nd/^{144}Nd$ [a]
Pl-1	12.16	1.47	6.24	0.1426 2	0.511333 40
Pl-2	20.08	1.40	5.99	0.1412 1	0.511186 16
Pl-3	17.43	1.62	7.24	0.1352 1	0.511026 19
Pl-4	24.22	0.466	1.86	0.1513 2	0.511442 36
Pl-5	18.17	1.59	7.02	0.1369 1	0.511041 18
Px-1	46.35	0.814	1.81	0.2726 3	0.514956 24
Px-2	67.45	0.812	1.39	0.3540 3	0.517354 20
Px-3	71.41	0.785	1.45	0.3270 3	0.516466 25
Px-4	74.22	0.774	1.18	0.3968 3	0.518543 29

[a]Quoted uncertainties are $2\sigma_{mean}$; the Nd data are first corrected for isotopic fractionation to $^{148}NdO/^{144}NdO = 0.242436$ and thereafter for oxygen ($^{148}Nd/^{144}Nd = 0.241572$).

Table 3: K, Rb, and Sr analytical results for 78236.
From Nyquist et al. (1981).

Sample	wt. (mg)	K (ppm)	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$ (a)	$^{87}Sr/^{86}Sr$ (b)
WR(c)	35.3	–	0.862	104.0	0.02398 ± 17	0.70057 ± 4
Plag 1(d)	8.7	844	1.056	207.1	0.01475 ± 11	0.70005 ± 6
Plag 2(d)	79.9	–	1.168	206.9	0.01634 ± 12	0.70011 ± 5
Mask 1(d)	8.7	789	0.796	209.9	0.01097 ± 8	0.69979 ± 7
Mask 2(d)	41.2	–	0.966	206.5	0.01354 ± 10	0.70003 ± 5
Mask 3(e)	23.4	–	1.450	210.3	0.01995 ± 15	0.70030 ± 5
Px 1(d)	19.6	42.6	0.237	1.56	0.44	–
Px 2(d)	120.2	–	0.195	2.42	0.233 ± 2	0.71282 ± 8
Px 3(e)	58.5	–	0.25(g)	2.03	–	0.72135 ± 9
Px 4(c)	55.5	–	0.259	6.20	0.1208 ± 9	0.70531 ± 6
Px 5(c)	55.3	–	0.407	2.32	0.508 ± 4	0.73095 ± 8
Px 6(c)	70.9	–	0.526	4.86	0.313 ± 3	0.72176 ± 5
DBG(c)	3.3	–	0.956	99.06	0.0279 ± 2	0.70069 ± 6
NBS 987(f)						0.71021 ± 3

(a) Uncertainties correspond to last figures.
(b) Uncertainties correspond to last figures and are $2\sigma_m$. Normalized to $^{88}Sr/^{86}Sr = 8.37521$.
(c) Final Rb-Sr procedure.
(d) Initial Rb-Sr procedure.
(e) Interim Rb-Sr procedure.
(f) Average of 8 analyses from April, 1980 to April, 1981.
(g) Rb content calculated assuming a 4.3 AE age.

Table 4: Sm-Nd analytical data for 78236.
From Nyquist et al. (1981).

Sample	wt. (mg)	Sm (a) (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (b)	$^{143}Nd/^{144}Nd$ (c)	$^{145}Nd/^{144}Nd$	$^{144}Sm/^{144}Nd$ (d) (x 10^{-5})
WR	35.3	2.001	7.020	0.1724 ± 2	0.511191 ± 29	0.34896 ± 3	0.8
Plag 2	79.9	1.640	6.811	0.1456 ± 2	0.510363 ± 18	0.34897 ± 5	0.5
Mask 2	41.2	1.122	4.697	0.1445 ± 2	0.510334 ± 39	0.34894 ± 4	0.2
Mask 3	23.4	1.400	6.050	0.1399 ± 2	0.510354 ± 34	0.34897 ± 5	0.2
Px 2	120.2	0.9361	1.526	0.3710 ± 4	0.516731 ± 85	0.34890 ± 10	7.2
Px 3	58.5	0.9211	1.552	0.3589 ± 4	0.516475 ± 36	0.34902 ± 4	0.8
Px 4	55.5	1.027	2.329	0.2667 ± 3	0.513883 ± 21	0.34898 ± 4	0.2
Px 5	55.3	0.9783	2.026	0.2920 ± 3	0.514678 ± 18	0.34900 ± 3	0.4
Px 6	70.9	0.9800	2.228	0.2660 ± 3	0.513738 ± 31	0.34902 ± 4	0.3
Ames Nd(e)					0.511146 ± 28	0.34898 ± 3	
La Jolla Nd(f)					0.511116 ± 33	0.34893 ± 3	

(a) Calculated using measured Sm isotopic composition.
(b) Uncertainties correspond to last figures and do not include the ≤0.1% uncertainty in the Sm/Nd ratio of the spike.
(c) Uncertainties are $2\sigma_m$ and correspond to last figures. Normalized to $^{148}Nd/^{144}Nd = 0.24308$.
(d) Estimated assuming mass 147 due entirely to ^{147}Sm.
(e) Average of 4 analyses for January, 1980 to July, 1980.
(f) Single analysis—January, 1981.

78238
Shocked Norite
57.58 g, 5.9 x 4.5 x 3.5 cm

INTRODUCTION

Sample 78238 is another piece of the same norite as 78235 *(see section on the boulder at Station 8)*. It is a heavily shocked, coarse-grained, plutonic norite of cumulate origin. It also has a coating of black glass. It has a penetrating vein of black glass which includes vesicles (Fig. 1).

MINERAL CHEMISTRY

Fig. 2 shows the shocked plagioclase and crushed pyroxene. McCallum and Mathez (1975), Hewins and Goldstein (1975), and Sclar and Bauer (1975) found that the composition of iron metal in 78238 was high in Co and low in Ni (Fig. 3). These Co-rich metal grains are found in both the shocked coarse zones and finer-grained crushed zones in the rock. These high-Co metal grains presumably crystallized slowly from intercumulus liquid. Mehta and Goldstein (1980) have studied metal in glass and found it to contain more Ni.

WHOLE-ROCK CHEMISTRY

The composition of 78238 has not been determined.

RADIOGENIC ISOTOPES

Sample 78238 has not been dated.

THE SURFACE

The original catalog (Butler, 1973) notes that the glass coating on 78238 is pitted. There are 10-15 pits/cm^2 on the T, N, and S surfaces.

PROCESSING

The largest piece of 78238 weighs 56 g. There are only three thin sections.

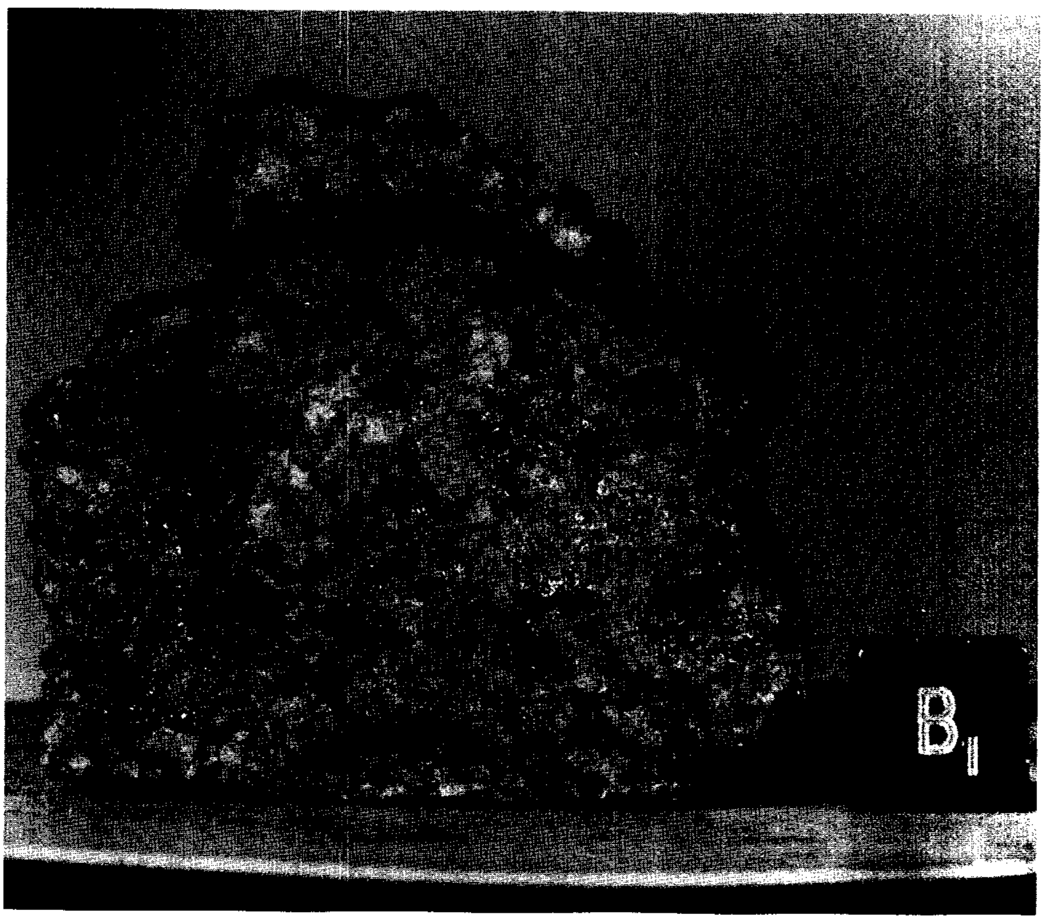


Figure 1: Photograph of 78238. Cube is 1 cm. S73-15461.

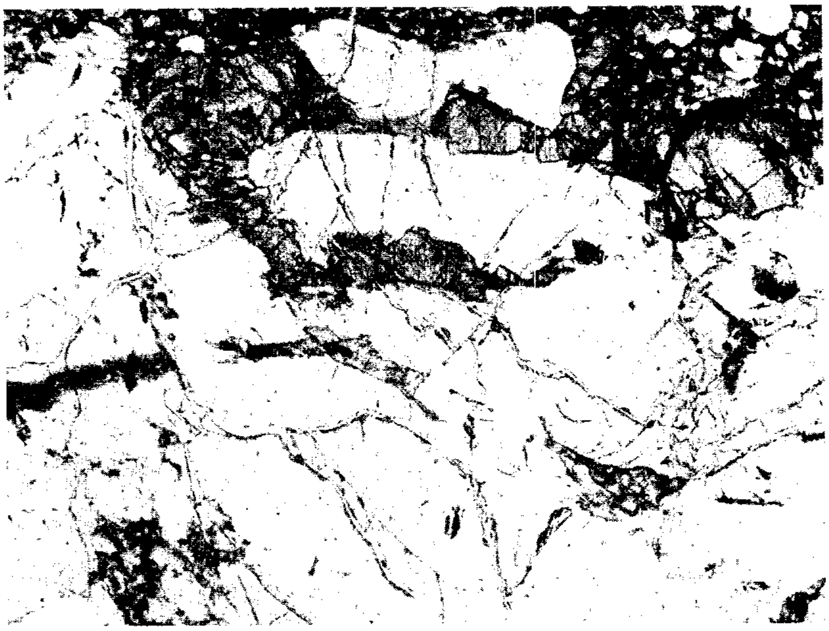


Figure 2: Photomicrograph of thin section 78238,8. Field of view is 3 x 4 mm.

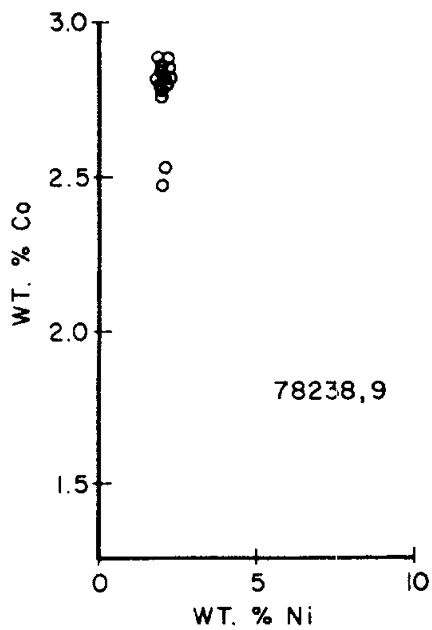


Figure 3: Composition of metal grains in 78238. From Hewins and Goldstein (1975).

78255
Shocked Norite
48.31 g, 4 x 3 x 2 cm (2 pieces)

INTRODUCTION

Sample 78255 was chipped off the "bottom" of the Station 8 Boulder and collected from the soil (*see section on the Station 8 Boulder*). Sample 78256 was combined with 78255. The bag in which they were returned included 50.57 g of dirt that may include additional fragments of 78255. The glass coating on 78255 has been pitted by micrometeorites.

PETROGRAPHY

Sample 78255 is a heavily shocked, coarse-grained, plutonic norite of cumulate origin. It also has a glass coating and penetrating veins of glass including vesicles (Fig. 1). It is the same rock as 78235 (see section of 78235 for petrographic description). Fig. 2 illustrates shocked plagioclase and glass veinlets.

MINERAL CHEMISTRY

Bersch et al. (1991) have precisely determined the composition of pyroxene in 78255.

WHOLE-ROCK CHEMISTRY

Warren and Wasson (1978) provided an analysis of 78255 (Table 1 and

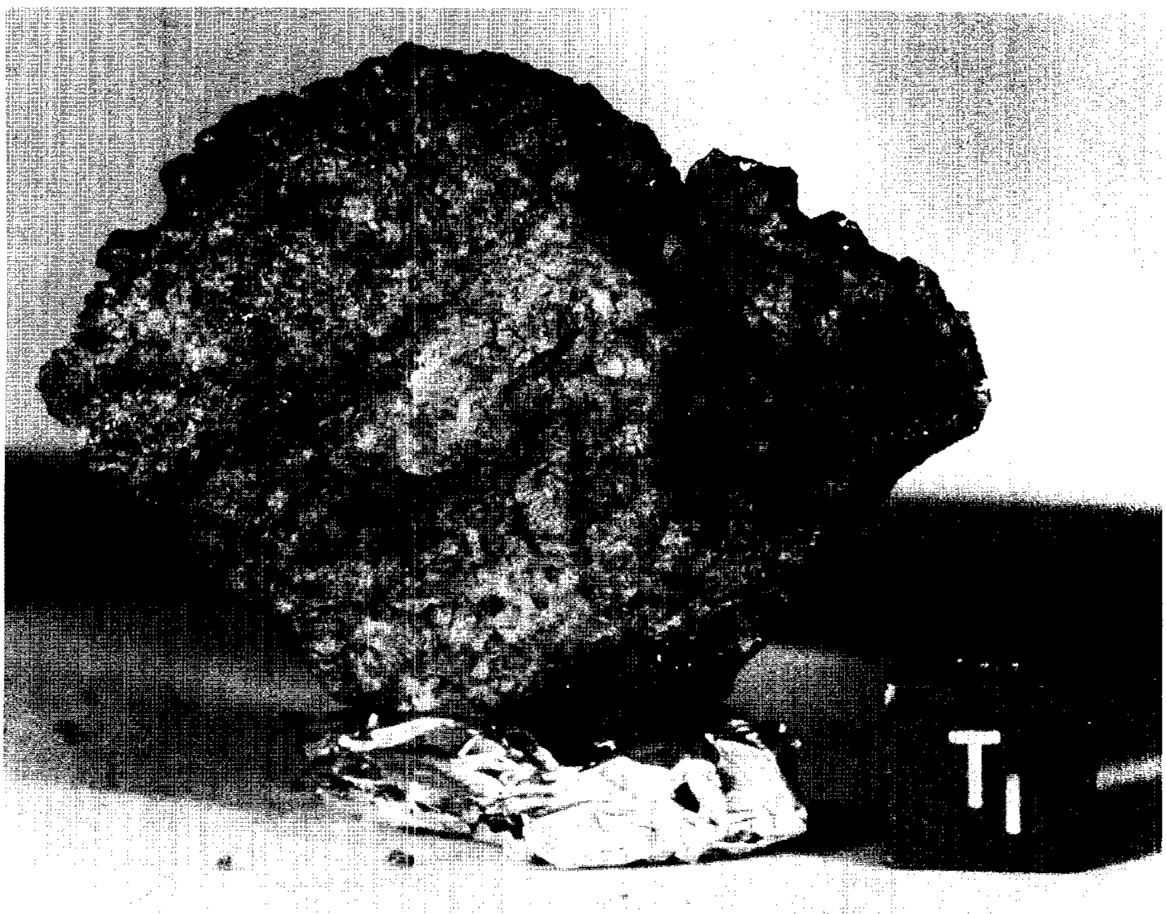


Figure 1: Photograph of 78255. Scale is 1 cm. S73-15189.

Fig. 3). This analysis was very high in Al_2O_3 (27.4%), indicating that their sample split may have had excess plagioclase. Note that the Eu is also high. Photos of the hand specimen indicate that the sample may have a higher content plagioclase than 78235. This is consistent with plutonic layering observed by Jackson et al. (1975). The Ir content is slightly elevated, but low enough to conclude that this sample is a pristine lunar rock.

Keith et al. (1974) determined K, U, and Th (see table in section on 78235). These data should be representative of the rock as a whole, and it is interesting to note that they are slightly different from those of 78235.

RADIOGENIC ISOTOPES

Although sample 78255 has not been dated, it should give an age identical to that of 78235-78236.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Keith et al. (1974) have determined the amount of ^{56}Co, ^{46}Sc, and ^{54}Mn in 78255 (see table in 78235 section).

SURFACE STUDIES

The glass coating on 78255 is reported to have numerous micro-meteorite craters (Butler, 1973) which is an interesting observation, because 78255 was from the "bottom" of the boulder, which means it had rolled around on the surface—even before the astronauts got there.

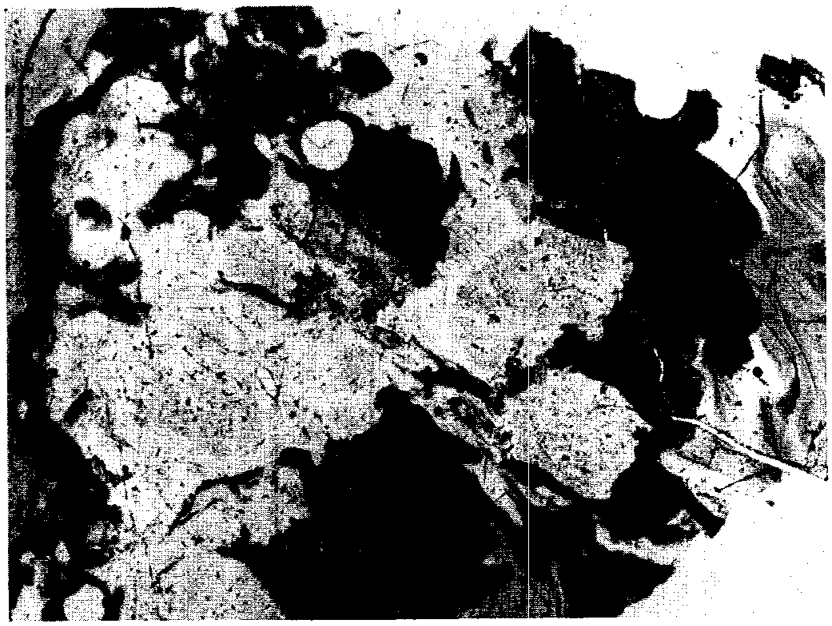


Figure 2: Photomicrograph of thin section 78255. Field of view is 4 x 5 mm.

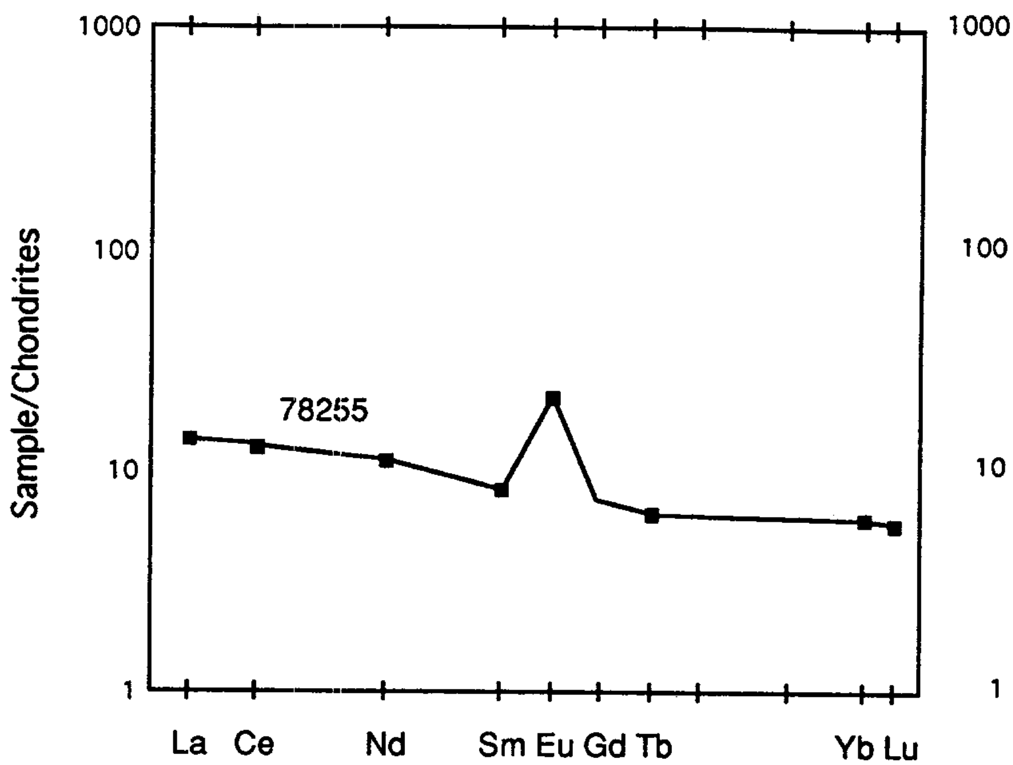


Figure 3: Normalized rare earth element diagram for 78255. From Warren and Wasson (1978).

Table 1: Whole-rock chemistry of 78255.
From Warren and Wasson (1978).

Split **Technique**	**,4** **INAA, RNAA**
SiO_2 (wt%)	47.29
TiO_2	0.068
Al_2O_3	27.40
Cr_2O_3	0.145
FeO	2.64
MnO	0.046
MgO	5.98
CaO	14.98
Na_2O	0.446
K_2O	0.084
Nb (ppm)	
Zr	49
Hf	0.67
Ta	0.086
U	0.19
Th	0.44
Ba	86
Zn	0.95
Ni	21.7
Co	22.6
Sc	4.6
La	3.3
Ce	7.8
Nd	5
Sm	1.2
Eu	1.21
Tb	0.23
Dy	
Er	
Yb	0.98
Lu	0.14
Ga	5.1
Ge (ppb)	58.3
Ir	0.43
Au	0.107

78465
Soil Breccia
1.039 g, 1.5 x 1 x 1 cm

INTRODUCTION

This fragment was sieved from trench soil 78460. It is the only rock fragment larger than 1 cm from the trench, and it was sampled from between 1–6 cm deep in the trench soil (Wolfe and others, 1981).

PETROGRAPHY

Sample 78465 is a friable dark matrix breccia. It has a glass splash on one end (Fig. 1).

There is no thin section of this sample.

WHOLE-ROCK CHEMISTRY

There are no data on 78465.

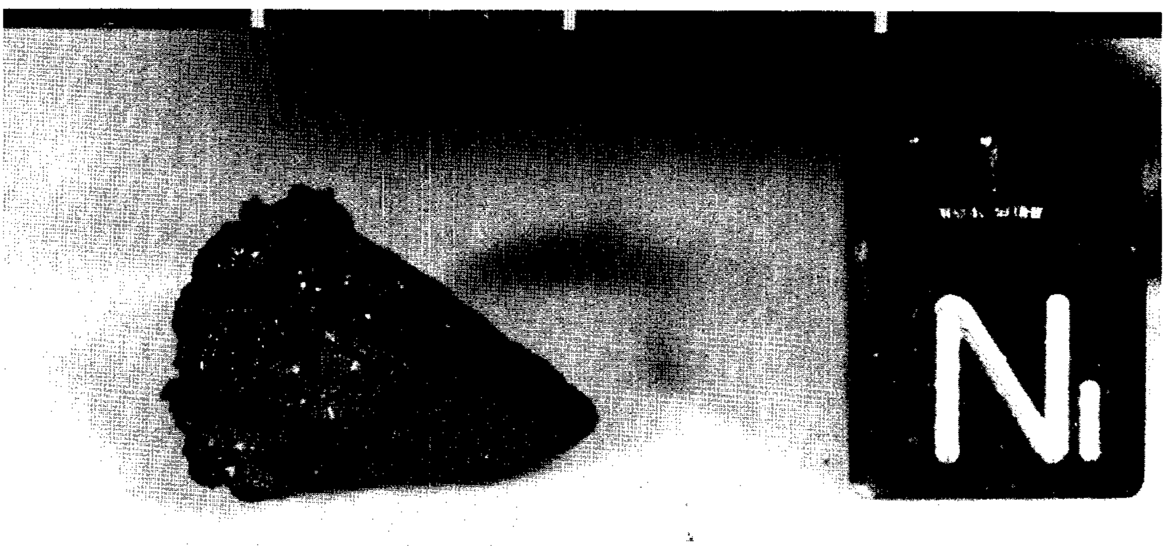


Figure 1: Photograph of 78465. The sample is 1 cm across. S73-19724.

Rake Fragments from Station 8

RAKE FRAGMENTS FROM STATION 8

Station 8 was located only about 20 meters above the Taurus-Littrow Valley (Wolfe and others, 1981). The comprehensive sample at Station 8 consisted of both a rake sample and a soil sample from which rock fragments and "coarse-fine" fragments were separated. Soil 78500 (called the rake soil) contained rock fragments 78505-78518, and the rake sample contained 78525-78599 (the residual dirt in the rake bag was called 78530). A soil sample from trench 78460 also yielded one particle greater than 1 cm (78465).

Keil et al. (1974) prepared a catalog of the rake samples from Station 8 and reported studies of them in several catalogs from the University of New Mexico (Warner et al., 1978). Fig. 1 shows the location of the rake sample and rake soil on the rim of a subdued small crater (10 meters).

Table 1 gives a summary of the rake samples. Judging from the large number of mare basalts and small number of highland breccias, the Sculptured Hills formation was not well sampled at Station 8. Meyer (1973) prepared a catalog of additional small "coarse-fine" fragments from the Apollo 17 soils. There was a total of 84 particles in 78504 (the 4-10 mm size range). There may also be important particles in the residual dirt from the rake sample 78530 (89 g) and the trench soils (78220-78280). There is only time here to refer to a few of the studies of the numerous coarse-fine particles.

Irving et al. (1974) and Steele and Smith (1975) have studied a number of coarse fines from Apollo 17. Bence et al. (1974) have studied a small fragment, 78503,7,1, which they claim is the equivalent of 77017. Jolliff et al. (1993) has begun an extensive study of the coarse fines from the talus slopes of Massifs surrounding the Taurus-Littrow Valley.

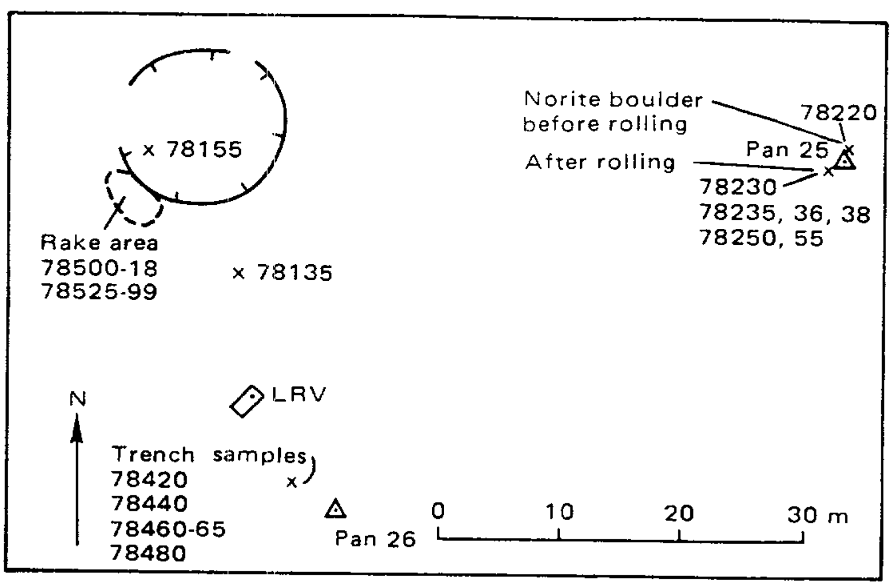


Figure 1: Map of Station 8 showing location of the rake sample.

Table 1: Summary of the "Rake Samples" from Station 8.

78465	Soil Breccia	78556	Dark Matrix Soil Breccia
78505	High-Ti Mare Basalt	78557	Dark Matrix Soil Breccia
78506	High-Ti Mare Basalt	78558	Dark Matrix Soil Breccia
78507	High-Ti Mare Basalt	78559	Dark Matrix Soil Breccia
78508	Light Matrix Soil Breccia	78565	Dark Matrix Soil Breccia
78509	High-Ti Mare Basalt	78566	Dark Matrix Soil Breccia
78515	Dark Matrix Breccia	78567	Dark Matrix Soil Breccia
78516	Dark Matrix Soil Breccia	78568	Breccia
78517	Friable White Cataclasite	78569	High-Ti Mare Basalt
78518	Dark Matrix Soil Breccia	78575	High-Ti Mare Basalt
78525	Agglutinate	78576	High-Ti Mare Basalt
78526	Green Glass Vitrophyre	78577	High-Ti Mare Basalt
78527	Granulitic Noritic Breccia	78578	High-Ti Mare Basalt
78528	Basalt	78579	High-Ti Mare Basalt
78535	Dark Matrix Breccia	78585	High-Ti Mare Basalt
78536	Dark Matrix Breccia	78586	High-Ti Mare Basalt
78537	Dark Matrix Breccia	78587	High-Ti Mare Basalt
78538	Dark Matrix Breccia	78588	High-Ti Mare Basalt
78539	Dark Matrix Breccia	78589	High-Ti Mare Basalt
78545	Dark Matrix Breccia	78595	High-Ti Mare Basalt
78546	Dark Matrix Breccia	78596	High-Ti Mare Basalt
78547	Dark Matrix Breccia	78597	High-Ti Mare Basalt
78548	Soil Clod	78598	High-Ti Mare Basalt
78549	Soil Clod	78599	High-Ti Mare Basalt
78555	Soil Breccia		

78505
High-Ti Mare Basalt
506.3 g, 6.5 x 7.5 x 8.0 cm

INTRODUCTION

Sample 78505 was collected as part of a soil sample at Station 8. It is a typical ilmenite-rich mare basalt from Apollo 17 (Fig. 1).

PETROGRAPHY

Brown et al. (1975) give the modal mineralogy of 78505 as 0.5% olivine, 21% opaques, 27.7% plagioclase, 47.7% pyroxene, and 1.9% silica (Fig. 2). Warner et al. (1978) refer to this rock as plagioclase-poikilitic ilmenite basalt.

MINERAL CHEMISTRY

The compositions of minerals in 78505 are given in Warner et al. (1978) (Fig. 3). Heiken and Vaniman (1989) studied ilmenite, and Roedder (1979a) studied the melt inclusions in ilmenite in 78505.

WHOLE-ROCK CHEMISTRY

The chemical composition of 78505 is reported in Warner et al. (1975a) (Table 1 and Fig. 4). Keith et al. (1974) have determined the K, U, and Th contents of 78505 (Table 2).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Keith et al. (1974) have reported the solar flare and cosmic ray induced activity of ^{26}Al, ^{22}Na, ^{54}Mn, ^{56}Co, and ^{46}Sc (Table 2).

Drozd et al. (1977) have determined an exposure age of 121 m.y. for 78505 using the ^{81}Kr-Kr method.

MAGNETIC STUDIES

Stephenson et al. (1975 and 1977) used 78505 to look for changes in the Moon's magnetic field.

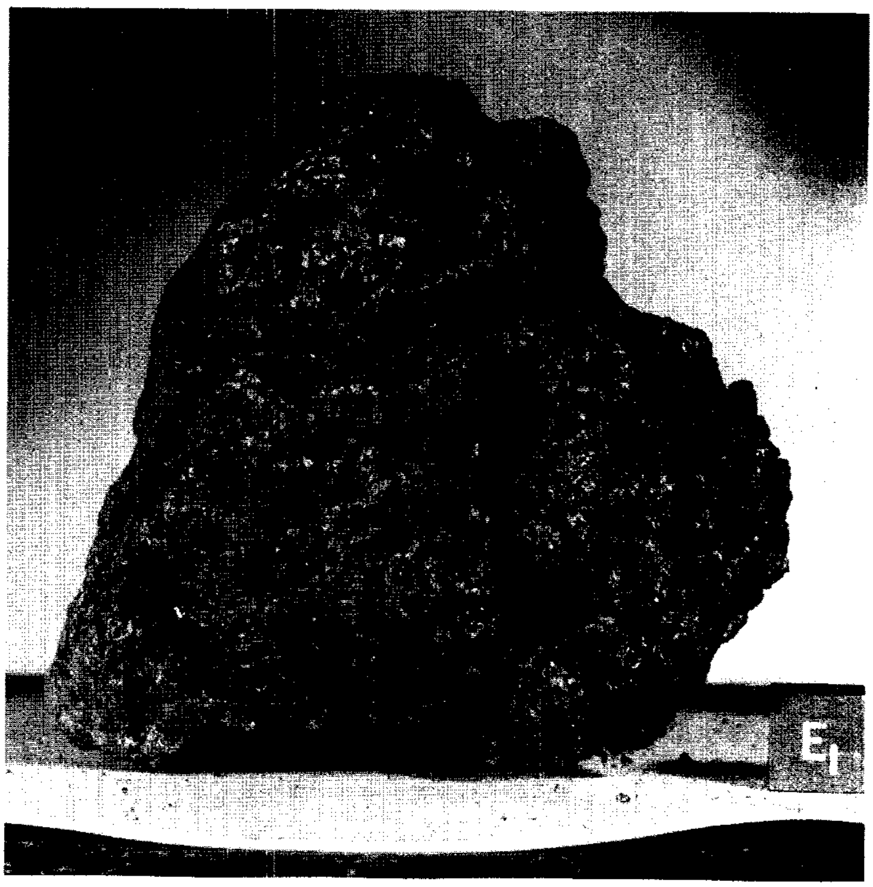


Figure 1: Photograph of 78505. Scale is 1 cm. S73-15384.

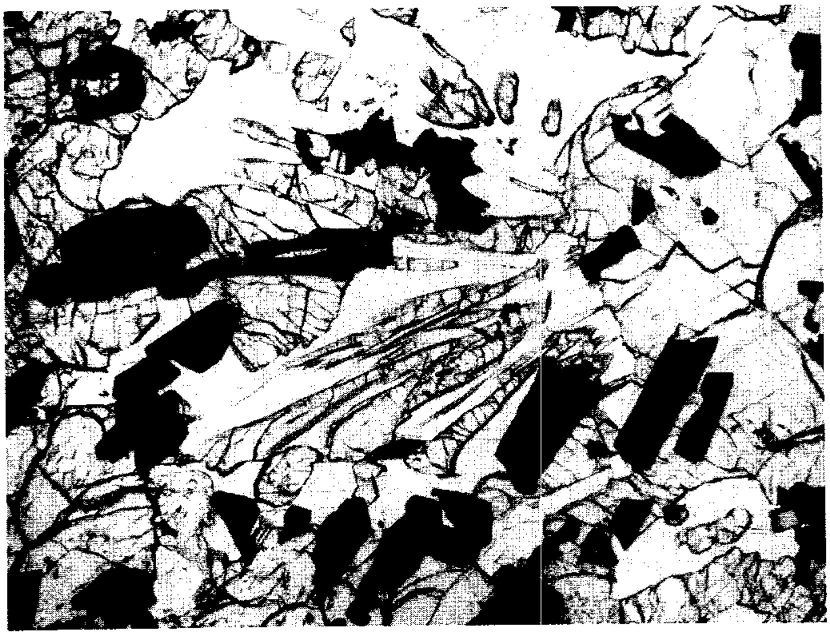


Figure 2: Photomicrograph of thin section 78505,61. Field of view is 3 x 4 mm.

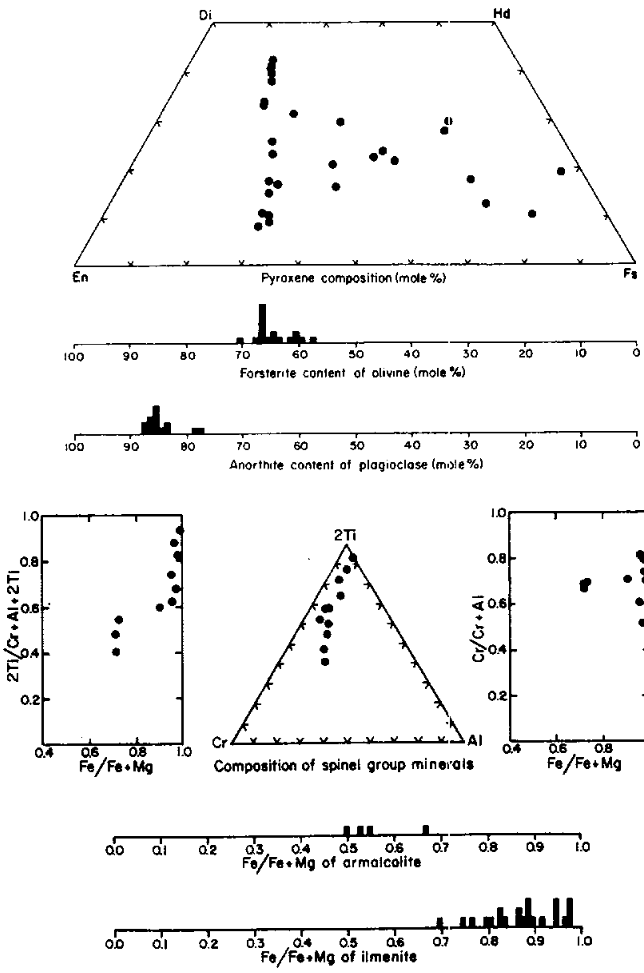


Figure 3: Compositions of minerals in 78505. From Warner et al. (1978).

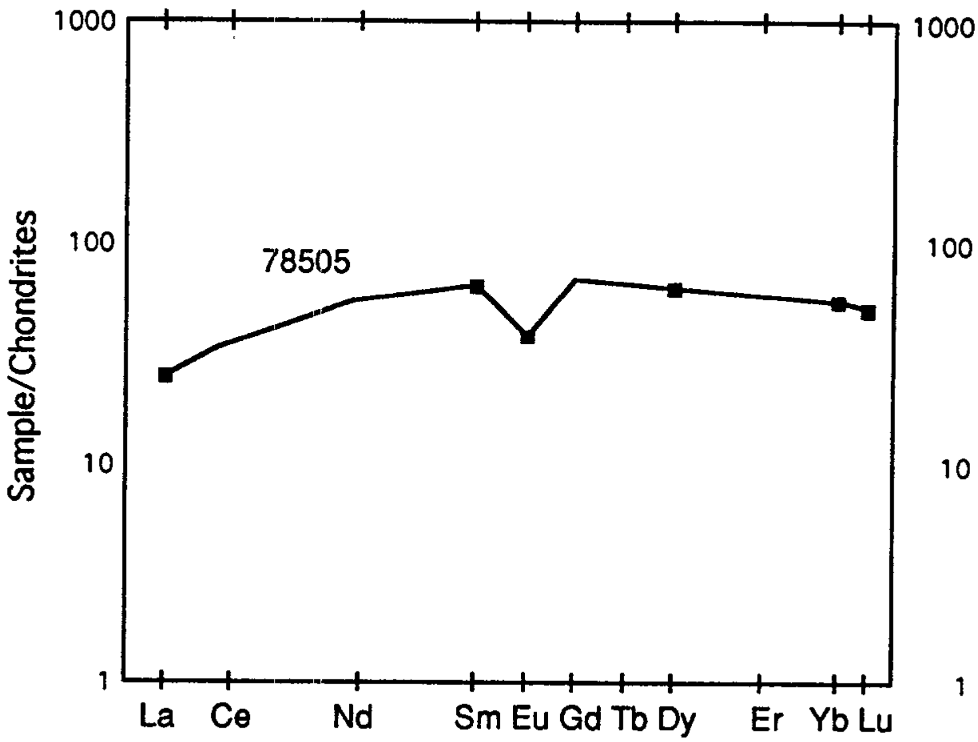


Figure 4: Normalized rare earth element diagram for 78505. Data from Warner et al. (1975a).

Table 1: Whole-rock chemistry of 78505.
From Warner et al. (1975a).

Split Technique	,32 INAA	Split Technique	,32 INAA
SiO_2 (wt%)	–	La	5.9
TiO_2	12.0	Ce	
Al_2O_3	10.6	Nd	
Cr_2O_3	0.436	Sm	9.4
FeO	18.6	Eu	2.1
MnO	0.227	Gd	
MgO	9.5	Tb	
CaO	9.9	Dy	15
Na_2O	0.458	Er	
K_2O	0.07	Yb	8.9
Nb (ppm)		Lu	1.2
Ni		Ge (ppb)	
Co	18.7	Ir	
Sc	74	Au	

Table 2: Solar flare induced activity from large solar flare, August 1972.
From Keith et al. (1974).

	Sample 78505
dpm/Kg	
^{26}Al	72 ± 10
^{22}Na	67 ± 8
^{54}Mn	100 ± 6
^{56}Co	59 ± 13
^{46}Sc	45 ± 4
Th (ppm)	.39 ± .05
U (ppm)	.135 ± .012
K (%)	.0508 ± .008

78506
High-Ti Mare Basalt
55.97 g, 4 x 4.5 x 3 cm

INTRODUCTION

Sample 78506 was collected as part of a soil sample at Station 8. It is a typical ilmenite-rich mare basalt from Apollo 17. It has a network of large vugs (Fig. 1).

PETROGRAPHY

Pyroxene and plagioclase have crystallized together in a nice coarse-grained subophitic texture (Fig. 2).

Brown et al. (1975) give the modal mineralogy of 78506 as 2.0% olivine, 22.6% opaques, 20.7% plagioclase, 52.4% pyroxene, and 2.3% silica. Irregular vugs take up about 10% of the volume of the rock.

MINERAL CHEMISTRY

Brown et al. (1975) have reported a "new" Zr-rich mineral in 78506 that is related to zirconolite.

WHOLE-ROCK CHEMISTRY

Rhodes et al. (1976a) reported the chemical composition of 78506, and Gibson et al. (1976) determined the sulfur content. These analyses are given in Table 1 and Fig. 3.

RADIOGENIC ISOTOPES

Nyquist et al. (1976) have reported Rb-Sr data for the whole rock (Table 2).

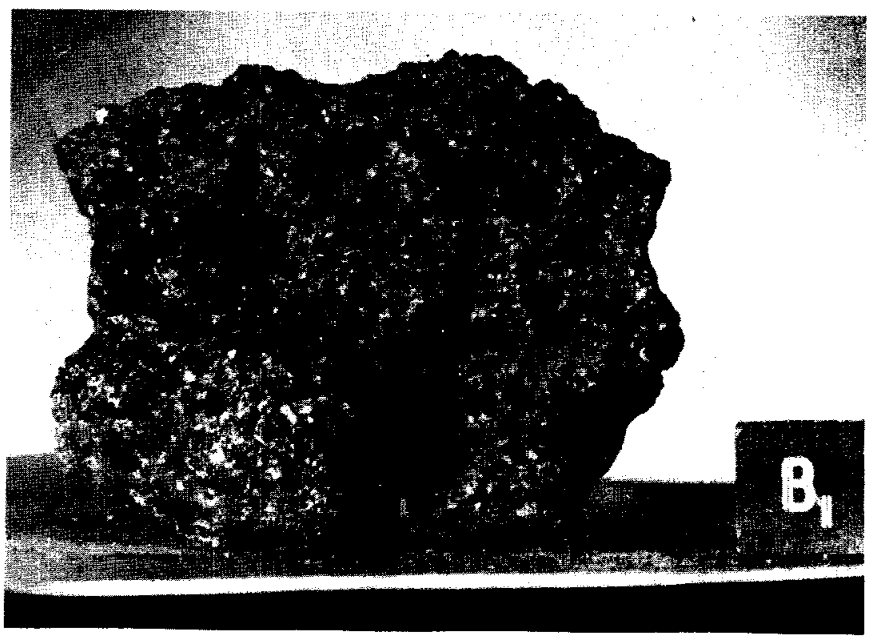


Figure 1: Photograph of 78506. Scale is 1 cm. S73-15467.

Figure 2: Photomicrograph of thin section 78506,27. Field of view is 3 x 4 mm.

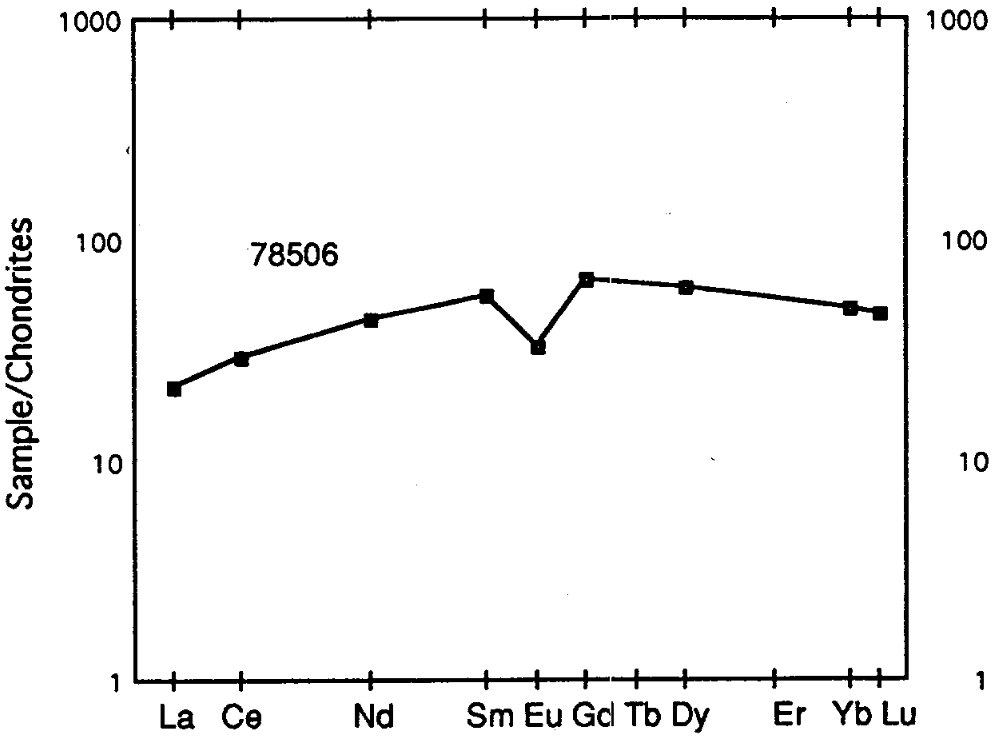


Figure 3: Normalized rare earth element diagram for 78506. Data from Rhodes et al. (1976a).

Table 1: Whole-rock chemistry of 78506.
From Rhodes et al. (1976a).

Split Technique	,29 XRF, IDMS, *INAA*	Split Technique	,29 XRF, IDMS, *INAA*
SiO_2 (wt%)	38.55	Ni	
TiO_2	12.93	Co	*17.6*
Al_2O_3	8.99	Sc	*73*
Cr_2O_3	0.51	La	5.1
FeO	19.36	Ce	17.8
MnO	0.27	Nd	19.6
MgO	9.59	Sm	8.19
CaO	9.94	Eu	1.85
Na_2O	0.39	Gd	12.9
K_2O	0.05	Tb	
P_2O_5	0.02	Dy	14.9
S	0.16	Er	–
Nb (ppm)		Yb	7.99
Hf	*8.2*	Lu	*1.11*
Sr	175	Ge (ppb)	
Rb	0.44	Ir	
Li	9.4	Au	
Ba	65.9		

Table 2: Rb-Sr composition of 78506.
Data from Nyquist et al. (1976).

Sample	78506,29
wt (mg)	50
Rb (ppm)	0.442
Sr (ppm)	175
$^{87}Rb/^{86}Sr$	0.0073 ± 3
$^{87}Sr/^{86}Sr$	0.69961 ± 6
T_B	4.85 ± 0.78
T_L	5.50 ± 0.78

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

78507
High-Ti Mare Basalt
23.35 g, 3.8 x 3.4 x 1.5 cm

INTRODUCTION

Sample 78507 was collected as part of a soil sample at Station 8. It is a typical ilmenite-rich mare basalt from Apollo 17 (Fig. 1).

PETROGRAPHY

Sample 78507 is a very vuggy, coarse-grained mare basalt. The large pyroxenes surround ilmenite. Plagioclase is intergrown with pyroxene (Fig. 2).

WHOLE-ROCK CHEMISTRY

Ma et al. (1979) have reported the chemical composition of 78507 (Table 1 and Fig. 3).

Based on its trace element content, sample 78507 would be classified as a Type B Apollo 17 basalt (see appendix).

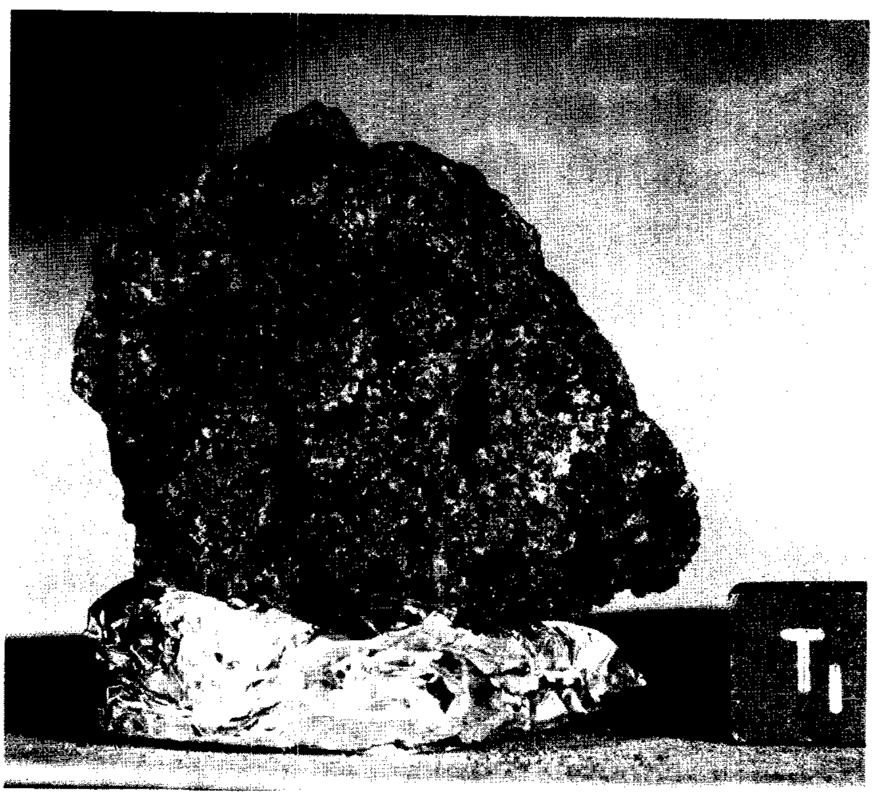


Figure 1: Photograph of 78507. Scale is 1 cm. S73-16144.

Figure 2: Photomicrograph of thin section 78507,4. Field of view is 3 x 4 mm.

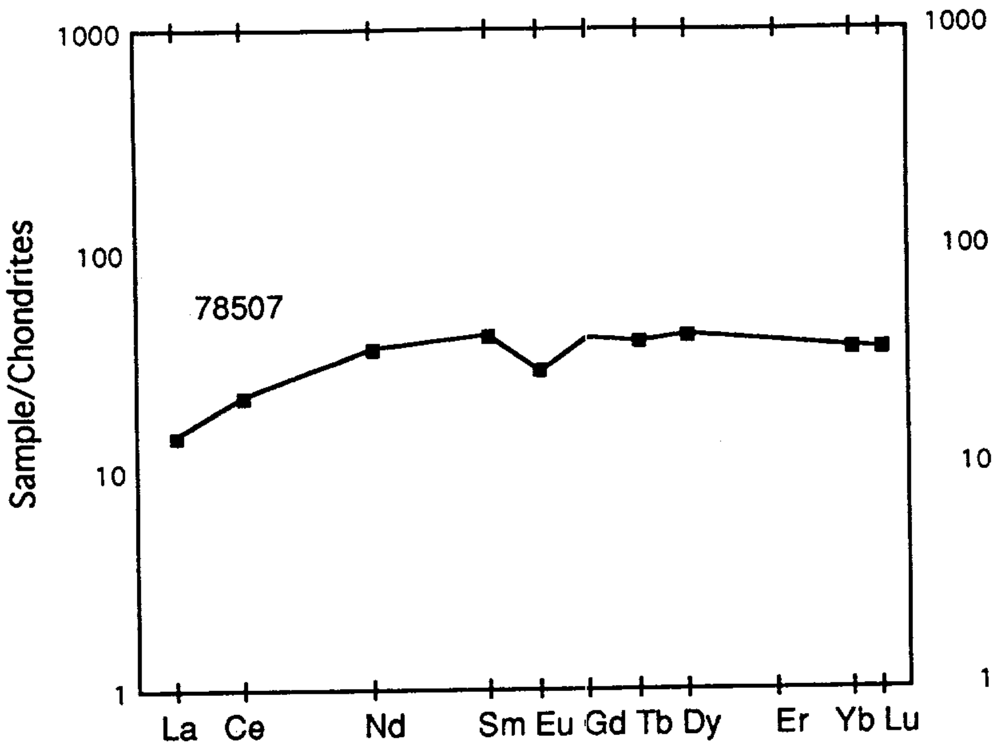


Figure 3: Normalized rare earth element diagram for 78507. Data from Ma et al. (1979).

Table 1: Whole-rock chemistry of 78507.
From Ma et al. (1979).

Split Technique	,1 INAA
SiO_2 (wt%)	–
TiO_2	11.9
Al_2O_3	8.8
Cr_2O_3	0.536
FeO	18.0
MnO	0.222
MgO	10
CaO	9.7
Na_2O	0.407
K_2O	0.037
Nb (ppm)	
Zr	
Hf	5.5
Ta	1.3
Ni	
Co	21
Sc	79
La	3.4
Ce	13
Nd	16
Sm	6
Eu	1.59
Gd	
Tb	1.4
Dy	10
Er	
Yb	5.8
Lu	0.86
Ge (ppb)	
Ir	
Au	

78508
Light Matrix Soil Breccia
10.67 g, ~2 x 1 x 1 cm

INTRODUCTION

Sample 78508 was collected as part of a soil sample at Station 8. It is a typical soil breccia from Apollo 17, although perhaps of a somewhat lighter color.

PETROGRAPHY

Butler (1973) described 78508 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

WHOLE-ROCK CHEMISTRY

78508 has never been studied. There are no thin sections, chemical analyses, or references in the literature.

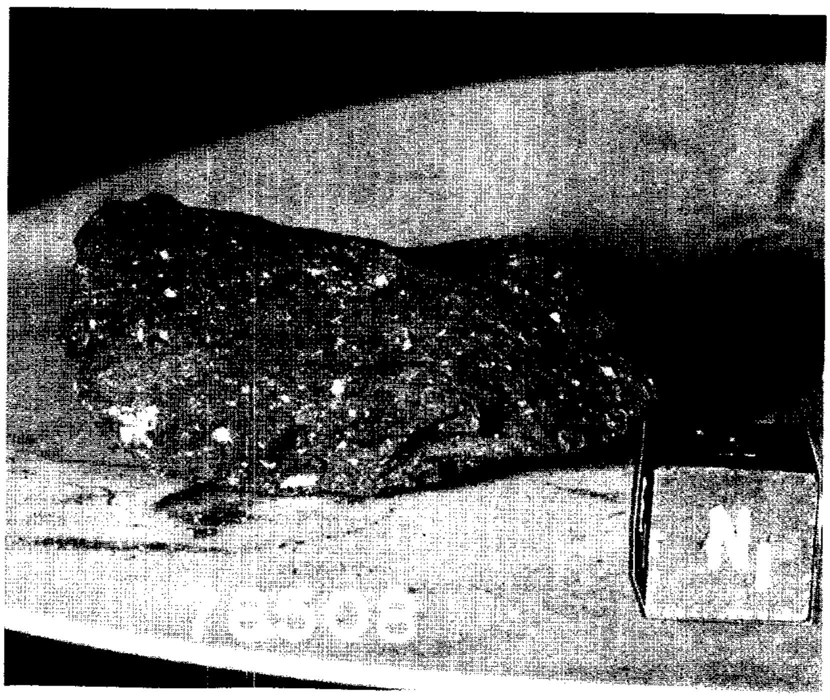


Figure 1: Photograph of 78508. Cube is 1 cm. S73-18608.

78509
High-Ti Mare Basalt
8.68 g, 1.5 x 1.0 x 1.0 cm

INTRODUCTION

Sample 78509 was collected as part of a soil sample at Station 8. It is a typical ilmenite-rich mare basalt from Apollo 17 (Fig. 1).

PETROGRAPHY

Sample 78509 is a typical vuggy mare basalt (Fig. 2) with medium grain size (Butler, 1973).

WHOLE-ROCK CHEMISTRY

Ma et al. (1979) have reported the chemical composition of 78509 (Table 1 and Fig. 3). The soil (78501) has a high percentage of mare basalt.

Sample 78509 is classified as a Type B Apollo 17 basalt (see appendix).

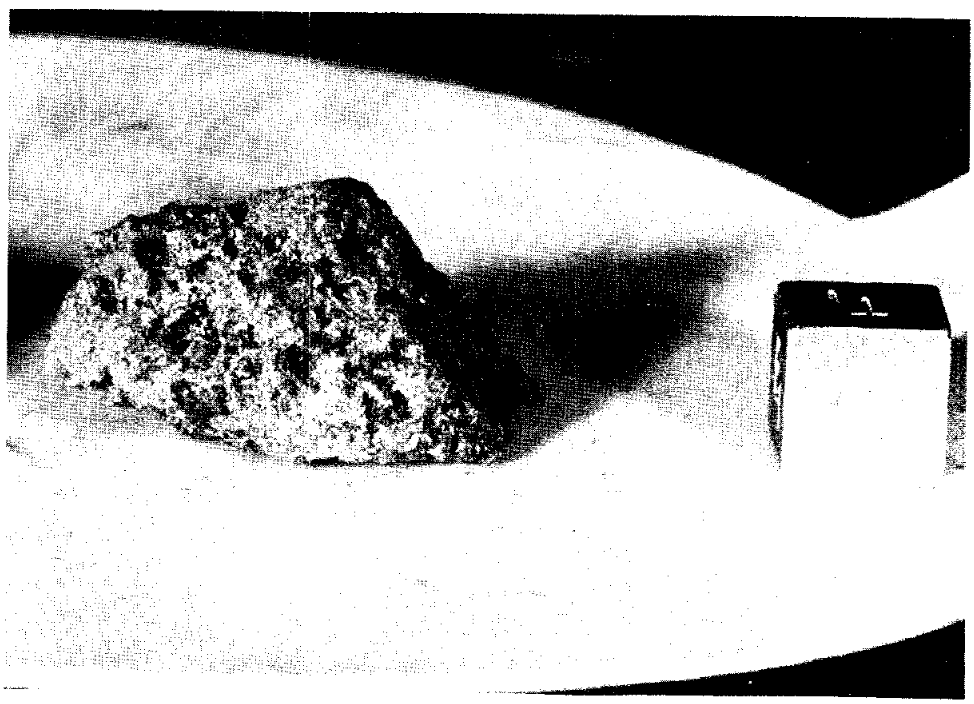


Figure 1. Photograph of 78509. Cube is 1 cm. S73-18608.

Figure 2. Photomicrograph of thin section 78509,5. Field of view is 3 x 4 mm.

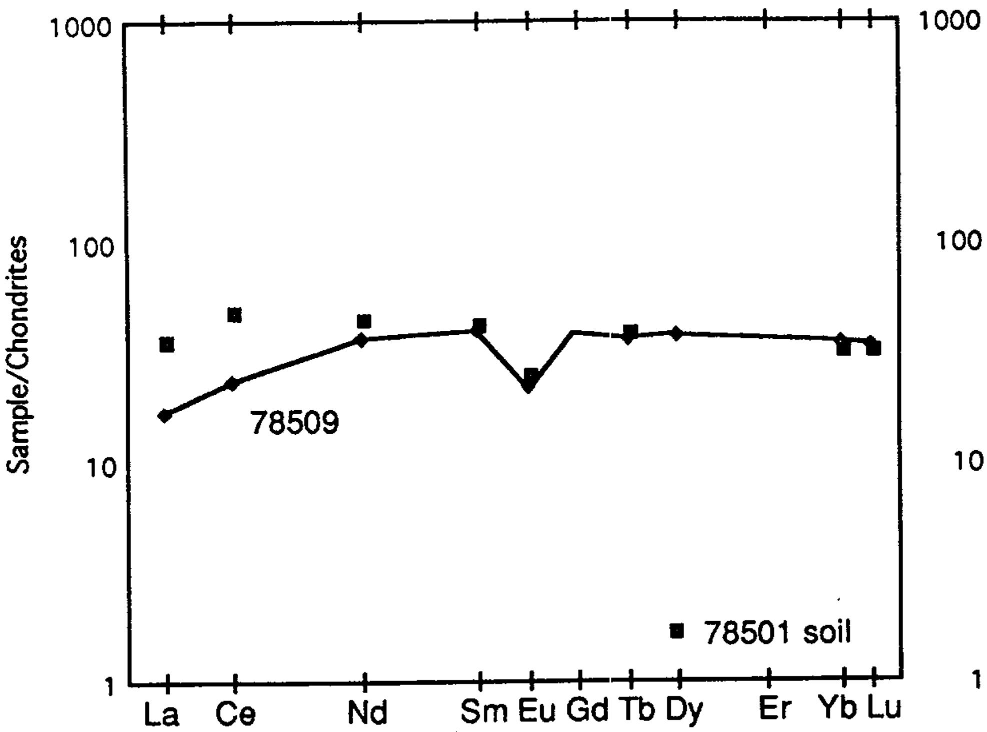


Figure 3. Normalized rare earth element diagram for 78509. Data for the local soil are also included for comparison. Data from Ma et al. (1979).

Table 1: Whole-rock chemistry of 78509.
From Ma et al. (1979).

Split Technique	,1 INAA
SiO_2 (wt%)	–
TiO_2	12.3
Al_2O_3	9.2
Cr_2O_3	0.388
FeO	19.0
MnO	0.252
MgO	8
CaO	10.9
Na_2O	0.414
K_2O	0.04
Nb (ppm)	
Hf	5.1
Ta	1.3
Ni	
Co	22
Sc	89
La	3.9
Ce	14
Nd	16
Sm	5.8
Eu	1.22
Gd	
Tb	1.3
Dy	9
Er	
Yb	5.5
Lu	0.8
Ge (ppb)	
Ir	
Au	

78515
Dark Matrix Breccia
4.76 g, 1.5 x 1.5 x 1.0 cm

INTRODUCTION

Sample 78515 was collected as part of a soil sample at Station 8. It appears to be an exotic breccia with relatively high Al_2O_3 (22.8%).

It also has an unusual rare earth element pattern.

PETROGRAPHY

Butler (1973) describes 78515 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. However, the texture of this sample is not like typical soil breccias (Fig. 1). Jerde et al. (1987) determined that the maturity (I_s/FeO) of 78515 was very low. Consequently, it may not be a soil breccia.

WHOLE-ROCK CHEMISTRY

Jerde et al. (1987) have reported the chemical composition of 78515 (Table 1). The sample has very high Ir (14 ppb). The rare earth element pattern is not like the local soil (Fig. 2).

PROCESSING

The largest piece of 78515 weighs 4.39 g. The only thin section is too small to study.

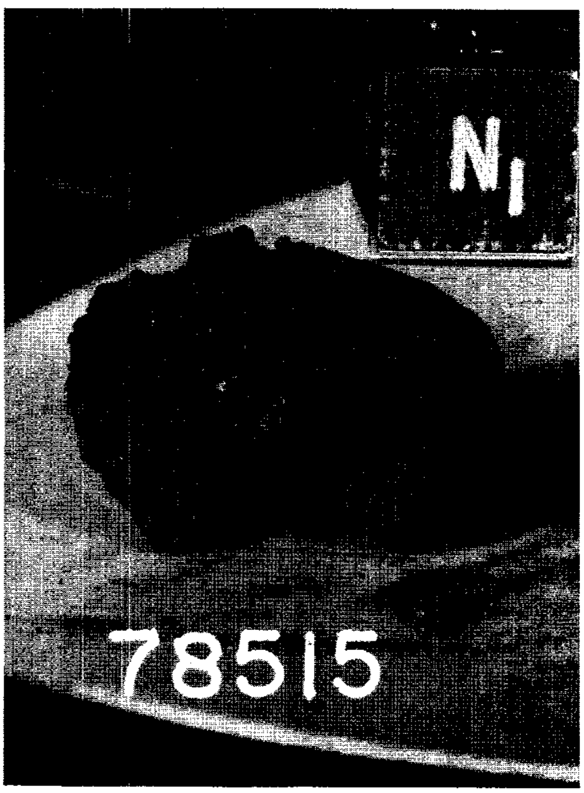


Figure 1: Photograph of 78515. Scale is 1 cm. S73-18607.

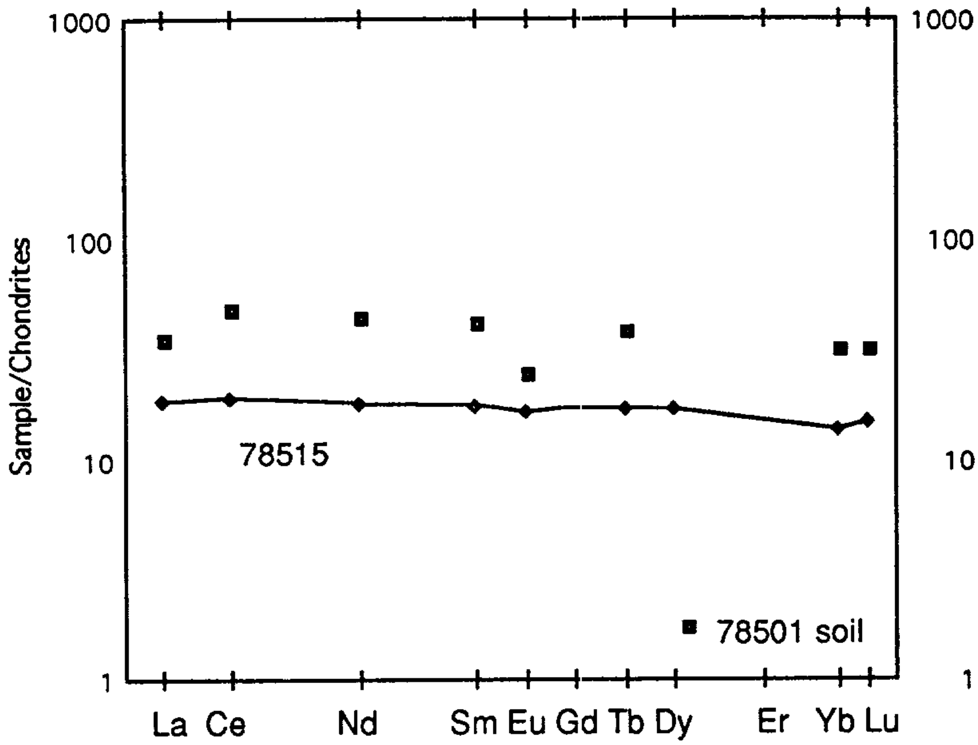


Figure 2: Normalized rare earth element diagram for 78515. Data from Jerde et al. (1987).

Table 1: Whole-rock chemistry of 78515.
From Jerde et al. (1987).

Split Technique	,1 INAA	Split Technique	,1 INAA
SiO_2 (wt%)	44.08	Ni	340
TiO_2	1.67	Co	31.9
Al_2O_3	22.87	Sc	18.7
Cr_2O_3	0.18	La	4.3
FeO	7.72	Ce	11.3
MnO	0.11	Nd	8.2
MgO	7.52	Sm	2.56
CaO	14.42	Eu	0.93
Na_2O	0.37	Gd	
K_2O	0.054	Tb	0.62
Nb (ppm)		Dy	4.1
Zr	200	Er	
Hf	1.8	Yb	2.2
Ta	0.29	Lu	0.36
U	0.24	Ga	3.6
Th	0.75	Ge (ppb)	
Sr	130	Ir	14.8
Ba	69	Au	4.9
Cs	0.26		

78516

Dark Matrix Soil Breccia

3.18 g, 1.5 x 1.0 x 1.0 cm

INTRODUCTION

Sample 78516 was collected as part of a soil sample at Station 8. It is a friable soil breccia and contains orange glass beads.

PETROGRAPHY

Butler (1973) described 78516 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass (Fig. 1).

The thin section of 78516 shows that it contains a seriate distribution of small mineral fragments in brown glass matrix (Fig. 2). Orange glass beads are a distinctive feature.

Jerde et al. (1987) have determined that the maturity (I_S/FeO) of 78516 is submature.

Sample 78518 appears to be the same material.

WHOLE-ROCK CHEMISTRY

Jerde et al. (1987) have reported the chemical composition of 78516 (Table 1 and Fig. 3). It has a composition almost exactly like that of the soil from which it was collected (78501), and it has a high Ir content.

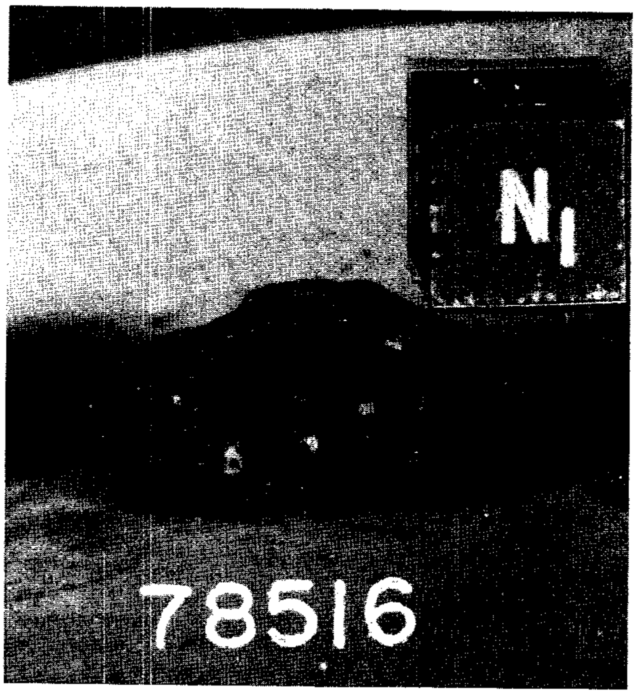


Figure 1: Photograph of 78516. Cube is 1 cm. S73-18607.

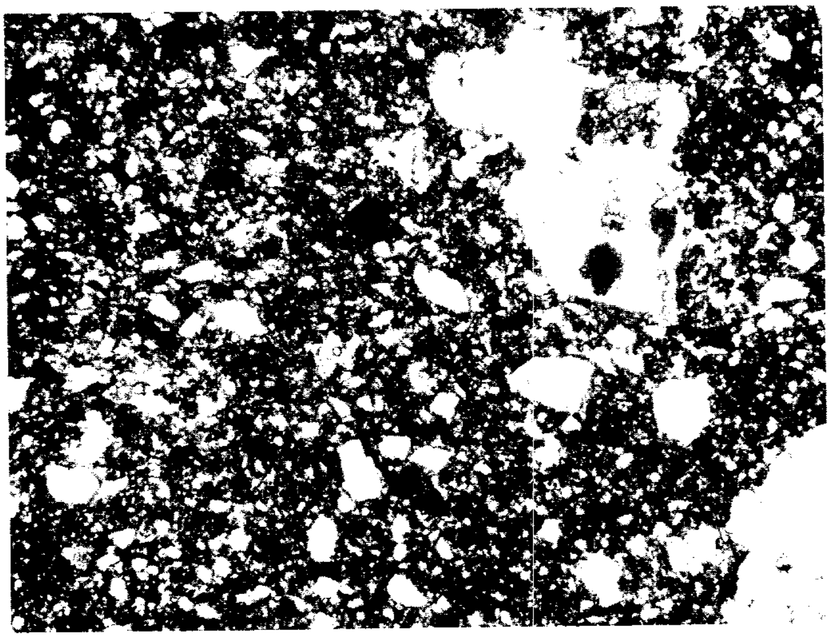


Figure 2: Photomicrograph of thin section 78516,3. Field of view is 3 x 4 mm.

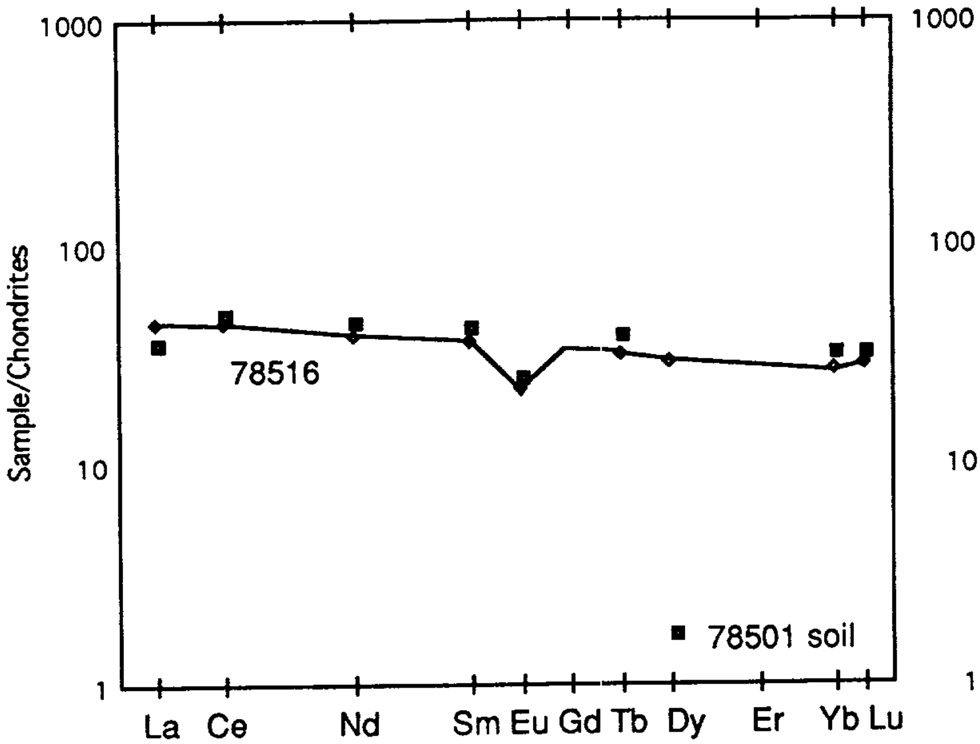


Figure 3: Normalized rare earth element diagram for 78516. Data from Jerde et al. (1987).

Table 1: Whole-rock chemistry of 78516.
From Jerde et al. (1987).

Split Technique	,1 INAA	Split Technique	,1 INAA
SiO_2 (wt%)	44.51	Ni	250
TiO_2	2.47	Co	35.7
Al_2O_3	18.09	Sc	26.1
Cr_2O_3	0.31	La	10.1
FeO	10.41	Ce	26
MnO	0.16	Nd	17
MgO	10.94	Sm	5.3
CaO	11.75	Eu	1.21
Na_2O	0.41	Gd	
K_2O	0.11	Tb	1.14
Nb (ppm)		Dy	6.9
Zr	190	Er	
Hf	3.9	Yb	4.3
Ta	0.52	Lu	0.67
U	0.44	Ga	4.4
Th	1.79	Ge (ppb)	
Sr	180	Ir	10.7
Ba	100	Au	<4
Cs	0.32		

78517

Friable White Cataclasite
1.82 g, 1.1 x 1.0 x 1.0 cm

INTRODUCTION

Sample 78517 was collected as part of a soil sample at Station 8. It appears to be a shocked anorthosite or cataclasite (Fig. 1). It apparently is nonpristine.

PETROGRAPHY

The Preliminary Examination Team described this small sample as a friable white cataclasite (Butler, 1973). During splitting for allocation in 1978, this sample appeared to have the relict texture of a coarse plutonic rock composed of white (80%) and green (20%) minerals. However, the thin sections of a small piece of 78517 (Fig. 2) exhibit a "granulitic" texture with "shear" zones of crushed material (Warren, private communication). Metal grains have high Ni contents (14%) and low Co (0.95%) (unpublished).

CHEMISTRY

Analyses of this sample are not yet published. Sample 78517 has a low rare earth element content; Ir is ~14 ppb, Au is ~9 ppb, and Ni is ~320 ppm (Warren, unpublished). It should be noted that anorthosites *senso stricto* are rare at the Apollo 17 site (Warren et al., 1991).

PROCESSING

A portion of this sample was allocated to P. Warren in 1978, and two thin sections were made.

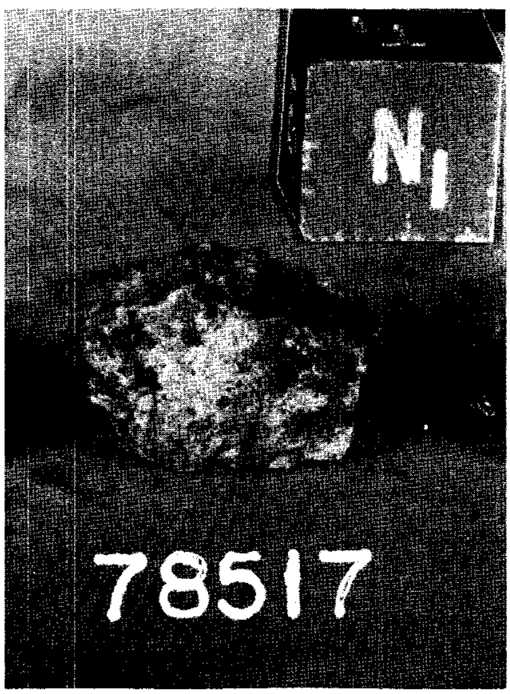


Figure 1: Photograph of 78517. Cube is 1 cm. S73-18607.

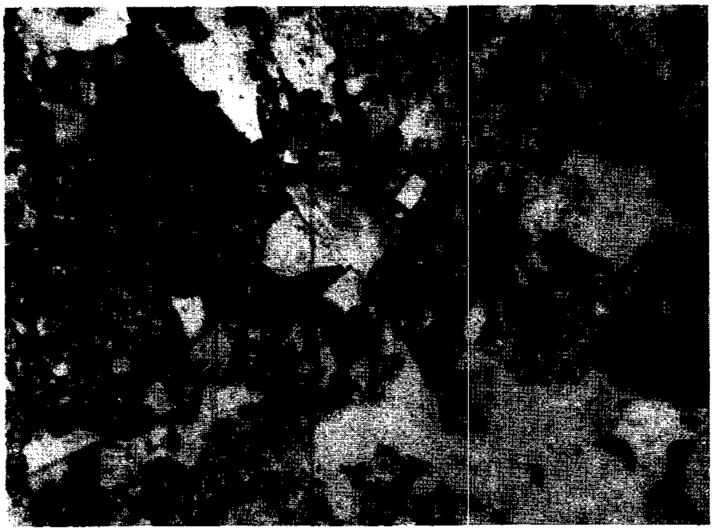


Figure 2. Photomicrograph of thin section 78517,3 with partially crossed polarizers. Field of view is 2.5 x 1.25 mm. (Photo courtesy of Paul Warren.)

78518
Dark Matrix Soil Breccia
0.88 g, 1.0 x 0.5 x 0.5 cm

INTRODUCTION

Sample 78518 was collected as part of a soil sample at Station 8. It is a dark matrix soil breccia, very similar to 78516 and 78555.

PETROGRAPHY

Butler (1973) described 78518 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

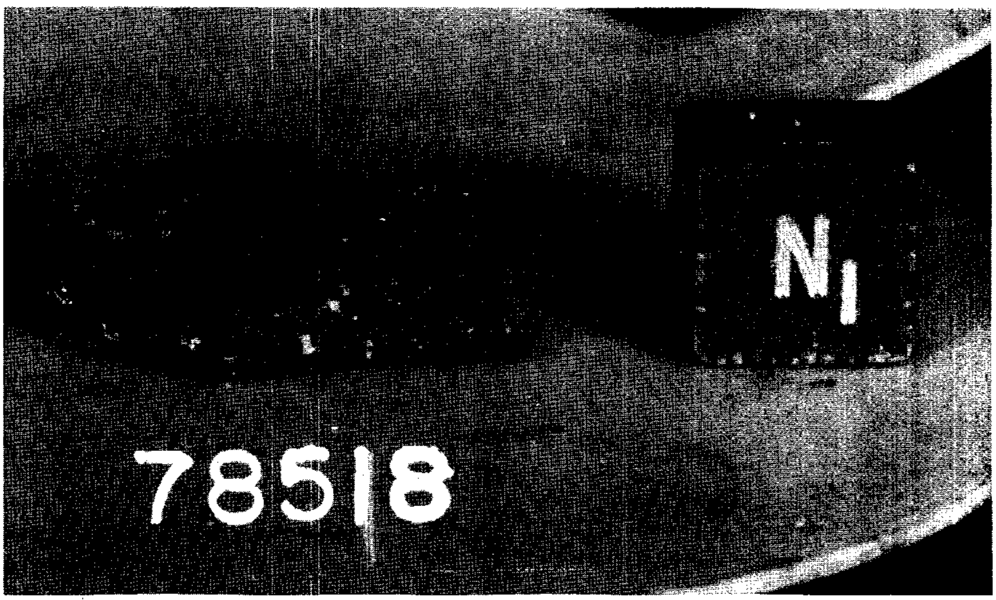


Figure 1: Photograph of 78518. Cube is 1 cm. S73-18607.

78525
Agglutinate
5.11 g, 2.6 x 2.1 x 1.7 cm

INTRODUCTION

Sample 78525 was collected as part of the large rake sample at Station 8 (Keil et al., 1974).

PETROGRAPHY

This relatively large agglutinate consists of about half fragments of dark matrix microbreccia welded in a vesicular black glass (Butler, 1973).

Sample 78525 has not been studied.

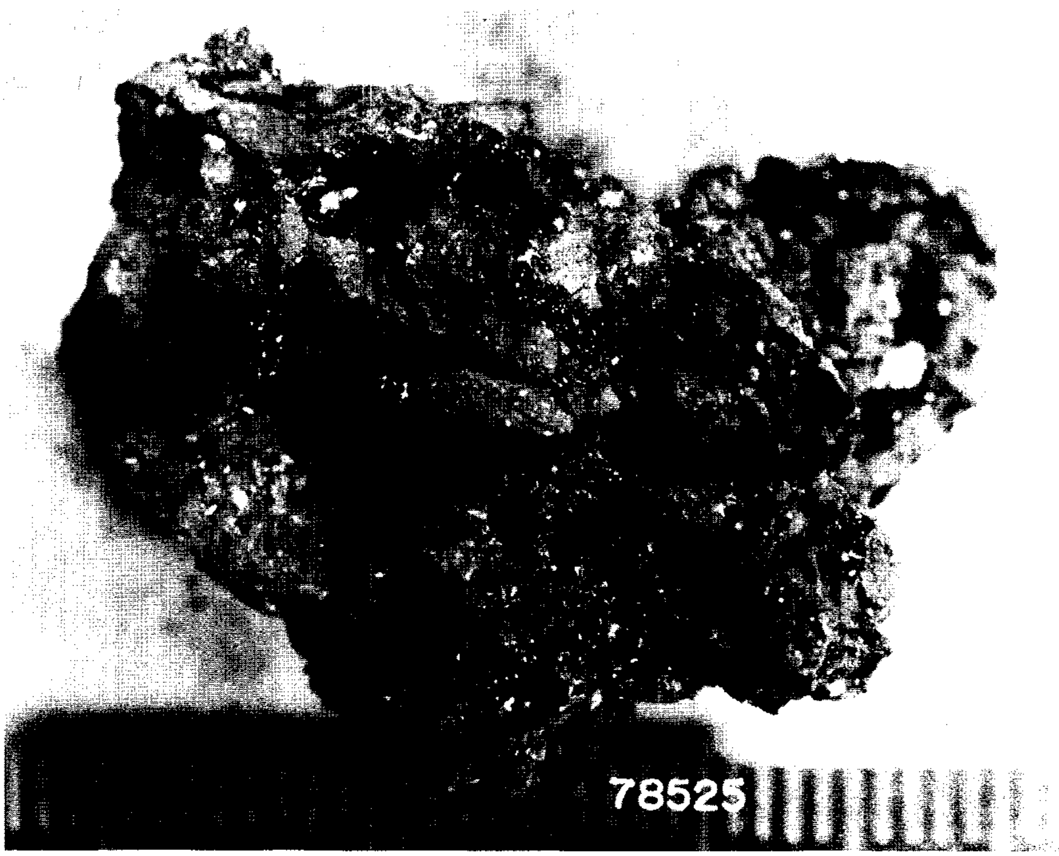


Figure 1: Photograph of 78525. Scale is 1 cm. S73-21033.

78526
Green Glass Vitrophyre
8.77 g, 2.2 x 1.6 x 1.6 cm

INTRODUCTION

Sample 78526 was collected as part of the large rake sample at Station 8 (Keil et al., 1974). It is a very primitive volcanic glass, with very low Ti and REE contents.

PETROGRAPHY

Butler (1973) described this sample as a "mixture of coherent grey breccia disrupted by numerous veins of pale green glass" (Fig. 1). A thin section of the glass shows that needles and chains of olivine and pyroxene have started to grow (Fig. 2). Warner et al. (1978f) find that two textural domains are prevalent in the glass. One has feathery pyroxene and acicular, chain olivine and pyroxene; the other has abundant small "hopper" olivine and tiny chromite euhedra. Relic grains of olivine, pigeonite, plagioclase, chromite, and metal are present in the glass, and two types of very low Ti (VLT) mare basalt are present as lithic clasts.

Warner et al. (1978a) have studied 78526 carefully and have concluded that it was formed as an impact melt that mixed at least two very different low Ti basalts.

Papike and Vaniman (1978) classify this glass as a VLT basalt.

MINERAL CHEMISTRY

The compositions of minerals in 78526 have been reported by Warner et al. (1978f) (Fig. 3). Plagioclase is almost pure anorthite.

Warner et al. (1978a) report that metal grains have a range in composition: in the porphyritic lithology, 1.0-6.7% Ni and 1.3-2.8% Co; in the granular lithology, 0.8-1.6% Ni and 1.0-1.4% Co; and individual grains in the glass, 1.2-18.9% Ni and 1.0-3.4% Co. None of the metal in 78256 appears to be of meteoritic origin, as all the grains analyzed by Warner et al. contain >1 wt % Co.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the chemical composition of 78526 (Table 1 and Fig. 4). In 1977, Murali et al. repeated the analysis and got identical results. Hughes and Schmitt (1985) have used the composition of 78526 to discuss the

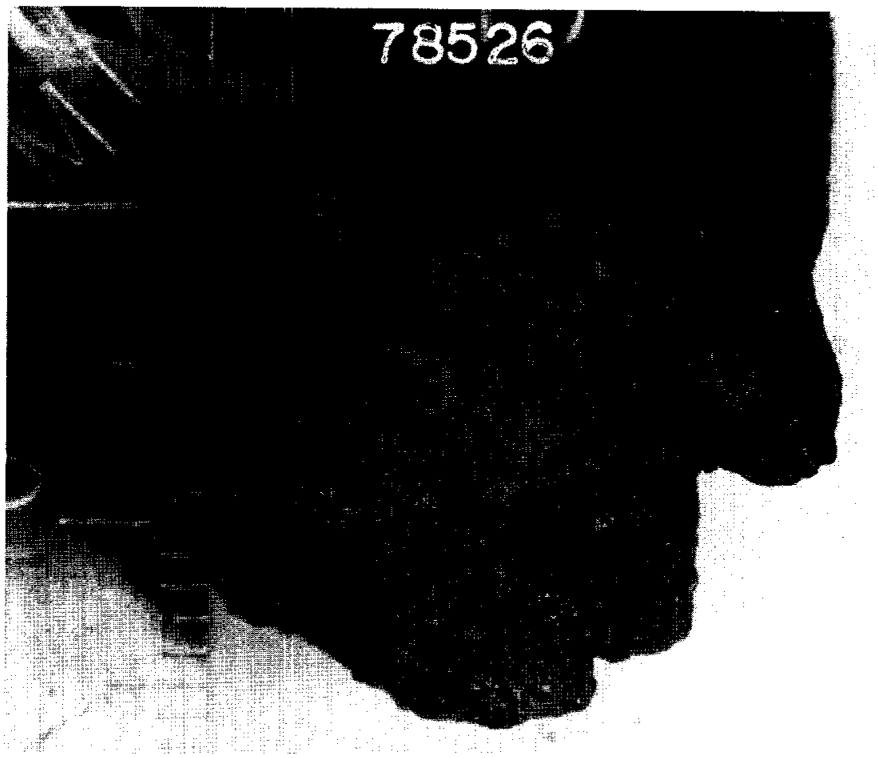


Figure 1: Photograph of 78526. Scale is 1 cm. S73-33667.

Zr-Hf-Ta fractionation during lunar evolution.

Jovanovic and Reed (1978) have determined Cl, Br, I, U, and P in 78526.

SIGNIFICANT CLASTS

Small clasts of VLT basalt are included in the glass. In hand specimen, large clasts of basalt appear to be present. At the time of cataloging, 78526 is being actively studied by P. Warren and M. Tatsumoto.

SURFACE STUDIES

The surface of 78526 has many micrometeorite craters.

Figure 2: Photomicrograph of thin section 78526,18. Field of view is 3 x 4 mm.

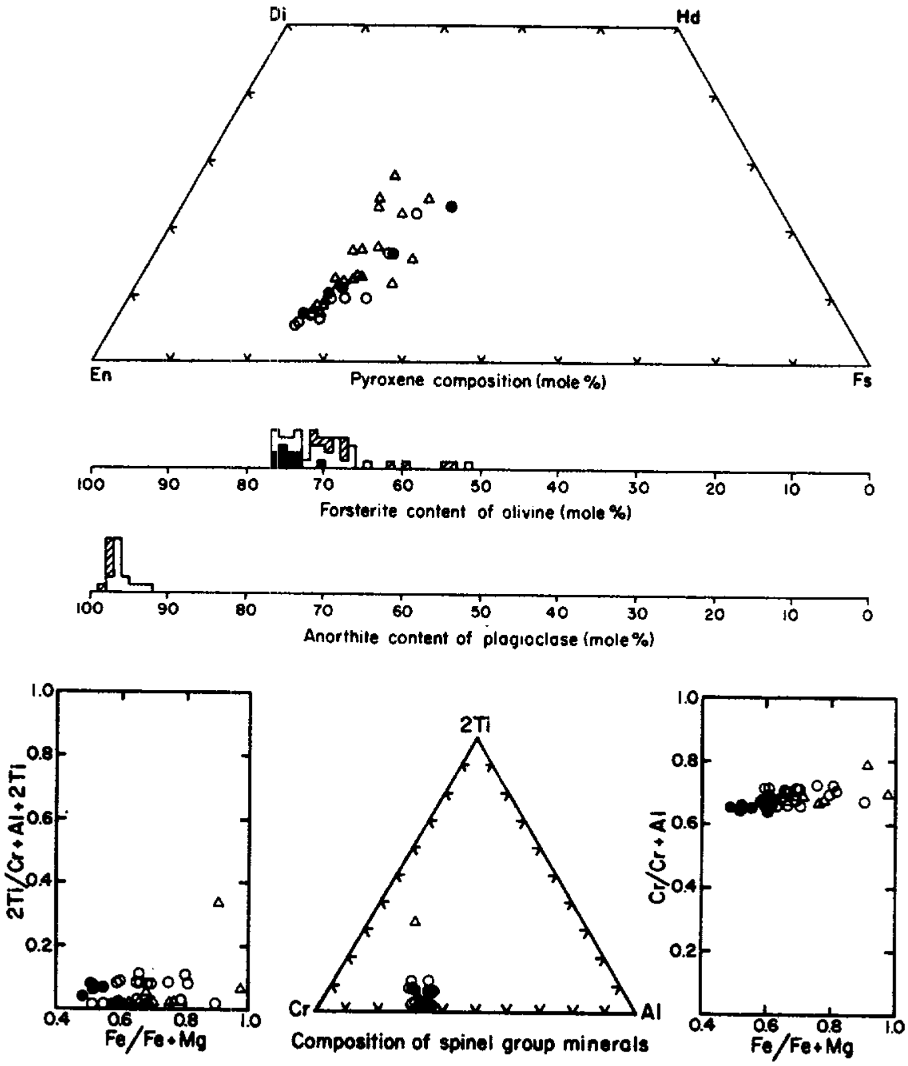


Figure 3: Compositions of minerals in 78526. From Warner et al. (1978a and f).

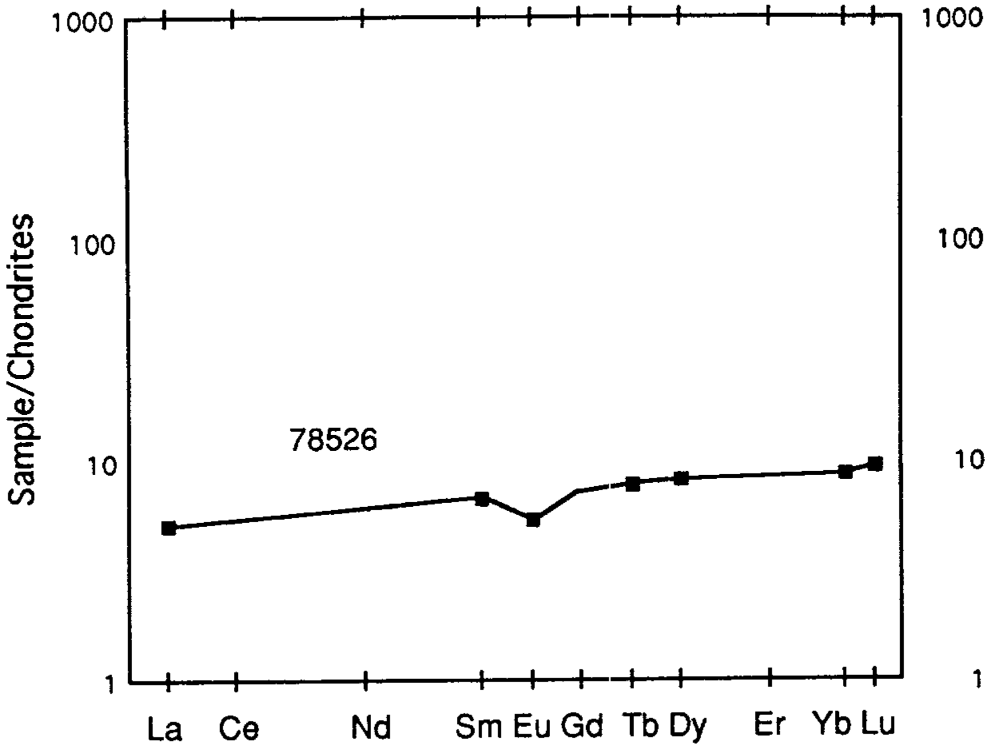


Figure 4: Normalized rare earth element diagram for 78526. Data from Laul and Schmitt (1975).

Table 1: Whole-rock chemistry of 78526.
a) Laul and Schmitt (1975c); b) Murali et al. (1977a)

Split Technique	,1 (a) INAA	,6 (b) INAA
SiO_2 (wt%)	–	–
TiO_2	0.8	1.1
Al_2O_3	11.1	10.7
Cr_2O_3	0.74	1.02
FeO	17.4	17.6
MnO	0.261	0.278
MgO	11	12
CaO	10	9.7
Na_2O	0.15	0.16
K_2O	0.02	0.015
Nb (ppm)		
Zr	–	226
Hf	0.5	0.7
Ta	0.06	
Ni	–	
Co	45.4	44
Sc	51	48
La	1.2	1.3
Ce	–	
Nd	–	
Sm	1	1.1
Eu	0.3	0.25
Gd		
Tb	0.28	0.27
Dy	2	1.8
Er		
Yb	1.4	1.4
Lu	0.23	0.24
Ge (ppb)		
Ir		
Au		

78527
Granulitic Noritic Breccia
5.16 g, 1.8 x 1.3 x 1.2 cm

INTRODUCTION

Sample 78527 was collected as part of a large rake sample at Station 8 (Kiel et al., 1974). It is a light-colored, recrystallized norite (Fig. 1).

PETROGRAPHY

Butler (1973) described this sample as a "brecciated, coarse-grained (up to 4 mm) gabbroic rock with a dark glass coating. The plagioclase is probably maskelynite, and the mafic silicate is pale green." In a few places the sample is thinly coated by dark breccia material, suggesting that it was a clast in a soil breccia.

Nehru et al. (1978) describe 78527 as a recrystallized norite, containing ~52% plagioclase (An_{94}), 45% orthopyroxene ($Wo_3En_{77}Fs_{20}$), 2% olivine (Fo_{77}), and ~0.3% accessories, including minor high-Ca pyroxene ($Wo_{42}En_{48}Fs_{10}$), armalcolite, ilmenite, rutile, chromite, baddeleyite, zirconolite, zircon, K-feldspar, metal, and troilite. The rock consists of large, seriate, subangular plagioclase (up to 2 mm) and orthopyroxene (up to 0.8 mm) crystals in a fine-grained recrystallized matrix (Fig. 2). Minor olivine occurs as large polygonized grains.

Cushing et al. (1993) include 78527 in their suite of lunar granulites.

MINERAL CHEMISTRY

The compositions of minerals in 78527 are given in Nehru et al. (1978) and Warren et al. (1978f) (Fig. 3). Metal grains in 78527 are all high in Ni (25-53%) and Co (1.9-2.2%).

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c), Murali et al. (1977a), and Warren et al. (1983) have reported the chemical composition of 78527 (Table 1 and Fig. 4). This composition and the mineral composition are similar to that of pristine lunar norite 78235. Warren (1993) lists it as a potentially pristine lunar sample. However, it has a relatively high Ir content.

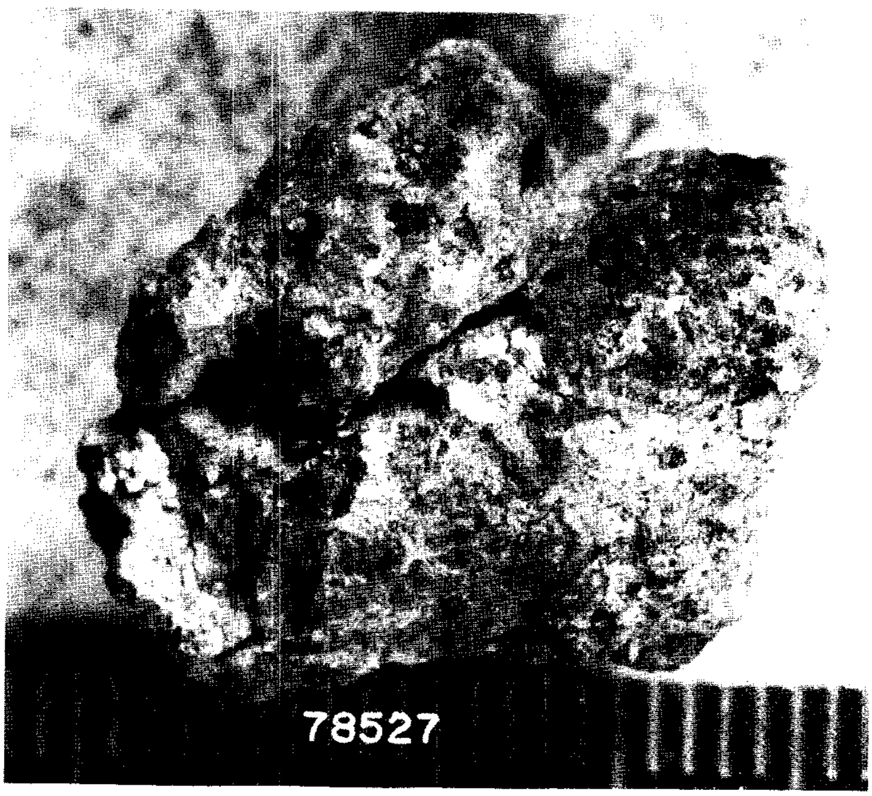


Figure 1: Photograph of 78527. The white spot in the center is an artifact. Scale is 1 cm. S73-21026.

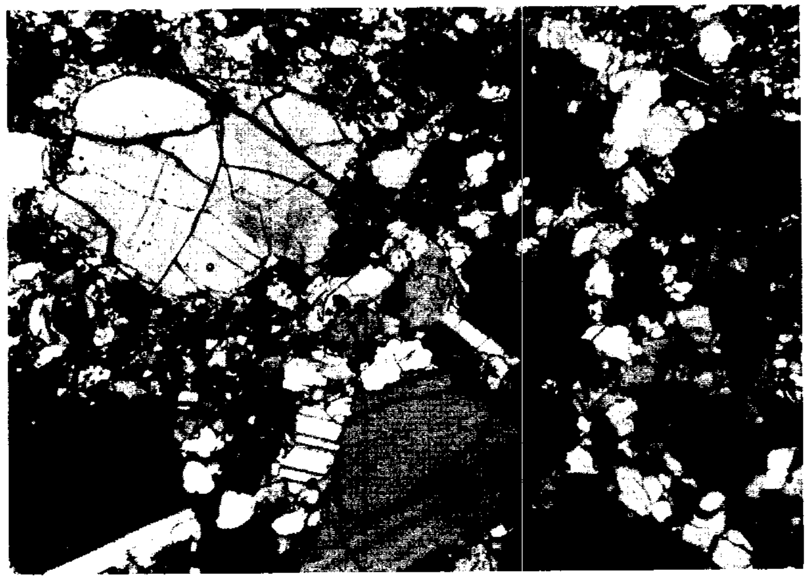


Figure 2: Photomicrograph of thin section 78257. Field of view is 3 x 4 mm. From Warner et al. (1978).

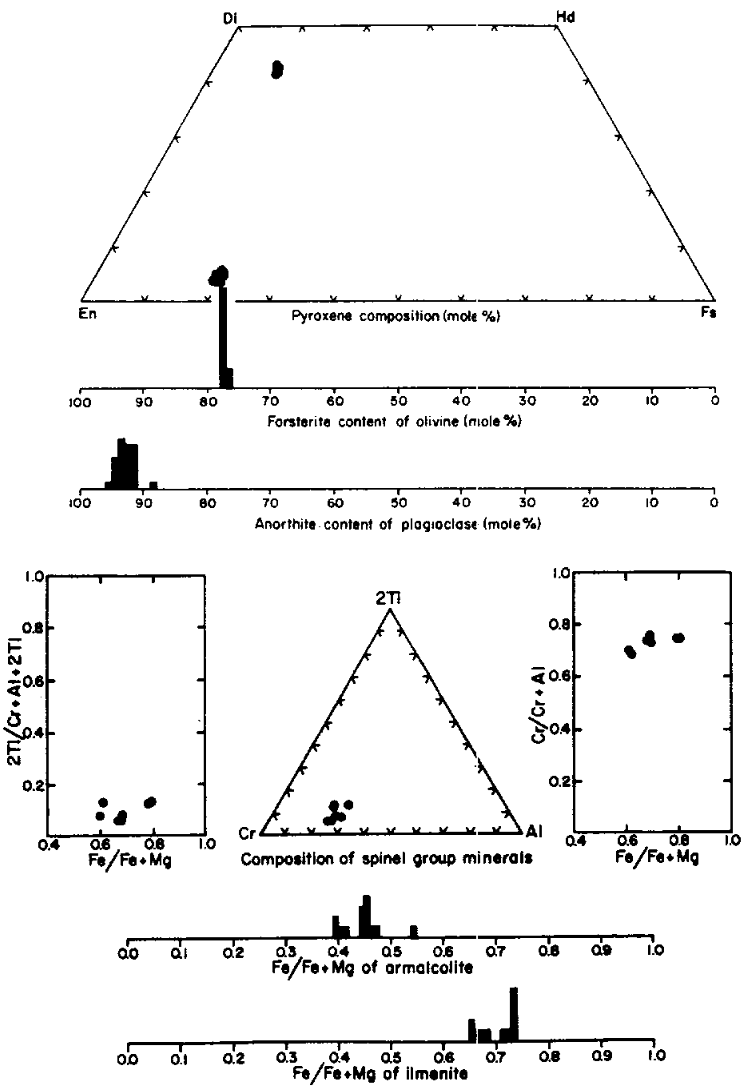


Figure 3: Compositions of minerals in 78527. From Warner et al. (1978).

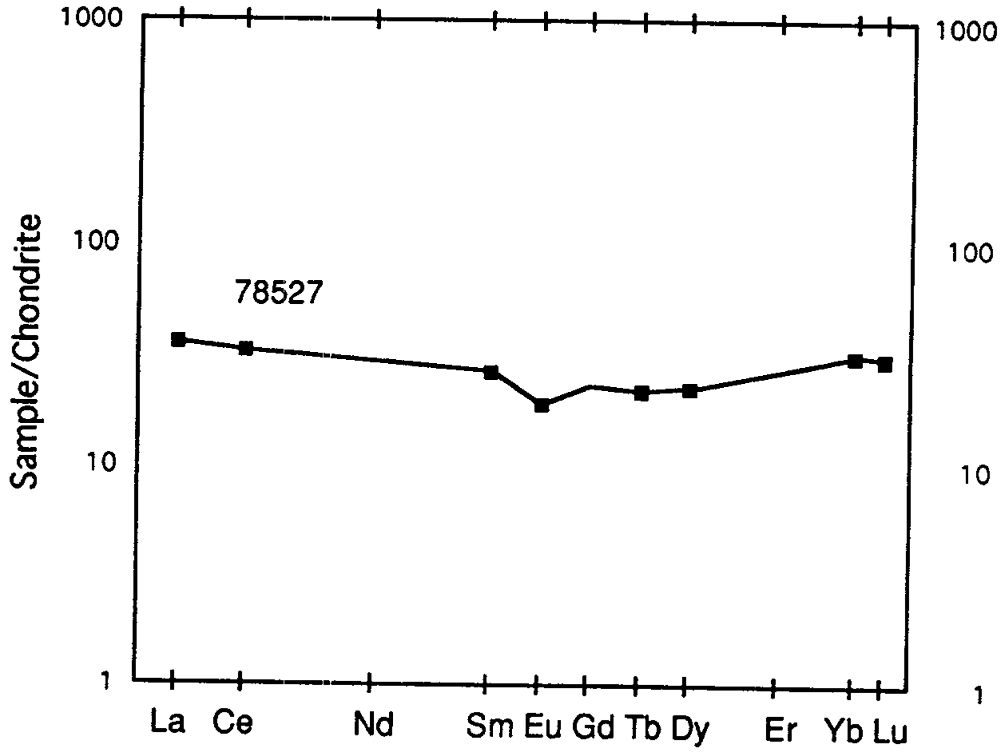


Figure 4: Normalized rare earth element diagram for 78527. Data from Laul and Schmitt (1975).

Table 1: Whole-rock chemistry of 78527.
a) Laul and Schmitt (1975c); b) Murali et al. (1977a); c) Warren et al. (1983)

Split Technique	,2 (a) INAA	,2 (b) INAA	,5 (c) INAA
SiO_2 (wt%)	–	–	45.37
TiO_2	0.6	0.38	0.37
Al_2O_3	16.8	13.3	14.93
Cr_2O_3	0.21	0.191	0.215
FeO	7.4	8.3	9.90
MnO	0.09	0.087	0.12
MgO	15	14	19.75
CaO	9.2	7.8	8.12
Na_2O	0.42	0.36	0.35
K_2O	0.065	0.054	0.07
Nb (ppm)			
Zr	–		<350
Hf	2.9	3.2	2.76
Ta	0.3	0.33	0.33
U	–		0.29
Th	1.4	0.7	1.6
Ba	150	110	140
Ni	120	170	102
Co	31.6	35	47
Sc	9.4	8	9.4
La	8.5	7.9	9.3
Ce	20	(25)	25.5
Nd			14
Sm	3.9	2.9	3.72
Eu	1.07	0.97	0.98
Gd			
Tb	0.8	0.7	0.83
Dy	5.5	4.7	5.7
Er			
Yb	5	3.4	3.76
Lu	0.73	0.59	0.61
Ge (ppb)			86
Ir		6	2.8
Au			0.23

78528
Basalt
7.00 g, 2.0 x 1.5 x 1.2 cm

INTRODUCTION

Sample 78528 was collected as part of a soil sample at Station 8. It appears to be a typical ilmenite-rich mare basalt from Apollo 17 (Fig. 1).

PETROGRAPHY

78528 is a fine-grained mare basalt with breccia attached to its surface. It may have been a clast in a breccia (Butler, 1973).

This sample has not been studied.

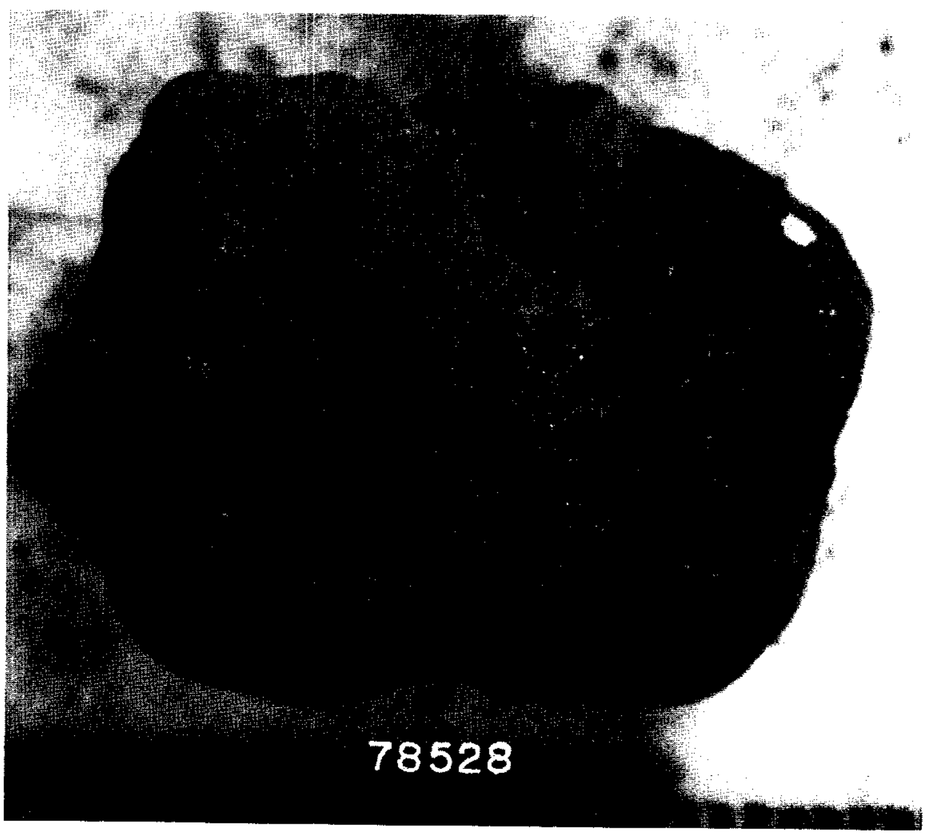


Figure 1: Photograph of 78528. Scale is 1 cm. S73-21028.

78535

Dark Matrix Breccia

103.4 g, 2 pieces: 6.0 x 5.0 x 4.1 cm; 1.5 x 1.5 x 0.5 cm

INTRODUCTION

Sample 78535 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). 78535 appears to be similar to 78546, which is perhaps the best studied of this group of soil breccias.

PETROGRAPHY

Butler (1973) describes 78535 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt. Keil et al. (1974) and Warner et al. (1978f) have also described 78535 in their catalogs.

In thin section, the breccia matrix consists of abundant small mineral clasts together with dark brown glass that firmly cements the rock (Fig. 2). Warner et al. found abundant mineral, glass, and lithic clasts. Lithic clasts include anorthosite and mare basalt. Orange and devitrified orange glass spherules are common.

Warner et al. (1979) have studied the glass compositions in 78535.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the chemical composition of 78535 (Table 1). The chemical composition is almost exactly like that of the local soil (78501) (Fig. 3).

SIGNIFICANT CLASTS

Fig. 1 shows a relatively large (8 mm), chalky white clast that apparently has not been studied.

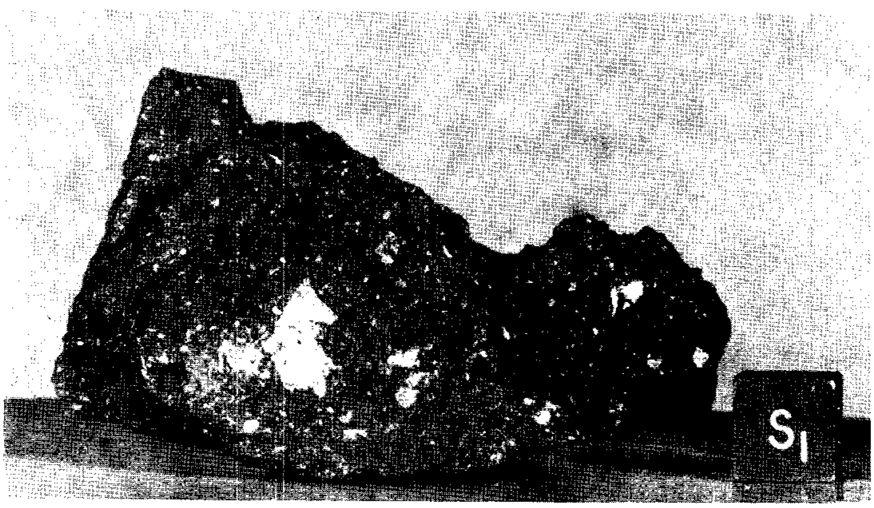


Figure 1: Photograph of 78535. Scale is 1 cm. S73-21429.

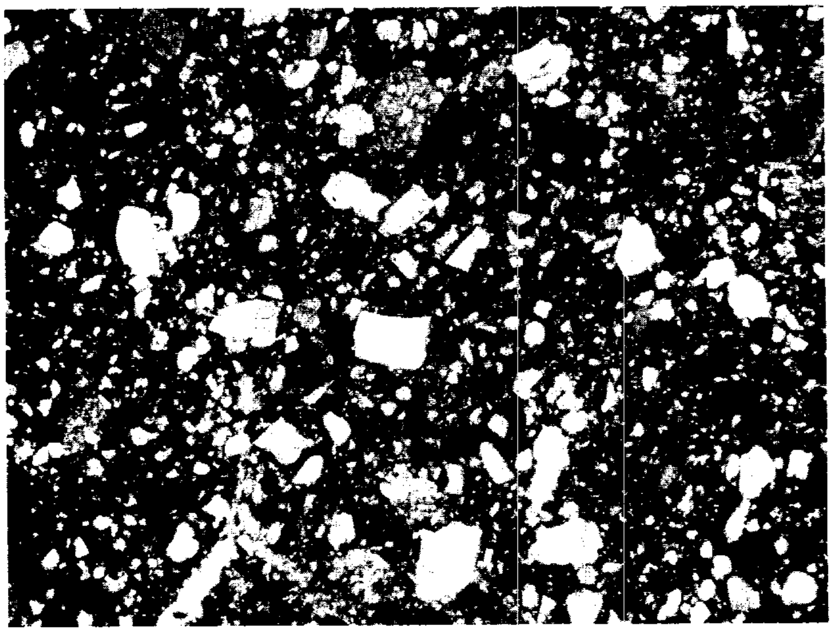


Figure 2: Photomicrograph of thin section of 78535,7. Field of view is 3 x 4 mm.

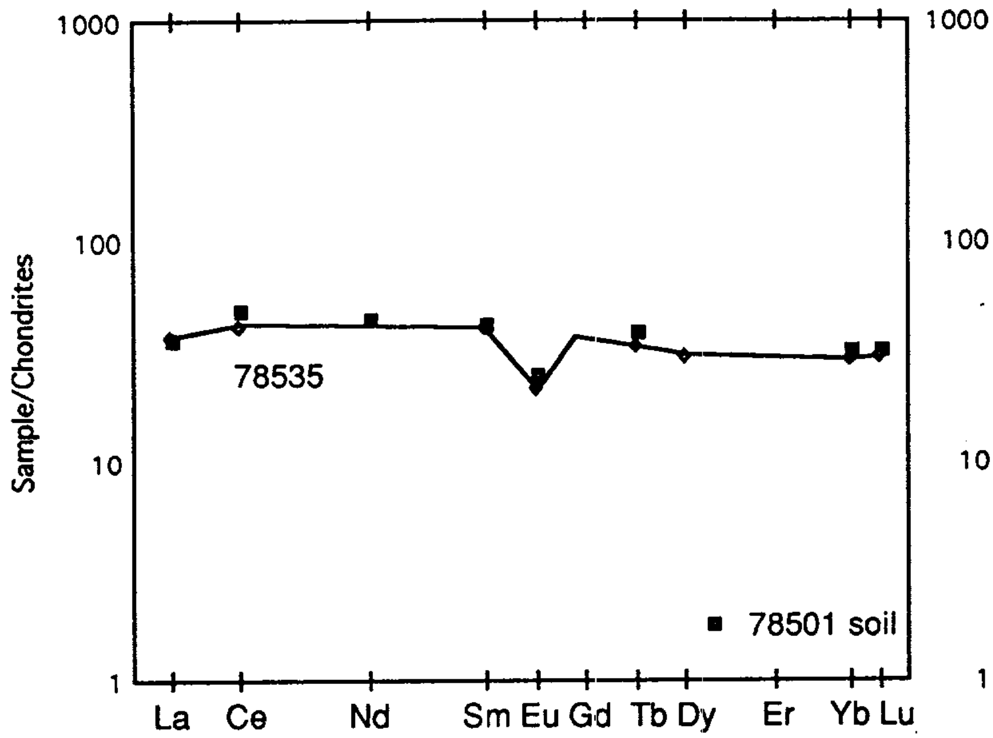


Figure 3: Normalized rare earth element diagram for 78535 compared with data from local soil. Data from Laul and Schmitt (1975c).

Table 1: Whole-rock chemistry of 78535.
From Laul and Schmitt (1975c).

Split Technique	,3 INAA
SiO_2 (wt%)	–
TiO_2	3.9
Al_2O_3	17.2
Cr_2O_3	0.30
FeO	11.3
MnO	0.14
MgO	9.7
CaO	11.6
Na_2O	0.38
K_2O	0.09
Nb (ppm)	
Hf	4.4
Ta	0.75
U	–
Th	1.0
Ba	–
Ni	200
Co	30.7
Sc	32
La	8.3
Ce	24
Nd	
Sm	5.9
Eu	1.2
Gd	
Tb	1.2
Dy	7.2
Er	
Yb	4.7
Lu	0.72
Ge (ppb)	
Ir	
Au	

78536
Dark Matrix Breccia
8.67 g, 3.0 x 1.8 x 1.3 cm

INTRODUCTION

Sample 78536 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It is similar to 78535 (Keil et al., 1974).

PETROGRAPHY

Butler (1973) describes 78536 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt.

Sample 78536 has not been studied.

Figure 1: Photograph of 78536. Scale is 1 cm. S73-33419.

78537
Dark Matrix Breccia
11.76 g, 3.0 x 2.0 x 1.9 cm

INTRODUCTION

Sample 78537 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). This brown glass matrix breccia is similar to 78535.

PETROGRAPHY

Butler (1973) describes 78537 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt.

Thin sections of 78537 show that it has a brown glass matrix including orange glass spheres and mare basalt fragments (Fig. 2). This breccia is probably from the mare surface near Station 8.

Warner et al. (1979) have studied the glass compositions in 78537.

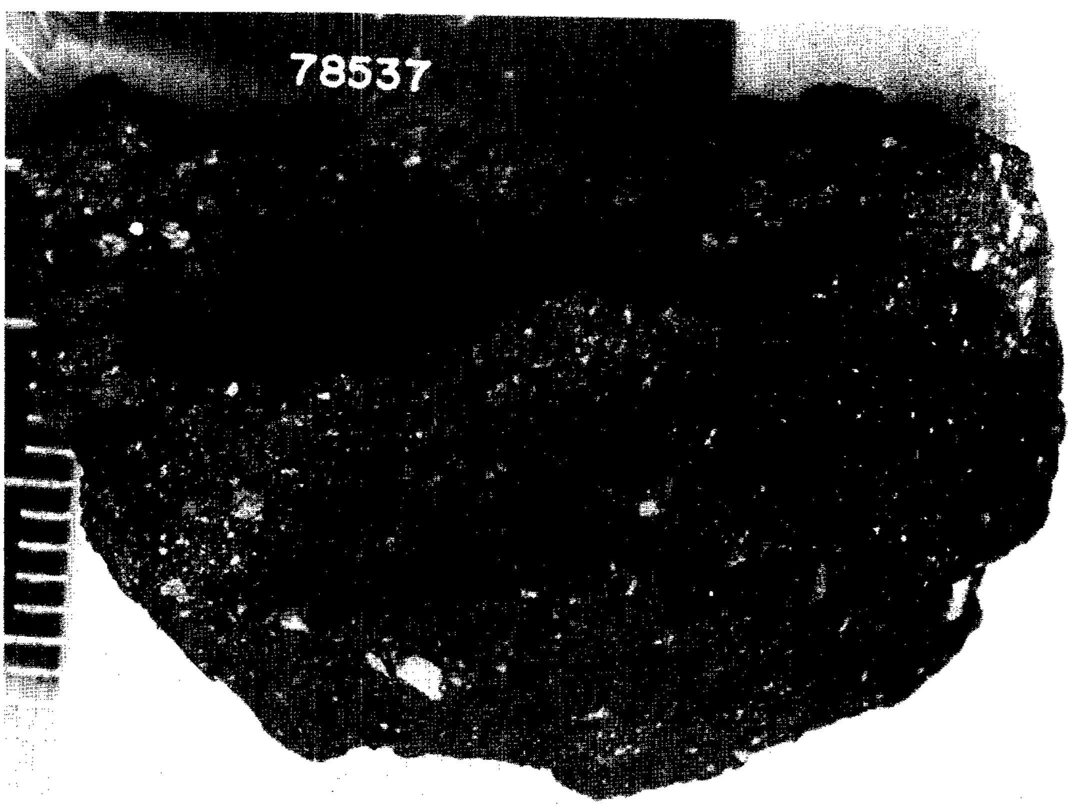


Figure 1: Photograph of 78537. Scale is 1 cm. S73-33404.

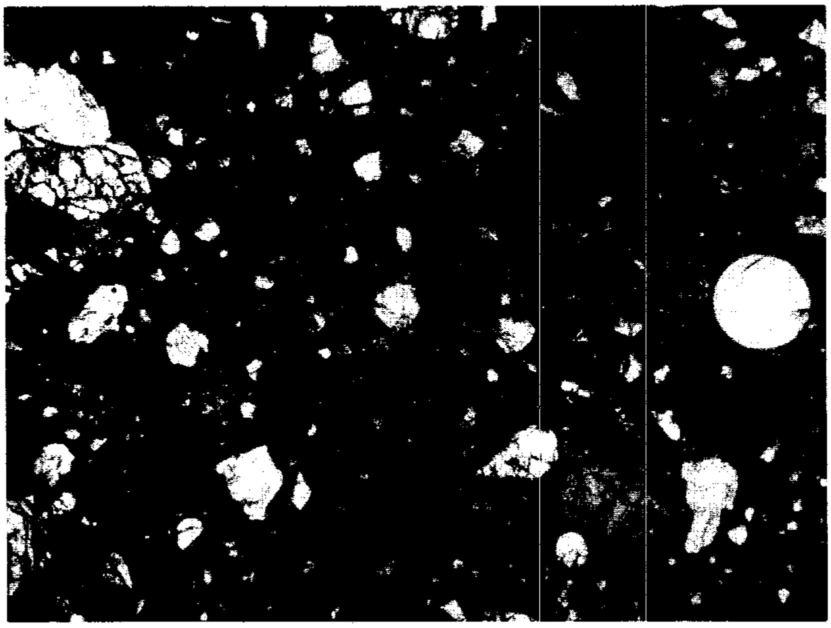


Figure 2: Photomicrograph of thin section 78537,17. Field of view is 3 x 4 mm.

78538
Dark Matrix Breccia
5.82 g, 2.1 x 1.8 x 1.0 cm

INTRODUCTION

Sample 78538 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It is similar to microbreccia 78535, but perhaps is darker grey (Keil et al., 1974).

PETROGRAPHY

Butler (1973) describes 78538 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt.

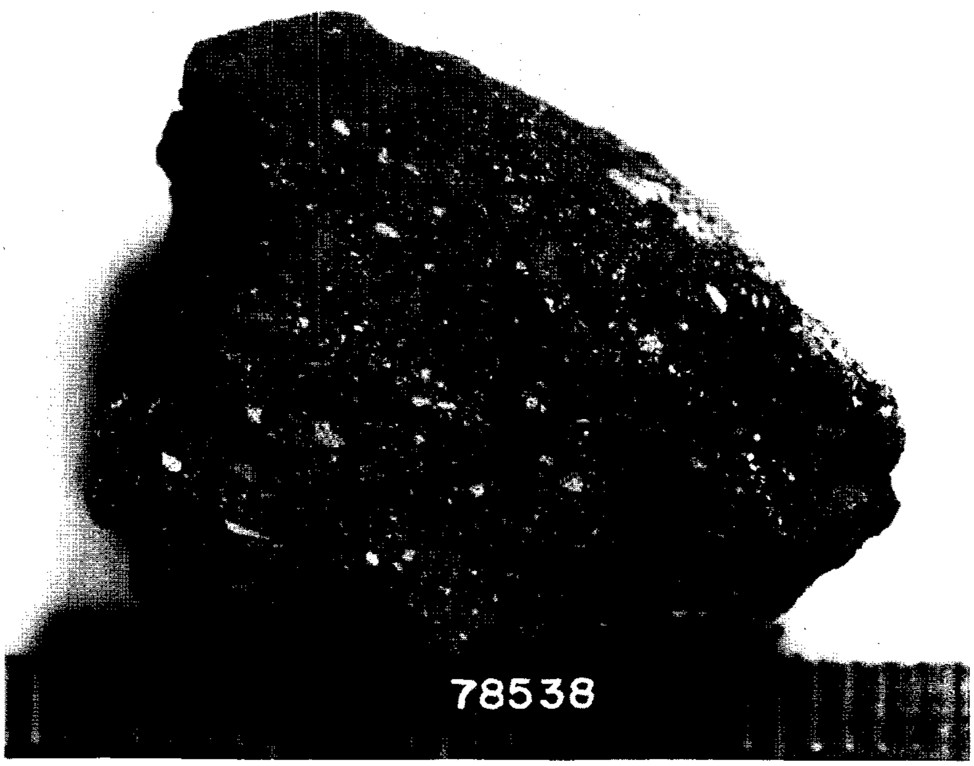


Figure 1: Photograph of 78538. Scale is 1 cm. S73-21010.

78539

Dark Matrix Breccia
3.73 g, 2.4 x 1.5 x 1.1 cm

INTRODUCTION

Sample 78539 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It is similar to 78535.

PETROGRAPHY

Butler (1973) describes 78539 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt.

Keil et al. (1974) suggest that the matrix of this fragment of soil breccia is "somewhat transitional to soil clods."

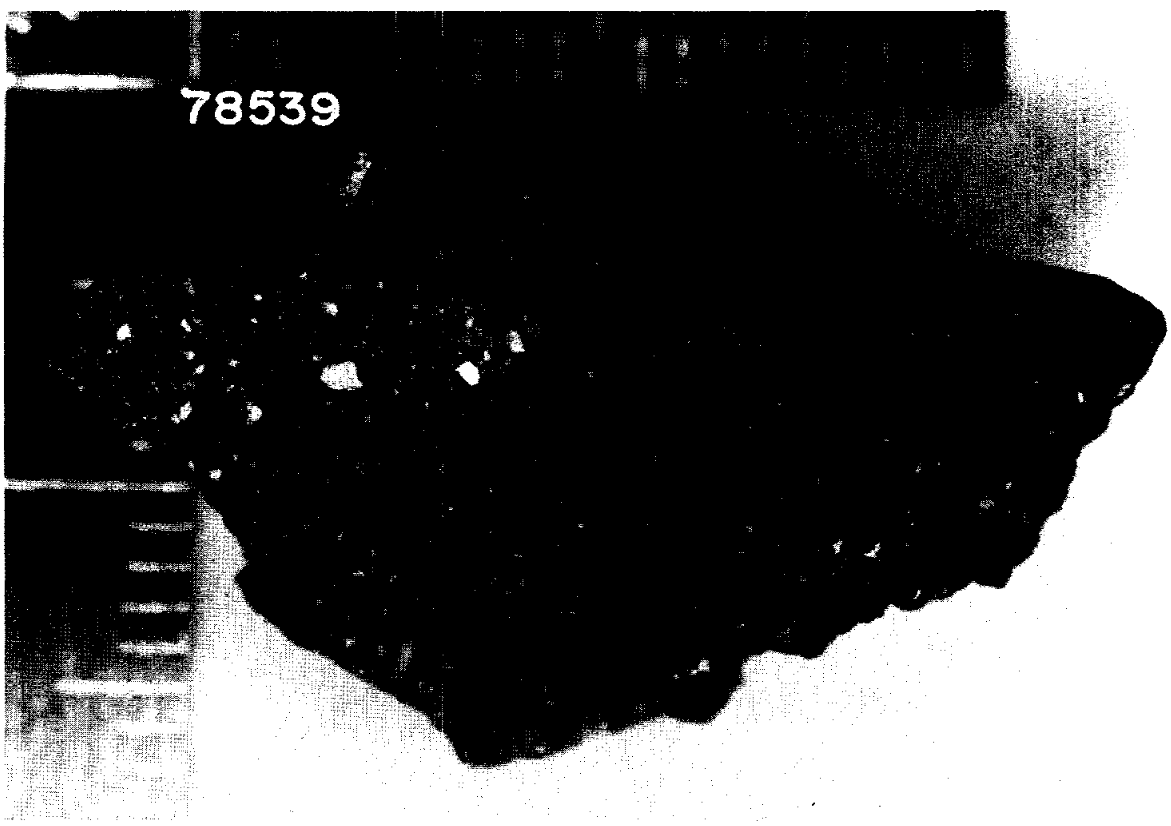


Figure 1: Photograph of 78539. Scale is 1 cm. S73-33443.

78545
Dark Matrix Breccia
8.60 g, 2.5 x 2.0 x 2.0 cm

INTRODUCTION

Sample 78545 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It is similar to 78535.

PETROGRAPHY

Butler (1973) describes 78545 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt.

Keil et al. (1974) describe one large clast of mare basalt.

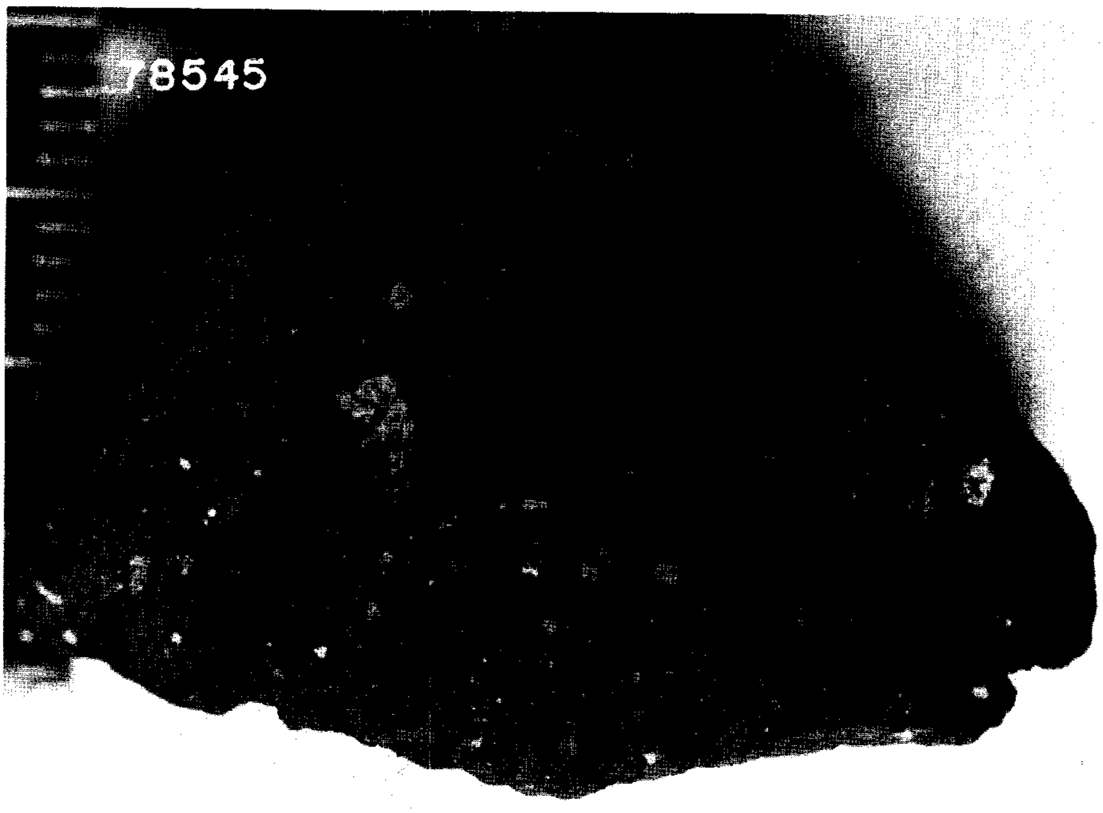


Figure 1: Photograph of 78545. Scale is 1 cm. S73-33398.

78546
Dark Matrix Breccia
42.66 g, 4.9 x 3.9 x 2.5 cm

INTRODUCTION

Sample 78546 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). Warner et al. (1978f) state that 78546 is similar to 78535. Fruland (1983) included 78546 in the suite of soil breccias to be studied by the Regolith Initiative.

PETROGRAPHY

Butler (1973) describes 78546 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt (Fig. 2).

Warner et al. (1978f) report that 78546 has a relatively high proportion of clasts to matrix. Part of the breccia is intruded by irregular, sometimes vesicular, glass veins. Lithic clasts include a large poikilitic anorthositic norite or gabbro, several mare basalt clasts (mostly fine-grained), and abundant fine-grained breccia clasts. Orange glass and devitrified orange glass spherules are abundant. Minor pale yellow, green, and colorless glass fragments are also reported.

Simon et al. (1990) give the mineralogical mode of 78546 and compare it with other regolith breccias.

MINERAL CHEMISTRY

Warner et al. (1979) have studied the glass compositions in 78546. Shearer et al. (1991) have used the ion microprobe to analyze glass beads in 78546.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) and Simon et al. (1990) have reported the chemical composition of 78546 (Table 1 and Fig. 3). This breccia has a high Ti content. The REE content is similar to the Station 8 soil (78501).

Figure 1: Photograph of 78546. Scale is 1 cm. S73-21410.

SURFACE

One side of 78546 had numerous micrometeorite craters (Butler, 1973).

PROCESSING

The largest piece of 78546 remaining weighs 32 g. There are three thin sections of 78546.

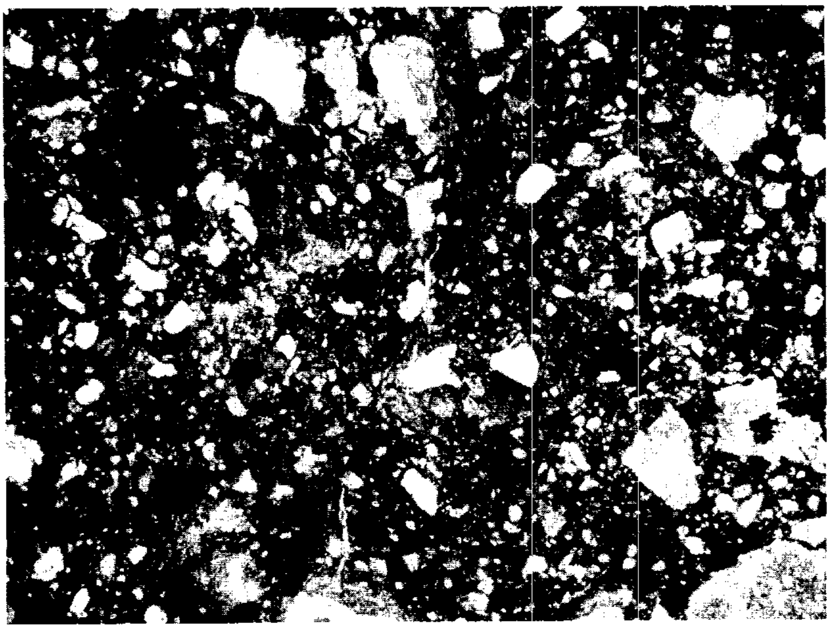


Figure 2: Photomicrograph of thin section 78546,8. Field of view is 3 x 4 mm.

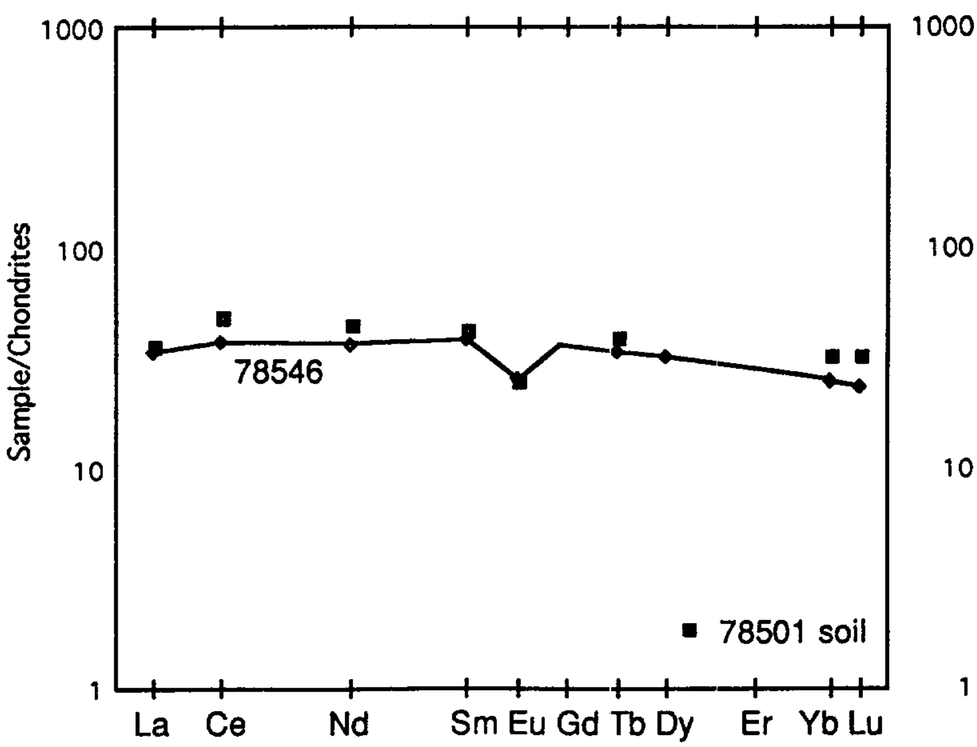


Figure 3: Normalized rare earth element diagram for 78546. Data from Laul and Schmitt (1975c). Data for local soil 78501 are for comparison.

Table 1: Whole-rock chemistry of 78546.
a) Simon et al. (1990); b) Laul and Schmitt (1975c)

Split Technique	,10 (a) INAA	,3 (b) INAA	Split Technique	,10 (a) INAA	,3 (b) INAA
SiO_2 (wt%)	–	–	Cs	0.13	
TiO_2	4.33	4.2	Zn	60	
Al_2O_3	13.9	15.3	Ni	100	150
Cr_2O_3	0.41	0.33	Co	37.1	35.3
FeO	13.6	13.2	Sc	40	31
MnO	0.18	0.16	La	8.62	7.8
MgO	10.6	10	Ce	22.7	22
CaO	11.5	11	Nd	17.8	16
Na_2O	0.47	0.45	Sm	5.8	5.5
K_2O	0.11	0.10	Eu	1.4	1.4
Nb (ppm)			Gd	7.3	
Zr	110	–	Tb	1.3	1.2
Hf	4.7	4.7	Dy	8.6	7.6
Ta	0.76	0.67	Tm	0.71	
U	0.33	–	Yb	4.42	3.9
Th	1.15	0.8	Lu	0.66	0.56
Sr	150		Ge (ppb)		
Rb	10.8		Ir	4.5	6
Ba	110	100	Au	6.0	1

78547
Dark Matrix Soil Breccia
29.91 g, 4.0 x 2.8 x 2.4 cm

INTRODUCTION

Sample 78547 is a friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78547 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

Keil et al. (1974) and Warner et al. (1978f) included this sample in their catalogs (Fig. 2). Warner et al. noted that it contained a fragment of very low-Ti basalt, a few recrystallized ANT clasts, and a variety of feldspathic breccia clasts. Also included are glass spherules, angular glass fragments, and several agglutinates (proof of soil origin).

MINERAL CHEMISTRY

Warner et al. (1979) have studied the glass compositions in 78547.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the chemical composition of 78547 (Table 1). This soil breccia has only about half the TiO_2 (2.2%) of the local soil 78501 (5.2%). It also has a lower and flatter REE pattern (Fig. 3) and may be a soil breccia derived from further up the slope of the Sculptured Hills.

SIGNIFICANT CLASTS

One clast is ~7 mm across (Fig. 1). This clast has not been studied.

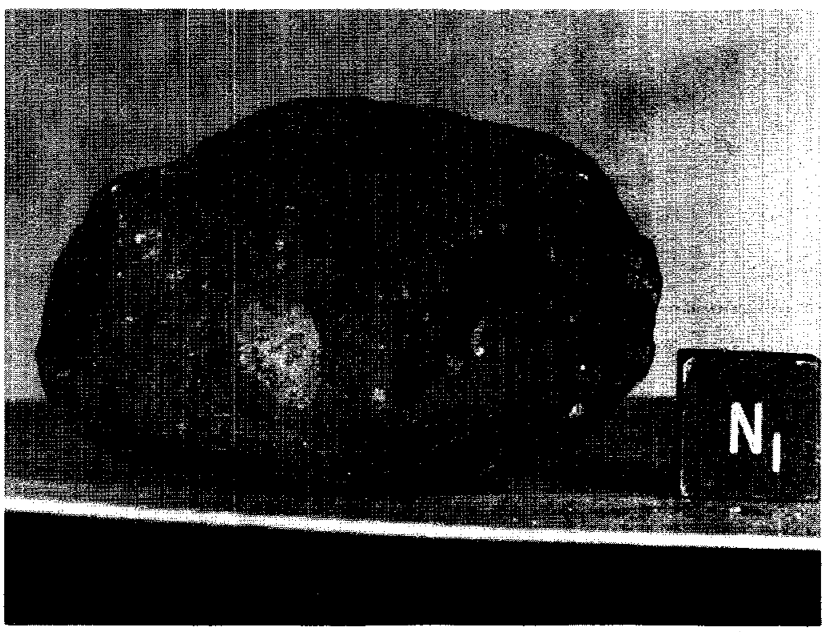


Figure 1: Photograph of 78547. Scale is 1 cm. S73-21404.

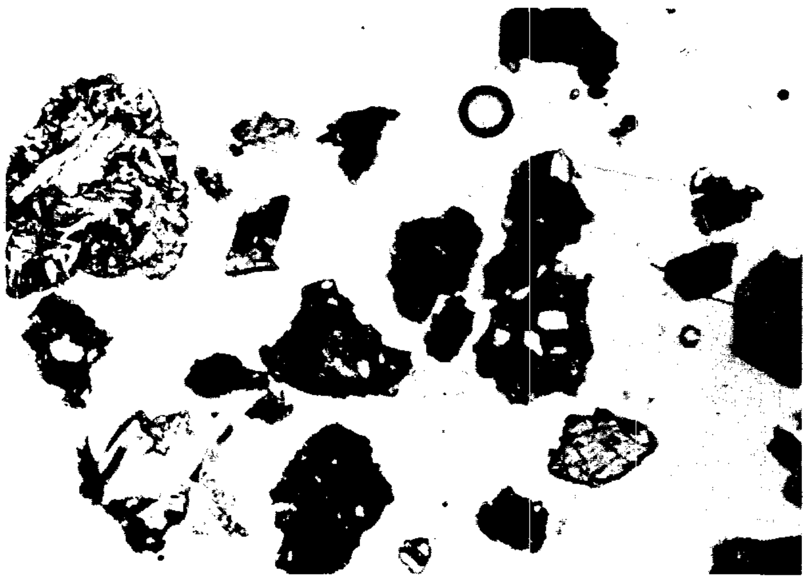


Figure 2: Photomicrograph of grains from 78547. From Warner et al. (1978f).

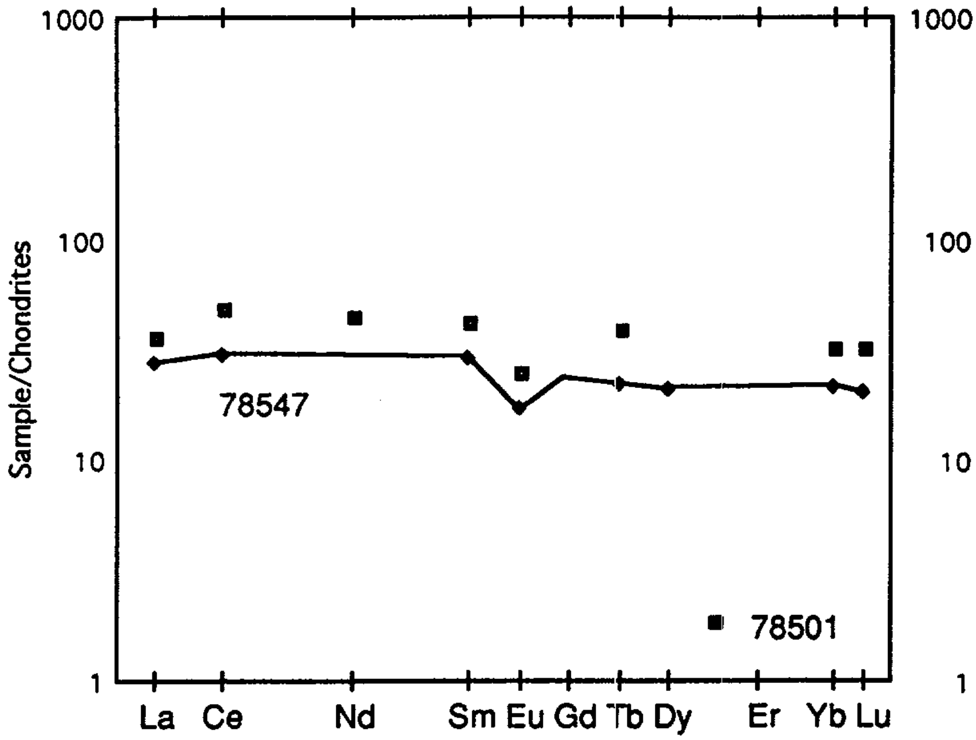


Figure 3: Normalized rare earth element diagram for 78547 with data from soil 78501 for comparison. Data from Laul and Schmitt (1975).

Table 1: Whole-rock chemistry of 78547.
From Laul and Schmitt (1975c).

Split Technique	,3 INAA
SiO_2 (wt%)	–
TiO_2	2.2
Al_2O_3	16.3
Cr_2O_3	0.36
FeO	11.8
MnO	0.16
MgO	11
CaO	11.1
Na_2O	0.36
K_2O	0.085
Nb (ppm)	
Zr	–
Hf	2.9
Ta	0.47
U	–
Th	1.0
Ni	150
Co	33
Sc	30
La	6.4
Ce	18
Nd	
Sm	4.2
Eu	0.94
Gd	
Tb	0.8
Dy	5
Er	
Yb	3.4
Lu	0.48
Ge (ppb)	
Ir	
Au	

78548
Soil Clod
15.95 g, 2.6 x 2.2 x 2.1 cm

INTRODUCTION

Sample 78548 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It broke up into soil during processing (Fig. 2).

PETROGRAPHY

Butler (1973) described 78548 as very friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%.

Keil et al. (1974) and Warner et al. (1978f) discussed this sample in their catalogs. They noted that it contains clasts of mare basalt and highland materials, and that there are fragments of pale green glass, or green glass vitrophyre, similar to 78526, as well as other glasses.

MINERAL CHEMISTRY

Warner et al. (1979) have studied the glass compositions in 78548.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the chemical composition of 78548 (Table 1 and Fig. 3). It has a chemical composition exactly like that of the rake soil (78501).

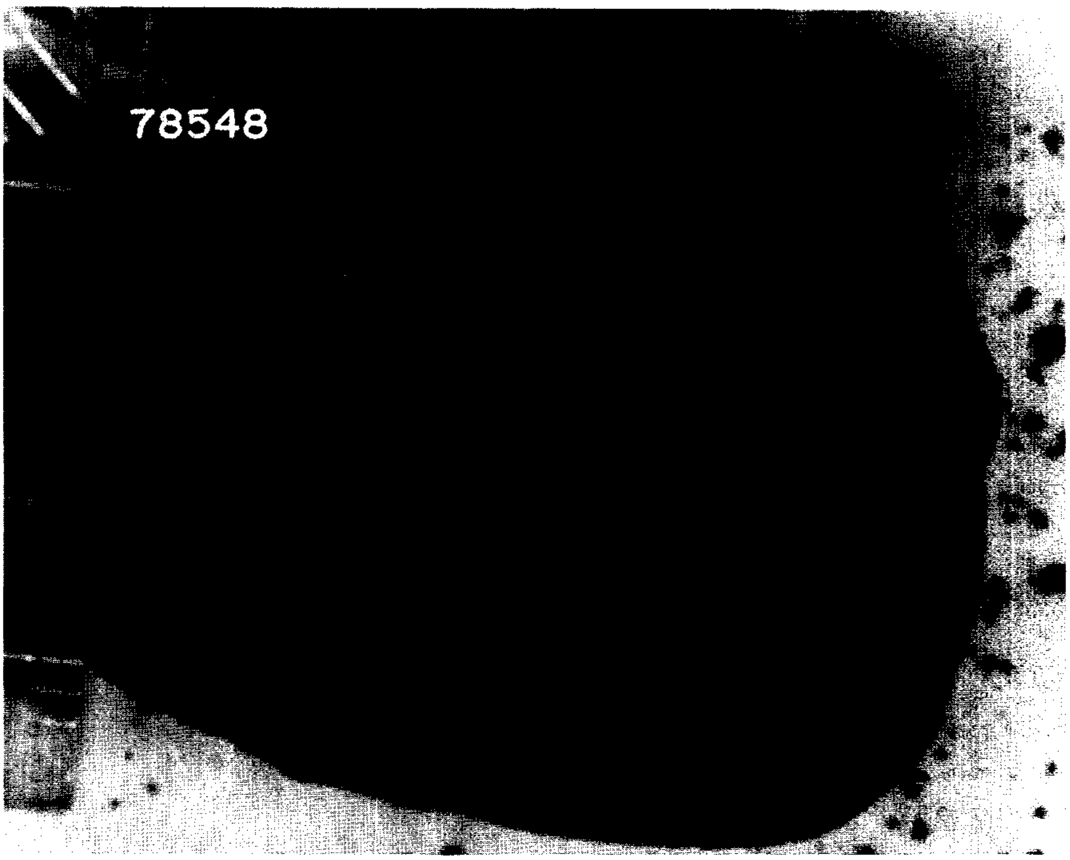


Figure 1: Photograph of 78548. Scale is 1 cm. S73-33400.

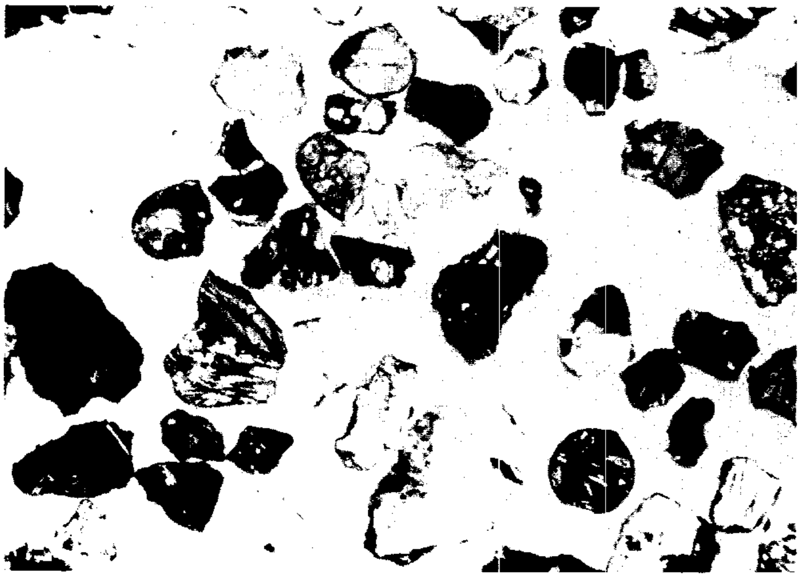


Figure 2: Photomicrograph of grains from 78548. From Warner et al. (1978f).

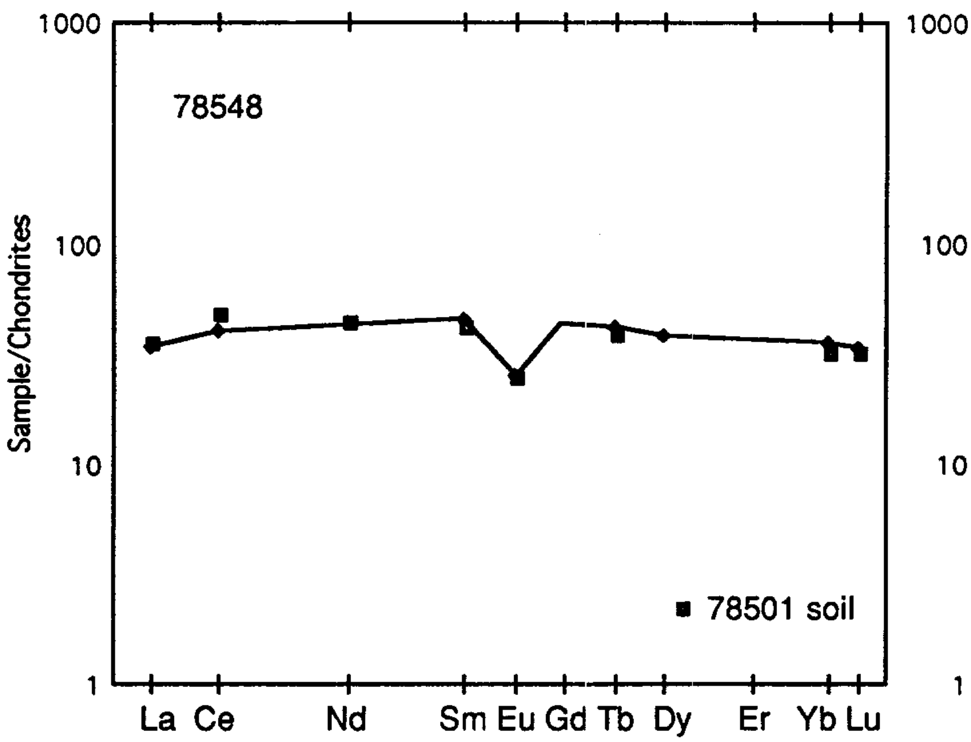


Figure 3: Normalized rare earth element diagram for 78548. Data from Laul and Schmitt (1975). Data for 78501 soil are for comparison.

Table 1: Whole-rock chemistry of 78548.
From Laul and Schmitt (1975c).

Split Technique	,3 INAA
SiO_2 (wt%)	–
TiO_2	5.2
Al_2O_3	16.0
Cr_2O_3	0.34
FeO	13.2
MnO	0.167
MgO	10
CaO	11.3
Na_2O	0.41
K_2O	0.09
Nb (ppm)	
Hf	5
Ta	0.9
U	–
Th	0.8
Ni	120
Co	31.2
Sc	41
La	7.9
Ce	24
Nd	
Sm	6.6
Eu	1.4
Gd	
Tb	1.5
Dy	9.3
Er	
Yb	5.7
Lu	0.81
Ge (ppb)	
Ir	
Au	

78549
Soil Clod
16.09 g, 2.2 x 2.6 x 1.4 cm

INTRODUCTION

Sample 78549 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It broke up into soil during processing (Fig. 2).

PETROGRAPHY

Butler (1973) described 78549 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

Keil et al. (1974) and Warner et al. (1978f) included this sample in their catalogs. They noted that it contained feldspathic breccia clasts, minor basalt fragments, and some agglutinates (which prove that it was a soil).

MINERAL CHEMISTRY

Warner et al. (1979) have studied the glass compositions in 78549.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1975c) have reported the chemical composition of 78549 (Table 1 and Fig. 3). This sample has only about half the TiO_2 of the 78501 soil. It may be a soil breccia from upslope on the Sculptured Hills.

Figure 1: Photograph of 78549. Scale is 1 cm. S73-21015.

Figure 2: Photomicrograph of grains from 78549. From Warner et al. (1978f).

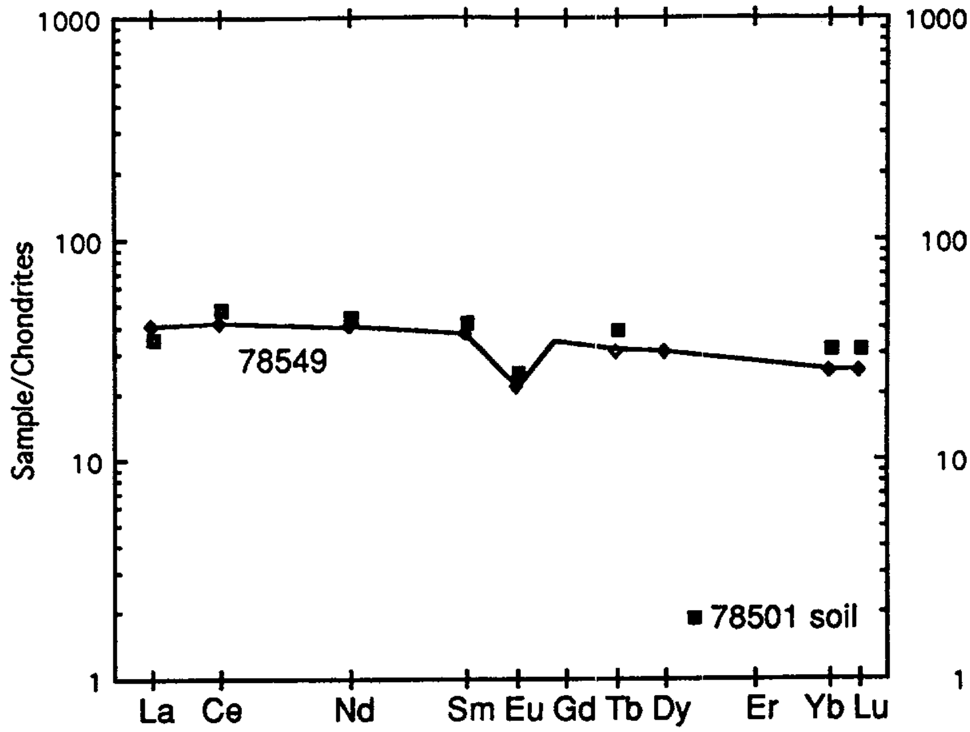


Figure 3: Normalized rare earth element diagram for 78549. Data from Laul and Schmitt (1975). Data for 78501 soil are for comparison.

Table 1: Whole-rock chemistry of 78549.
From Laul and Schmitt (1975c).

Split **Technique**	**,1** **INAA**
SiO_2 (wt%)	–
TiO_2	2.6
Al_2O_3	18.0
Cr_2O_3	0.294
FeO	11.4
MnO	0.142
MgO	10
CaO	11.9
Na_2O	0.39
K_2O	0.10
Nb (ppm)	
Zr	–
Hf	4.3
Ta	0.63
U	0.4
Th	1.2
Ba	140
Ni	300
Co	41.8
Sc	26
La	9.4
Ce	25
Nd	18
Sm	5.4
Eu	1.2
Gd	
Tb	1.1
Dy	7.3
Er	
Yb	4.1
Lu	0.6
Ge (ppb)	
Ir	10
Au	3

78555
Soil Breccia
6.64 g, 2.6 x 1.8 x 1.1 cm

INTRODUCTION

Sample 78555 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78555 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

Keil et al. (1974) and Warner et al. (1978f) included this sample in their catalogs. They noted that it was very porous and contained fine-grained breccia clasts, minor basalt fragments, and some agglutinates (which prove that it was a soil). Glass spherules and angular glass fragments are abundant.

Jerde et al. (1987) have determined the maturity (Is/FeO) of 78555 to be that of a submature soil.

MINERAL CHEMISTRY

Warner et al. (1979) have studied the glass compositions in 78555.

WHOLE-ROCK CHEMISTRY

Jerde et al. (1987) have reported the chemical composition of 78555 (Table 1 and Fig. 3). It has a TiO_2 content about half that of the local soil and may be another soil breccia from upslope on the Sculptured Hills.

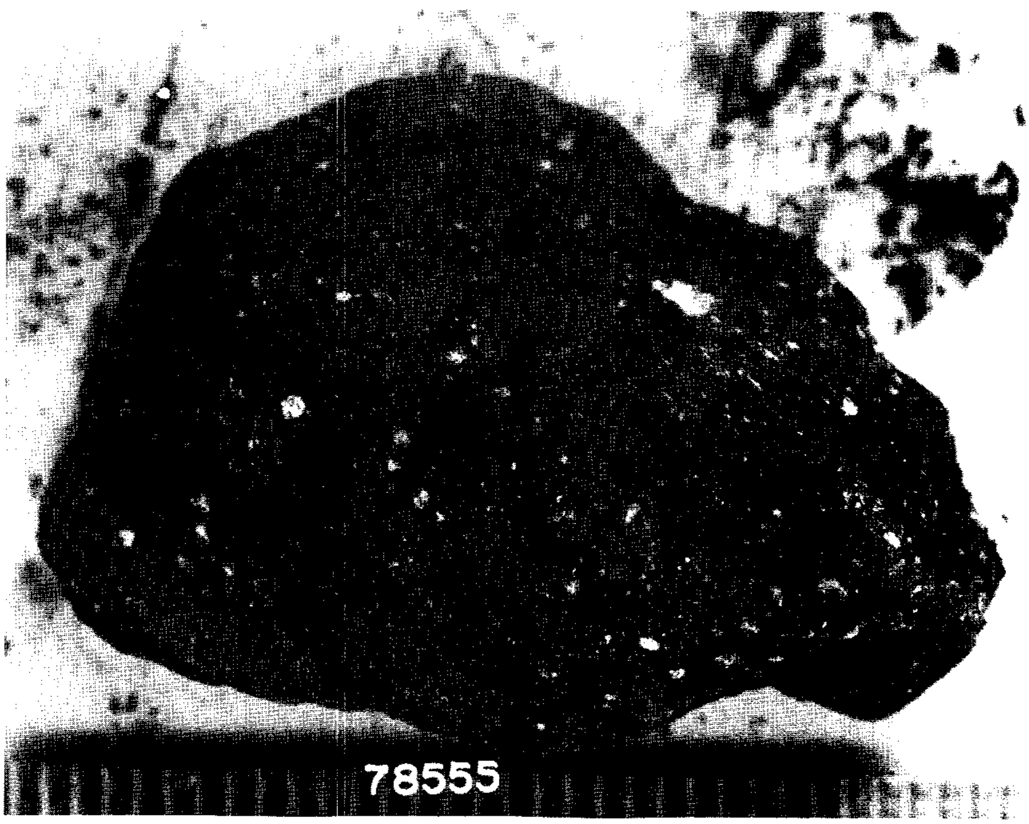


Figure 1: Photograph of 78555. Scale is 1 cm. S73-21021.

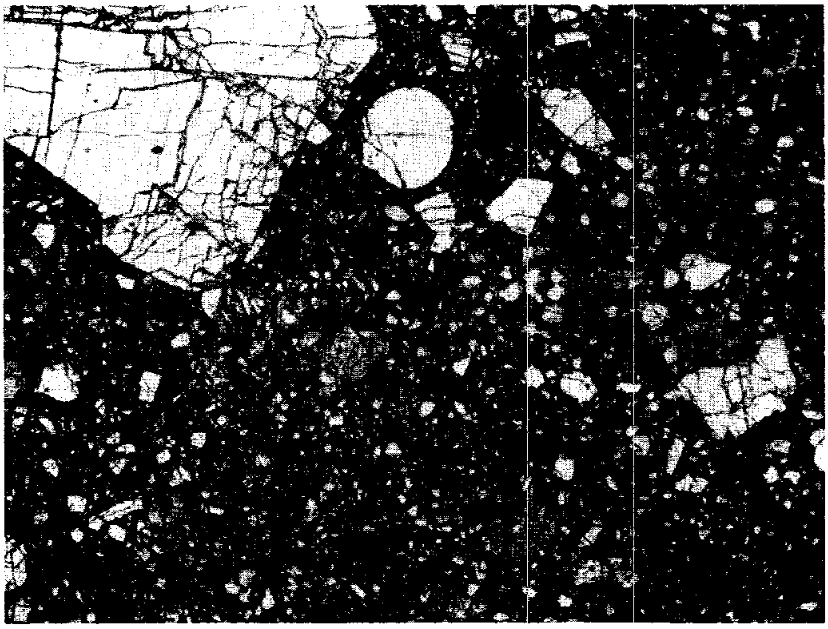


Figure 2: Photomicrograph of thin section of 78555,4. Field of view is 3 x 4 mm.

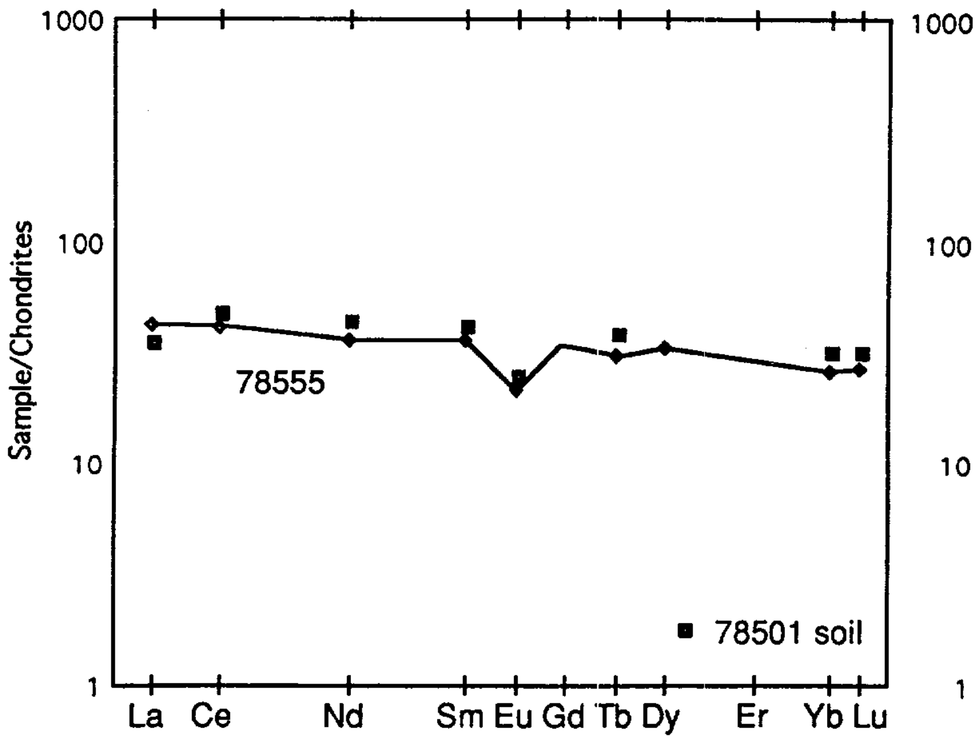


Figure 3: Normalized rare earth element diagram for 78555. Data from Jerde et al. (1987). Data for 78501 soil are for comparison.

Table 1: Whole-rock chemistry of 78555.
From Jerde et al. (1987).

Split Technique	,6 INAA	Split Technique	,6 INAA
SiO_2 (wt%)	44.51	Ni	260
TiO_2	2.42	Co	35.6
Al_2O_3	17.97	Sc	
Cr_2O_3	0.35	La	9.9
FeO	9.90	Ce	25
MnO	0.15	Nd	16
MgO	11.27	Sm	5.3
CaO	11.49	Eu	1.17
Na_2O	0.39	Gd	
K_2O	0.11	Tb	1.1
Nb (ppm)		Dy	8.1
Zr	180	Er	
Hf	3.7	Yb	4.2
Ta	0.56	Lu	0.65
U	0.53	Ga	4.2
Th	1.86	Ge (ppb)	
Sr	160	Ir	11
Ba	130	Au	3.3
Cs	0.55		

78556
Dark Matrix Soil Breccia
9.50 g, 3.4 x 2.0 x 1.3 cm

INTRODUCTION

Sample 78556 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78556 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

This sample has not been studied. It appears to be similar to 78555 (Keil et al., 1974).

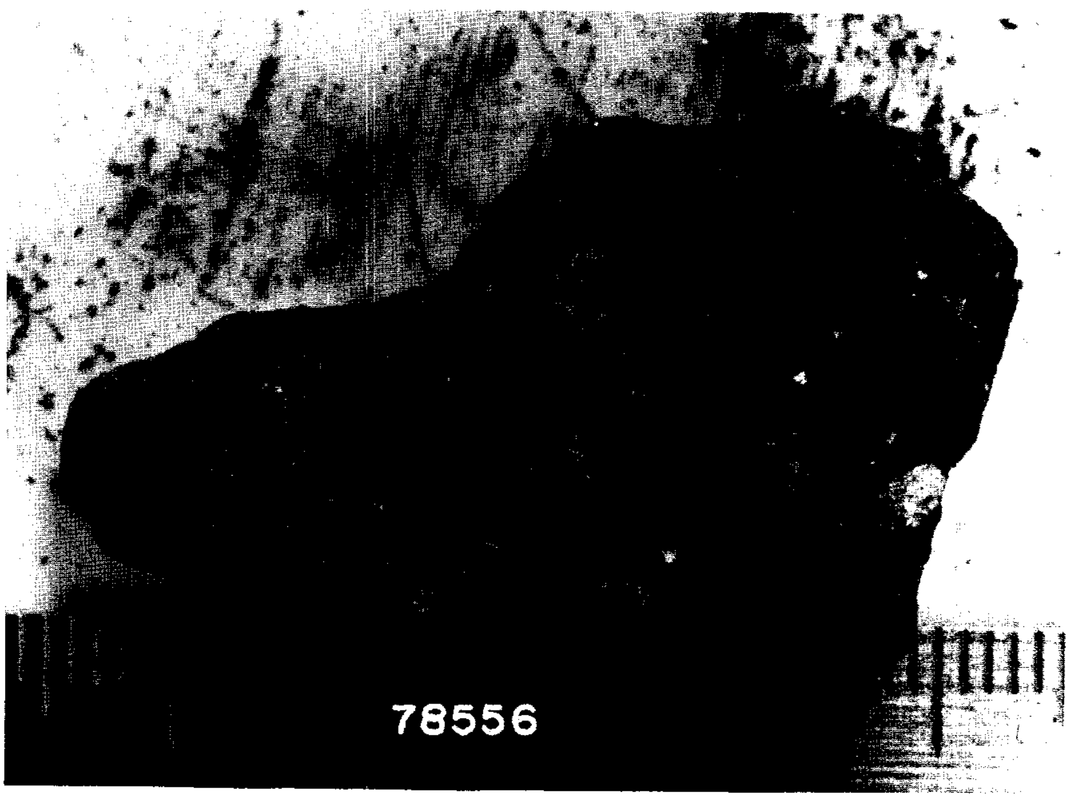


Figure 1: Photograph of 78556. Scale is 1 cm. S73-21020.

78557
Dark Matrix Soil Breccia
7.19 g, 3.0 x 1.8 x 1.2 cm

INTRODUCTION

Sample 78557 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78557 as friable, medium grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

This sample has not been studied. It appears to be similar to 78555 (Keil et al., 1974).

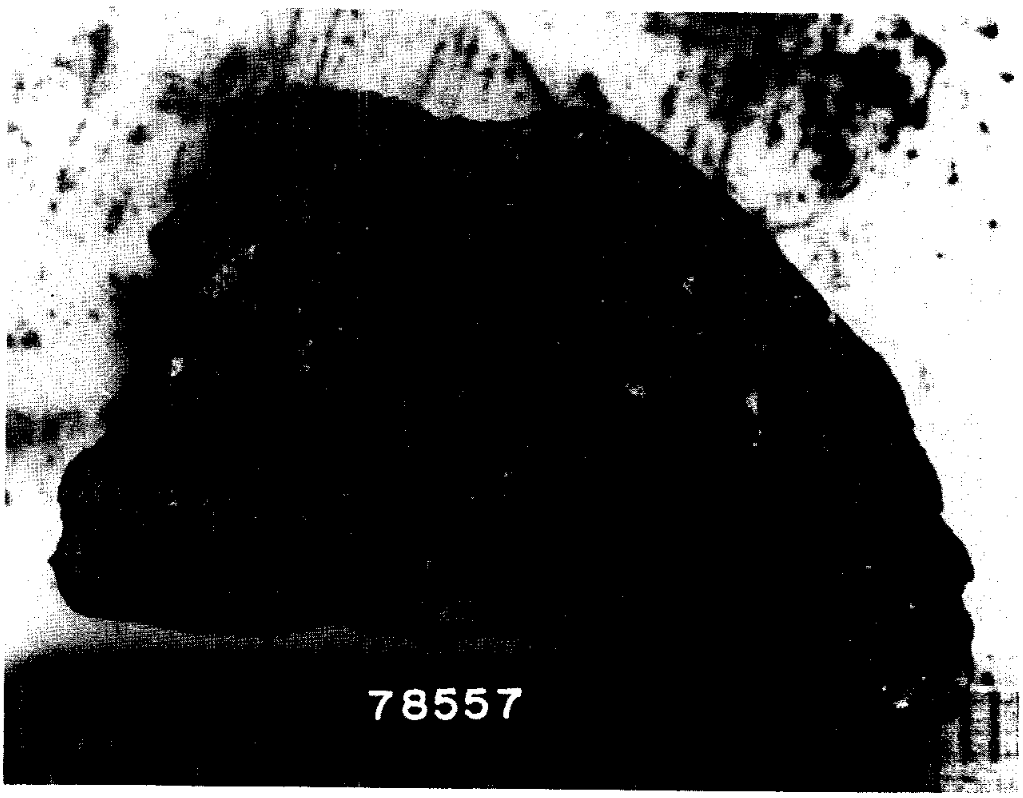


Figure 1: Photograph of 78557. Scale is 1 cm. S73-21012.

78558
Dark Matrix Soil Breccia
3.78 g, 2.2 x 1.5 x 1.4 cm

INTRODUCTION

Sample 78558 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78558 as friable, dark grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

This sample has not been studied. It appears to be similar to 78555 (Keil et al., 1974).

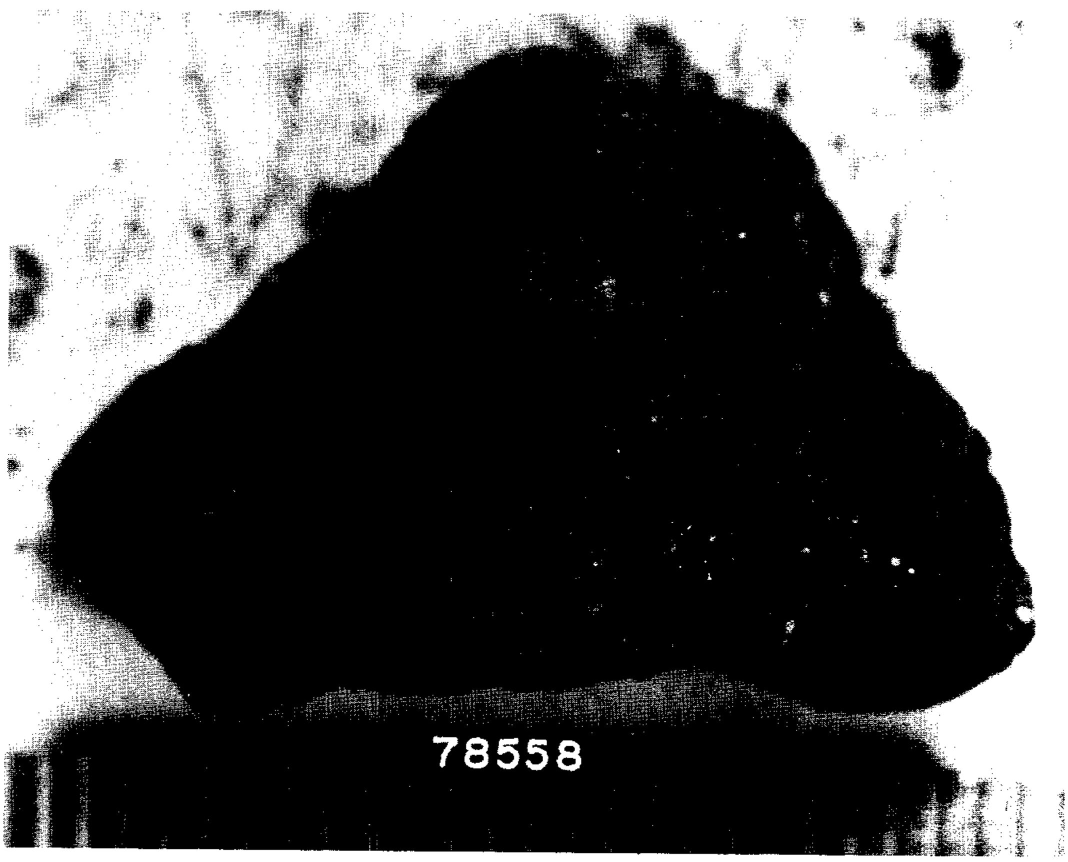


Figure 1: Photograph of 78558. Scale is 1 cm. S73-21019.

78559

Dark Matrix Soil Breccia
3.05 g, 2.2 x 1.5 x 0.8 cm

INTRODUCTION

Sample 78559 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78559 as friable, dark grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

This sample has not been studied. It appears to be similar to 78555 (Keil et al., 1974).

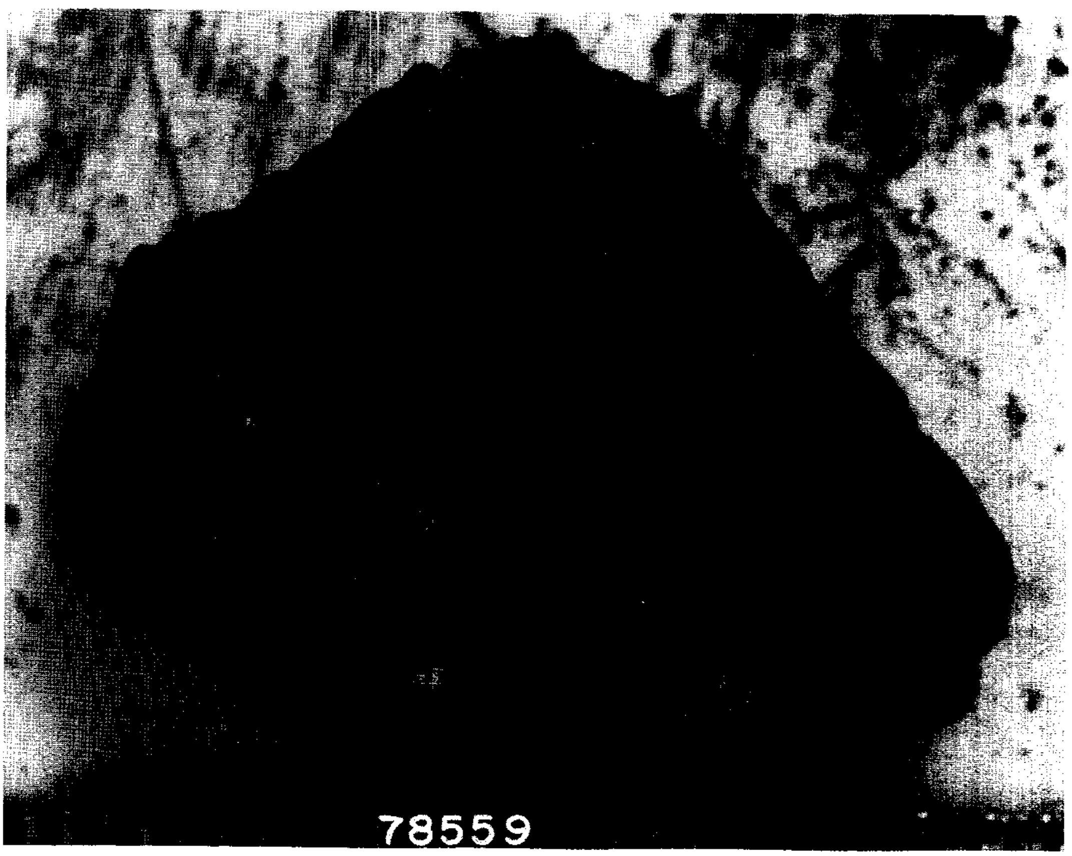


Figure 1: Photograph of 78559. Scale is 1 cm. S73-21008.

78565

Dark Matrix Soil Breccia
3.50 g, 1.9 x 1.5 x 1.0 cm

INTRODUCTION

Sample 78565 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78565 as friable, dark grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

This sample has not been studied. It appears to be similar to 78555 (Keil et al., 1974).

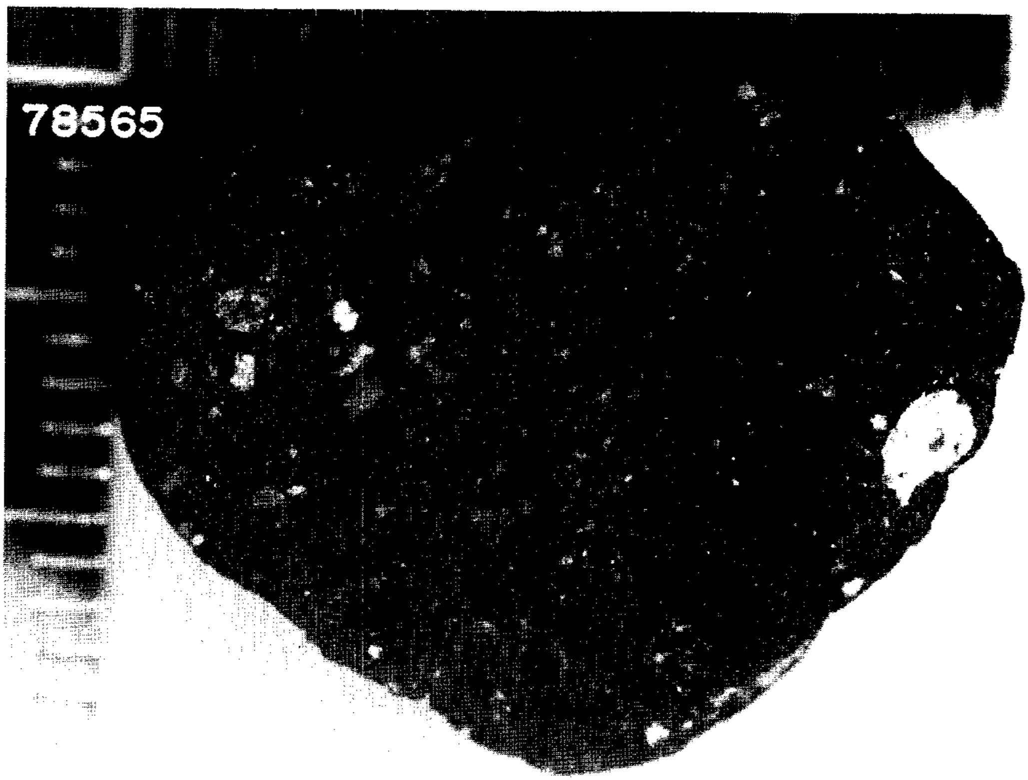


Figure 1: Photograph of 78565. Scale is 1 cm. S73-33414.

78566
Dark Matrix Soil Breccia
0.77 g, 0.5 x 0.5 x 0.5 cm

INTRODUCTION

Sample 78566 is a very friable soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Butler (1973) described 78566 as friable, dark grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

This sample has not been studied. It appears to be similar to 78555 (Keil et al., 1974).

Figure 1: Photograph of 78566. Scale is 1 cm. S73-21011.

78567
Dark Matrix Soil Breccia
18.88 g, 3.1 x 2.4 x 2.2 cm

INTRODUCTION

Sample 78567 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It is similar to 78546.

PETROGRAPHY

Butler (1973) described 78567 as friable, dark grey, matrix-rich breccia with clasts generally of millimeter size composing less than 5%. Small clasts are generally white plagioclase, mare basalt, black aphanite, and orange glass.

Compared with other soil breccias, thin sections of this sample show that it has less fine-grained matrix and more mineral fragments (Fig. 2). Keil et al. (1974) and Warner et al. (1978f) have provided very brief descriptions.

MINERAL CHEMISTRY

Warner et al. (1979) have studied the glass compositions in 78567.

The chemical composition of this sample has not been determined.

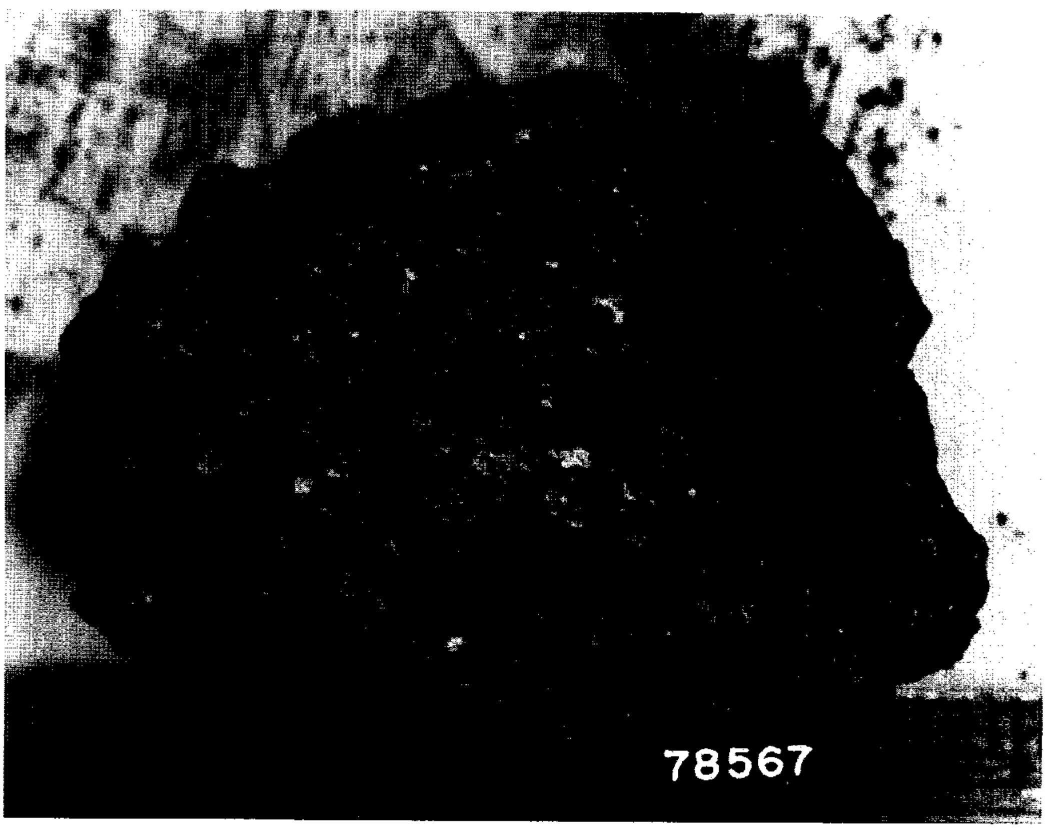


Figure 1: Photograph of 78567. Scale is 1 cm. S73-21017.

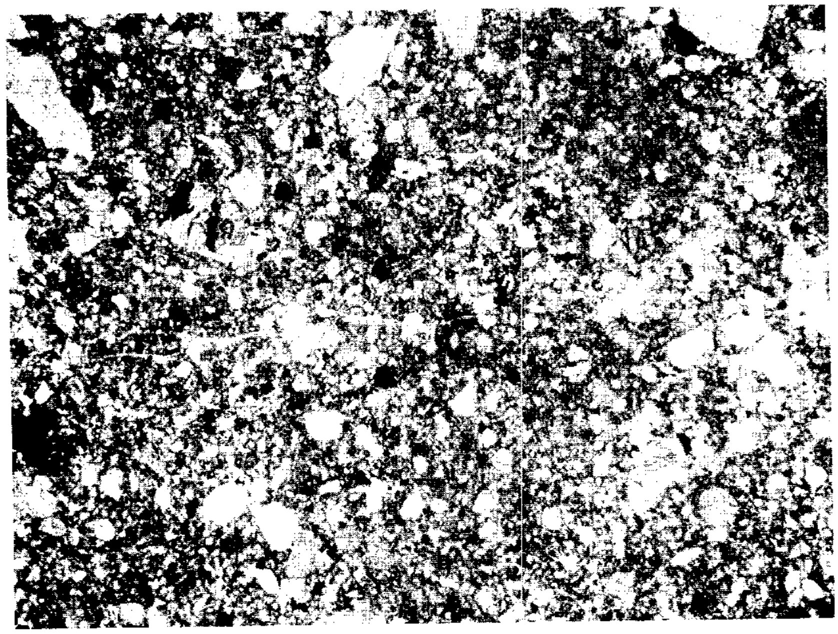


Figure 2: Photomicrograph of thin section 78567,7. Field of view is 3 x 4 mm.

78568
Breccia
3.57 g, 1.6 x 1.5 x 1.3 cm

INTRODUCTION

Sample 78568 is a coherent soil breccia that was collected as part of a large rake sample at Station 8 (Fig. 1). It is similar to 78535.

PETROGRAPHY

Butler (1973) describes 78568 as moderately coherent, medium grey, matrix-rich breccia with clasts composing less than 5% of the rock. Clasts are predominantly white and consist of plagioclase and mare basalt.

Keil et al. (1974) and Warner et al. (1978f) have given brief descriptions. One side of the particle has a white coating (Fig. 1). The interior has a brown glass matrix characteristic of a soil breccia (Fig. 2). Warner et al. noted that glass spheres were not very common. Lithic clasts include a medium-grained, granular, very low-Ti basalt, several fine-grain high-Ti basalts, a variety of fine-grained breccia fragments, and a large devitrified anorthosite clast.

MINERAL CHEMISTRY

Warner et al. (1979) have studied the glass compositions in 78568.

The chemical composition of this sample has not been determined.

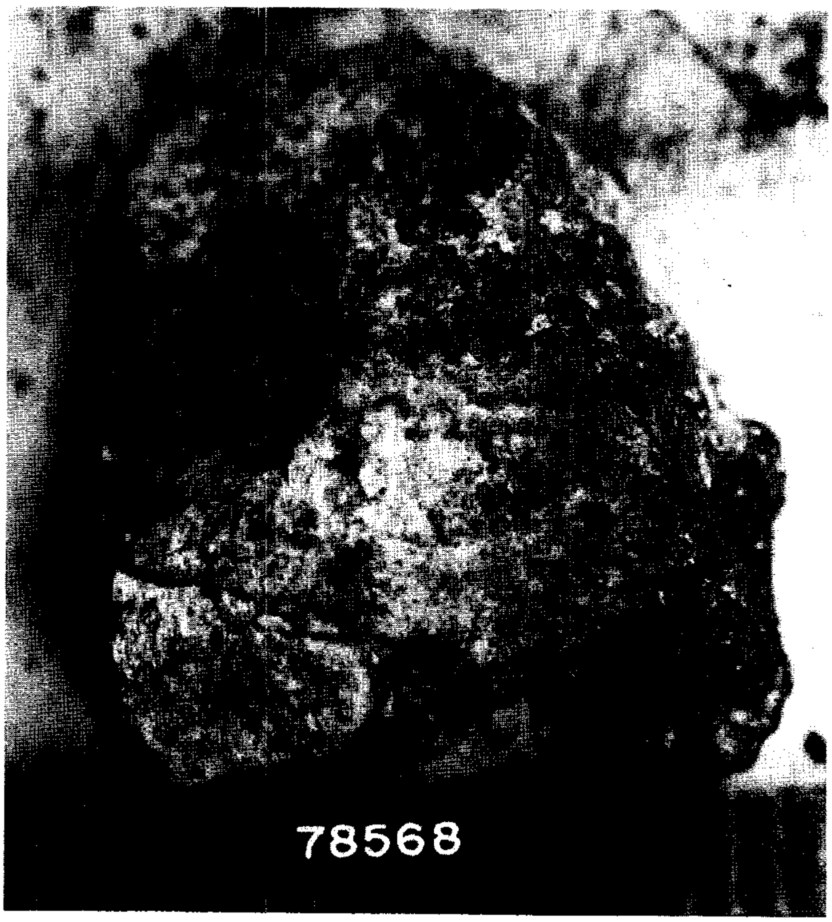


Figure 1: Photograph of 78568. Scale is 1 cm. S73-21007.

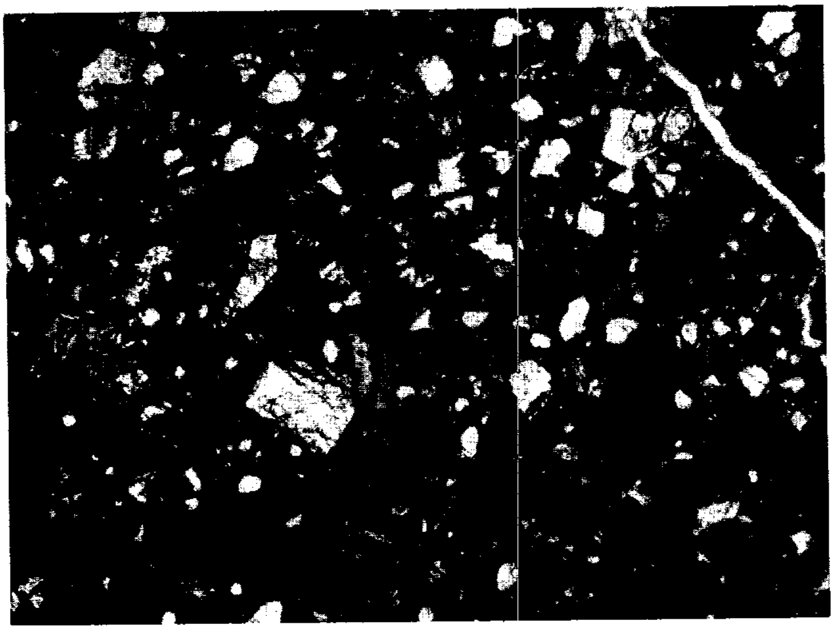


Figure 2: Photomicrograph of thin section 78568,3. Field of view is 3 x 4 mm.

78569
High-Ti Mare Basalt
14.53 g, 2.3 x 1.9 x 1.5 cm

INTRODUCTION

Sample 78569 was collected as part of the large rake sample at Station 8. It is a typical ilmenite-rich mare basalt from Apollo 17 (Fig. 1).

PETROGRAPHY

Sample 78569 is a fine- to medium-grained mare basalt with ~48% pyroxene, 27% plagioclase, 4% olivine, and 17% ilmenite (Fig. 2). There are trace amounts of silica, armalcolite, tranquillityite, and zirconolite (Keil et al., 1974 and Warner et al., 1978f).

Partial breccia coating suggests this basalt may have been a breccia clast (Butler, 1973).

MINERAL CHEMISTRY

The compositions of minerals in this basalt sample are given in the catalog by Warner et al. (1978f) (Fig. 3).

WHOLE-ROCK CHEMISTRY

Laul et al. (1975b) and Warner et al. (1975b) have reported the chemical composition of 78569 (Table 1 and Fig. 4).

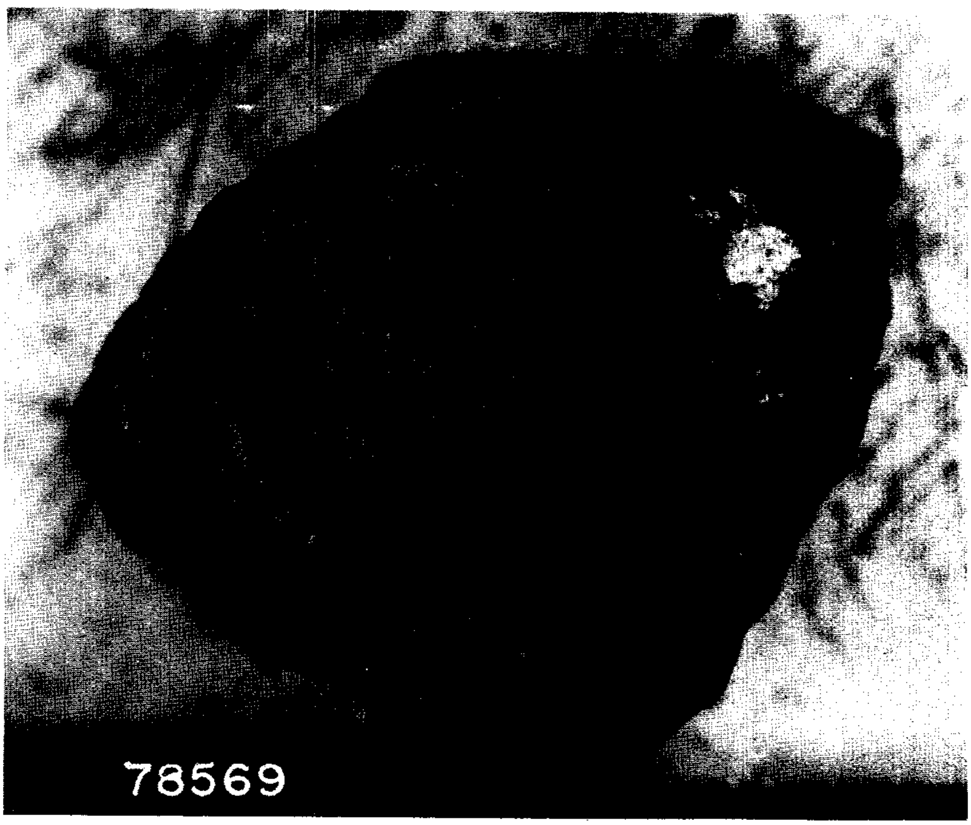


Figure 1: Photograph of 78569. Scale is 1 mm. S73-21035.

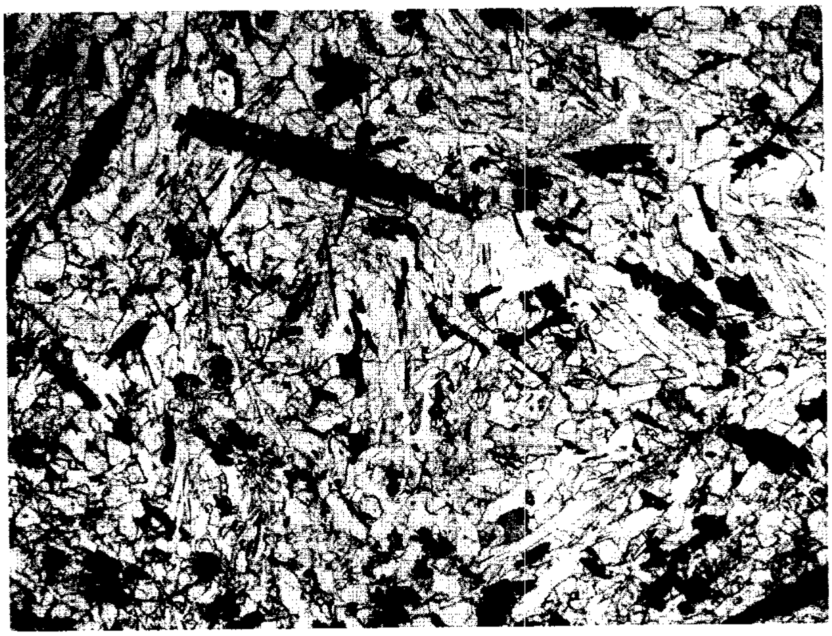


Figure 2: Photomicrograph of thin section 78569,7. Field of view is 3 x 4 mm.

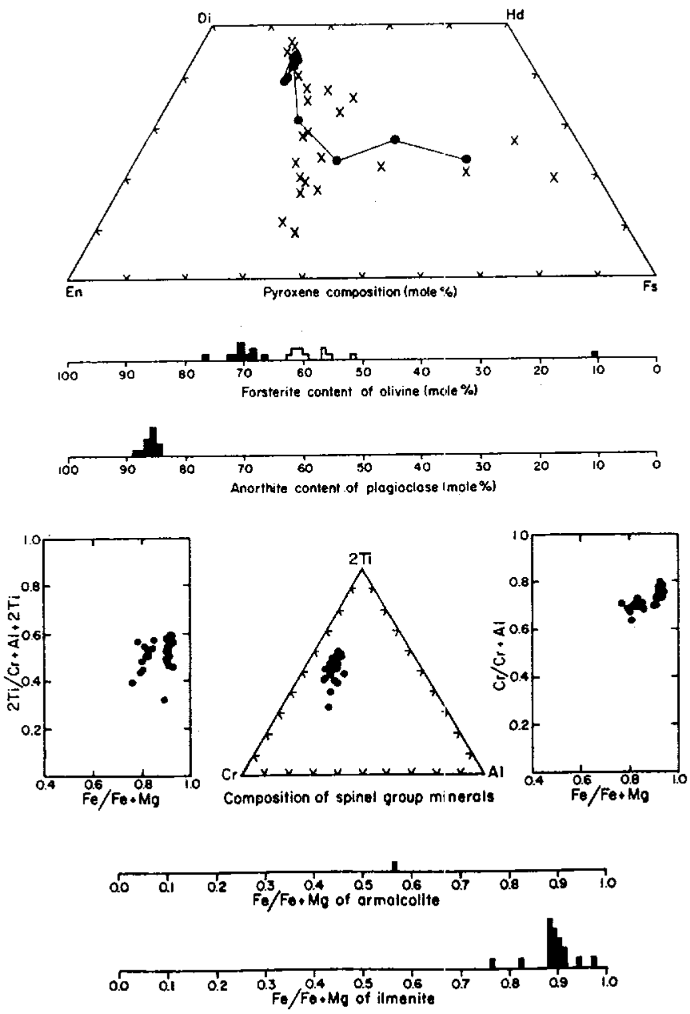


Figure 3: Mineral compositions for 78569. From Warner et al. (1978f).

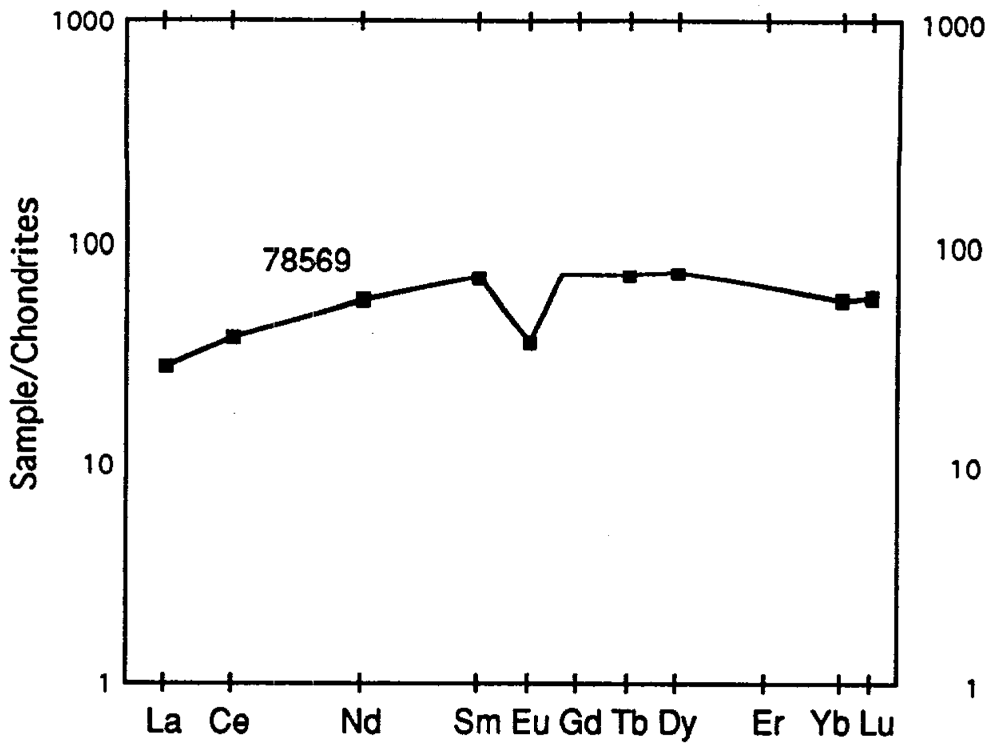


Figure 4: Normalized rare earth element diagram of 78569. Data from Warner et al. (1975b).

Table 1: Whole-rock chemistry of
From Warner et al. (1975b).

Split Technique	,3 INAA
SiO_2 (wt%)	–
TiO_2	12.3
Al_2O_3	8.7
Cr_2O_3	0.4
FeO	19.3
MnO	0.24
MgO	7.8
CaO	10.6
Na_2O	0.40
K_2O	0.075
Nb (ppm)	
Hf	8.8
Ta	1.7
Ni	
Co	19.2
Sc	76
La	6.6
Ce	23
Nd	25
Sm	10.3
Eu	2
Gd	
Tb	2.6
Dy	18
Er	
Yb	9.2
Lu	1.4
Ge (ppb)	
Ir	
Au	

78575
High-Ti Mare Basalt
140.0 g, 5.8 x 4.8 x 3.4 cm

INTRODUCTION

Sample 78575 was collected as part of the large rake sample at Station 8. It is a coarse-grained, vuggy, ilmenite-rich mare basalt from Apollo 17 (Fig. 1).

PETROGRAPHY

The modal mineralogy of 78575 is ~51% pyroxene, 30% plagioclase, 16% ilmenite, and trace olivine. Trace amounts of silica, armalcolite, tranquillityite, and zirconolite are also reported (Keil et al., 1974, and Warner et al., 1978f).

The texture of 78575 is described as allotriomorphic-granular by Warren et al. (Fig. 2). Coarse pyroxenes are subequant to equant, uniformly granular, and tend to cluster. Plagioclase occurs as broad, tabular, nonpoikilitic crystals. Ilmenite crystals are subequant and form chains.

MINERAL CHEMISTRY

The compositions of minerals in this basalt sample are given in the catalog by Warner et al. (1978f) (Fig. 3).

WHOLE-ROCK CHEMISTRY

Warner et al. (1975b) have reported the chemical composition of 78575 (Table 1 and Fig. 4).

Sample 78575 is a Type B Apollo 17 basalt (see appendix).

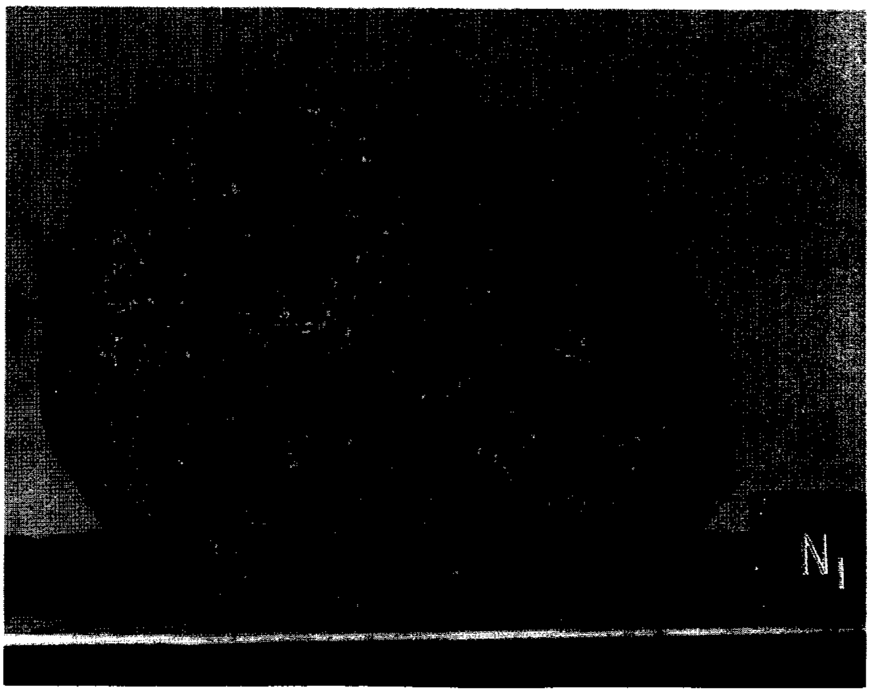


Figure 1: Photograph of 78575. Scale is 1 cm. S73-21414.

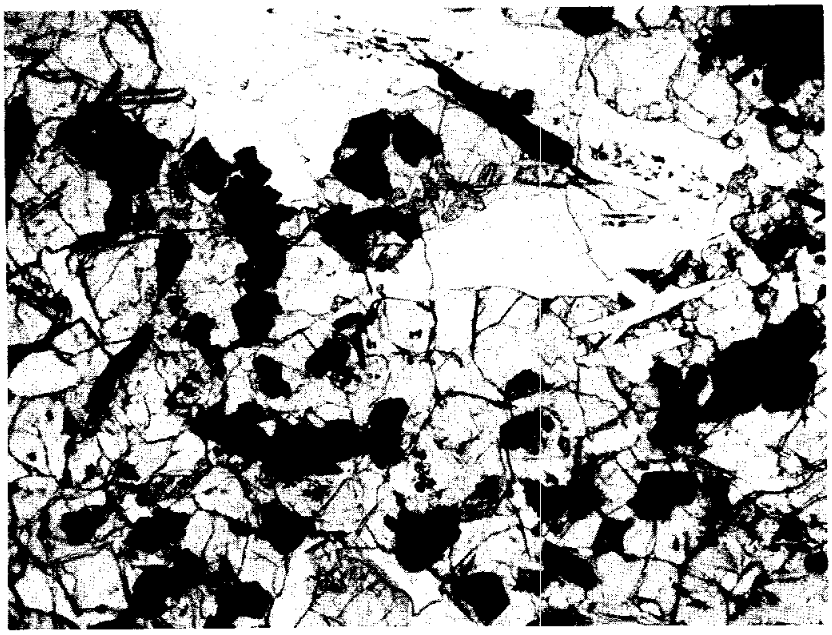


Figure 2: Photomicrograph of thin section 78575,6. Field of view is 3 x 4 mm.

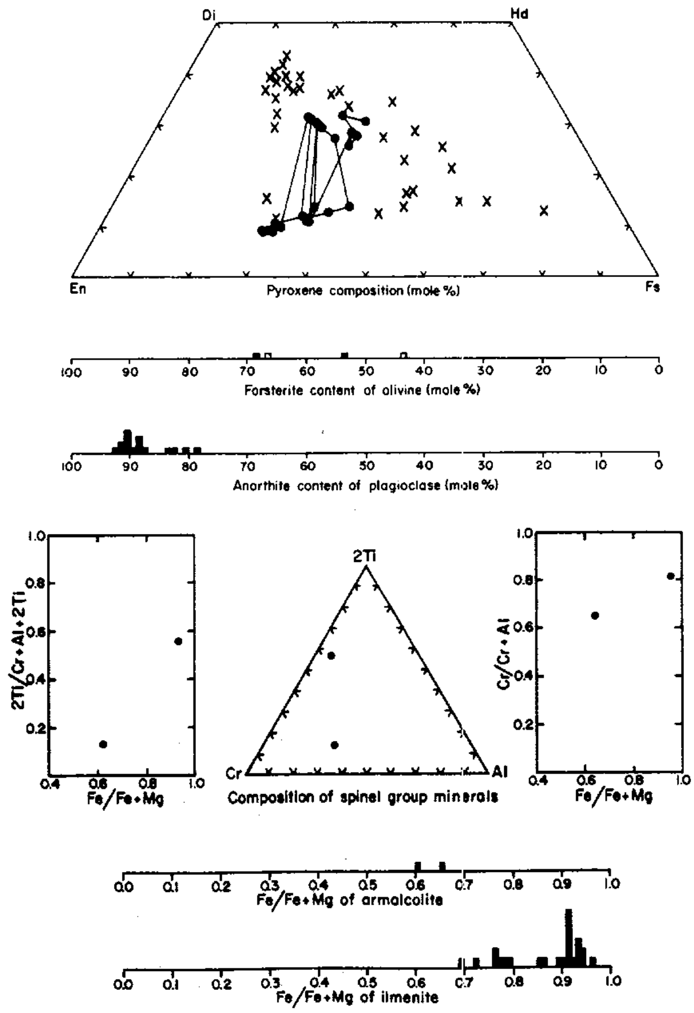


Figure 3: Chemical compositions of minerals in 78575. From Warner et al. (1978f).

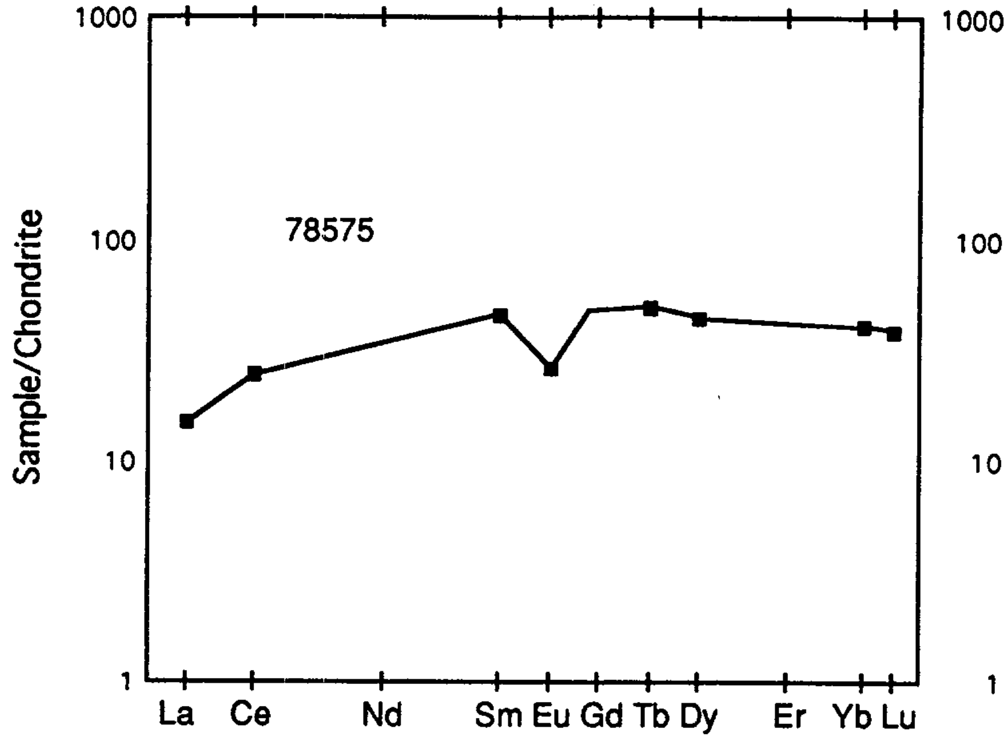


Figure 4: Normalized rare earth element diagram of 78575. Data from Warner et al. (1975b).

Table 1: Whole-rock chemistry of 78575.
From Warner et al. (1975b).

Split Technique	,3 INAA
SiO_2 (wt%)	–
TiO_2	11.8
Al_2O_3	9.0
Cr_2O_3	0.46
FeO	17.0
MnO	0.216
MgO	7.5
CaO	11.0
Na_2O	0.36
K_2O	0.04
P_2O_5	
Nb (ppm)	
Hf	5.4
Ta	1.2
Ni	
Co	16.1
Sc	75
La	3.6
Ce	15
Nd	
Sm	6.7
Eu	1.47
Gd	
Tb	1.8
Dy	11
Er	
Yb	6.6
Lu	0.95
Ge (ppb)	
Ir	
Au	

78576
High-Ti Mare Basalt
11.64 g, 3.0 x 1.6 x 1.5 cm

INTRODUCTION

Sample 78576 was collected as part of the large rake sample at Station 8. It is a coarse-grained, vuggy, ilmenite-rich mare basalt (Fig. 1).

PETROGRAPHY

The interior texture of 78576 is variolitic with coprecipitating plagioclase and pyroxene in radiating clusters (Fig. 2). Fig. 3 shows the pyroxene needles "end on" and also illustrates the chainlike behavior of the euhedral ilmenite crystals. The mode is estimated as ~50% pyroxene, 29% plagioclase, and 18% ilmenite with trace olivine, silica, armalcolite, tranquillityite, zirconolite, and spinel.

Keil et al. (1974) and Warner et al. (1978f) refer to the texture as plagioclase-poikilitic.

MINERAL CHEMISTRY

Warner et al. (1978f) have reported the mineral compositions of 78576 (Fig. 4).

WHOLE-ROCK CHEMISTRY

The chemical composition of 78576 has been reported by Warner et al. (1975b) (Table 1 and Fig. 5). The very high TiO_2 content (13.6%) and REE pattern are typical of Apollo 17 basalts.

Trace element data indicate that 78576 is a Type B Apollo 17 basalt (see appendix).

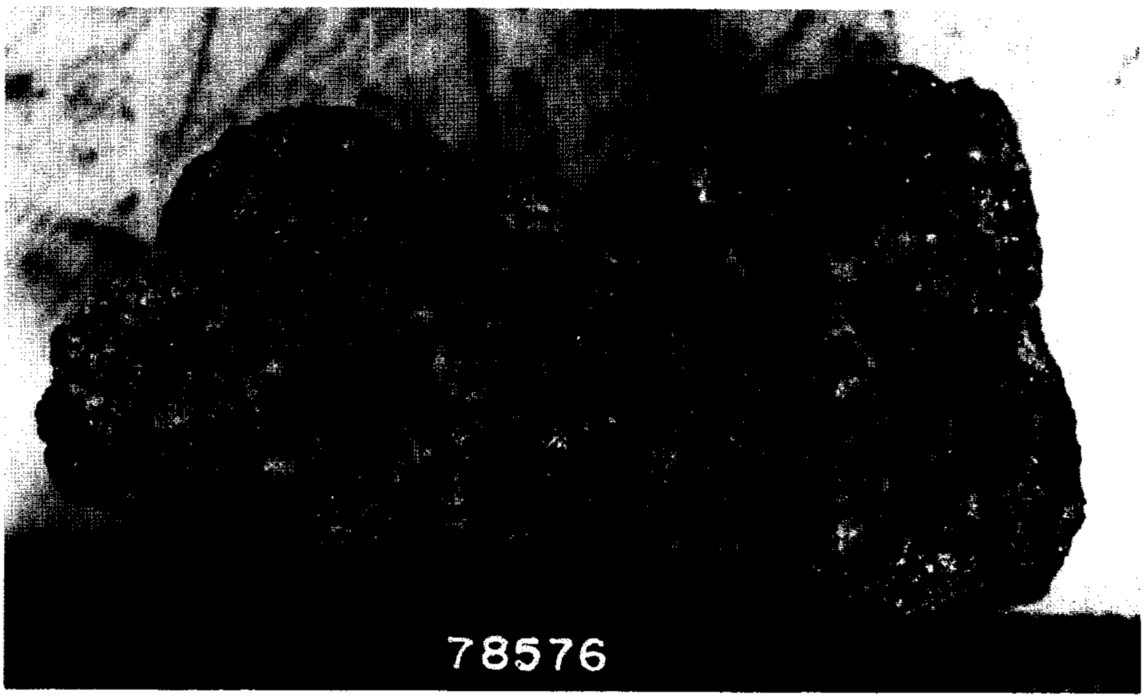


Figure 1: Photograph of 78576. Scale is 1 cm. S73-21036.

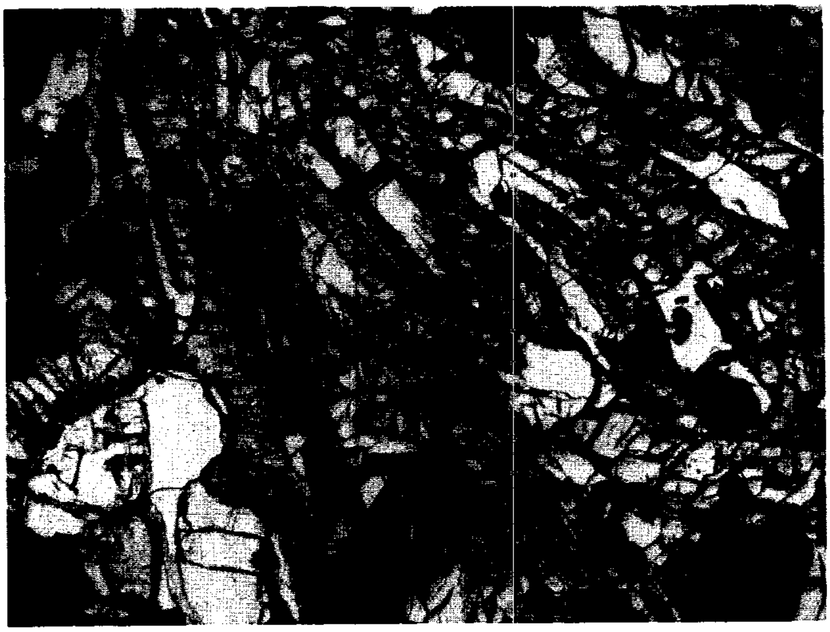


Figure 2: Photomicrograph of thin section 78576,6. Field of view is 3 x 4 mm. Note radiating cluster of pyroxene and plagioclase crystals.

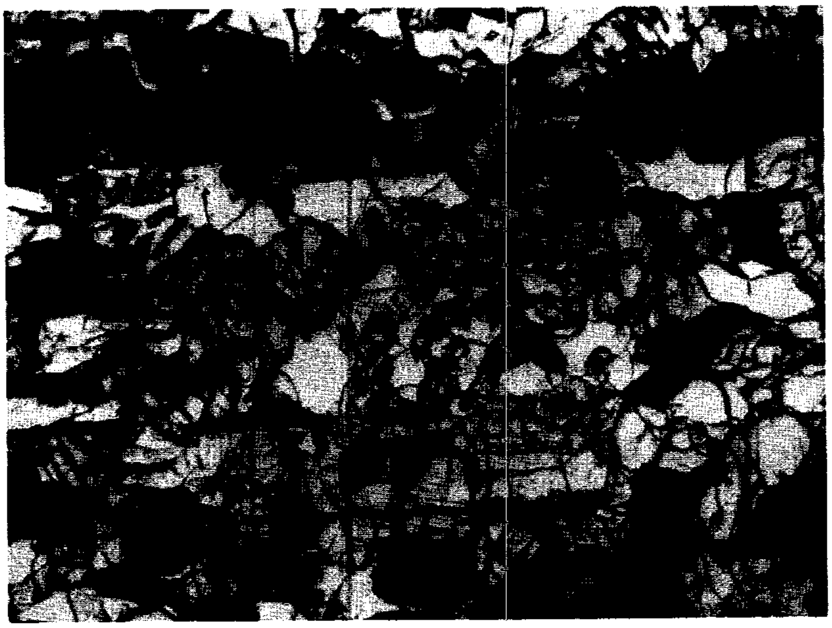


Figure 3: Photomicrograph of thin section 78576,6. Field of view is 3 x 4 mm. Note "end on" texture of pyroxene needles.

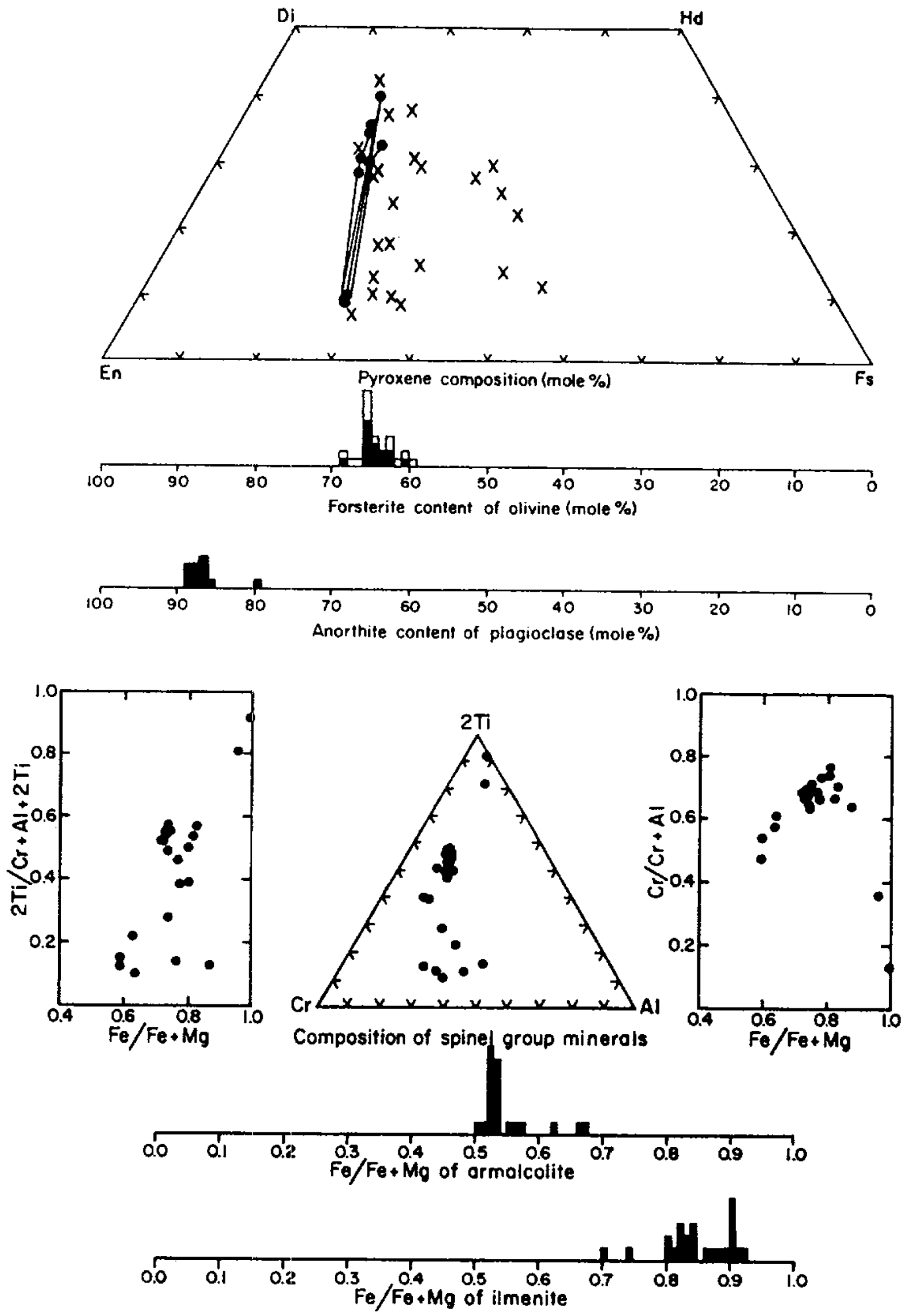


Figure 4: Chemical compositions of minerals in 78576. From Warner et al. (1978f).

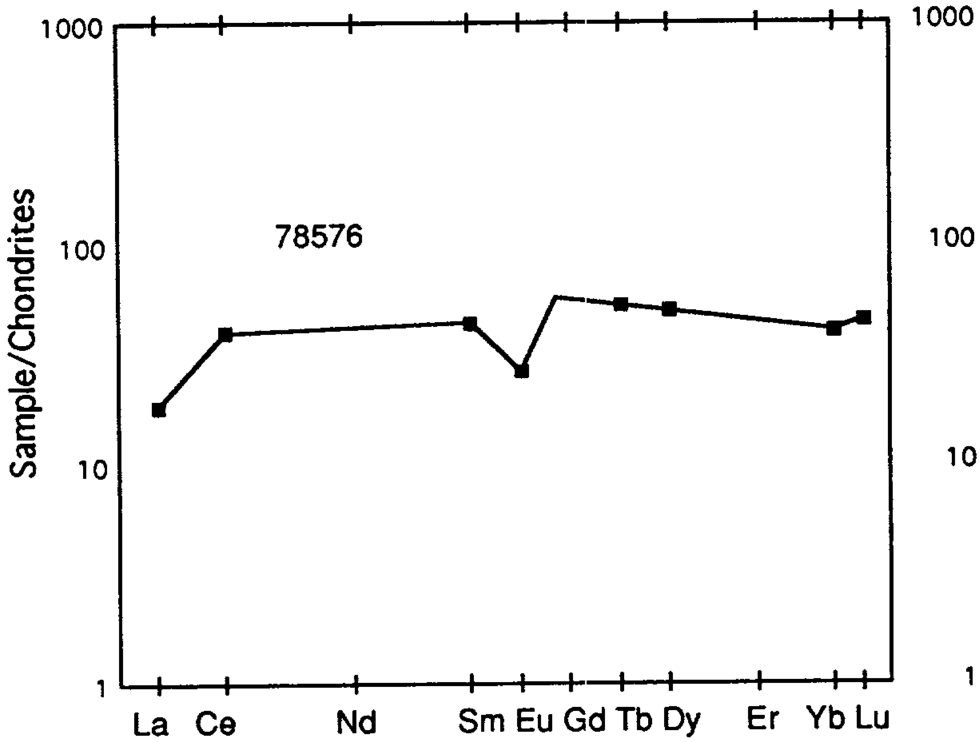


Figure 5: Normalized rare earth element diagram of 78576. Data from Warner et al. (1975b).

Table 1: Whole-rock chemistry of 78576.
From Warner et al. (1975b).

Split **Technique**	**,3** **INAA**
SiO_2 (wt%)	–
TiO_2	13.6
Al_2O_3	8.2
Cr_2O_3	0.60
FeO	19.1
MnO	0.23
MgO	9.0
CaO	9.4
Na_2O	0.35
K_2O	0.04
P_2O_5	
Nb (ppm)	
Hf	6.8
Ta	1.5
Ni	
Co	24
Sc	82
La	4.3
Ce	24
Nd	
Sm	6.4
Eu	1.49
Gd	
Tb	1.9
Dy	12
Er	
Yb	6.5
Lu	1.1
Ge (ppb)	
Ir	
Au	

78577
High-Ti Mare Basalt
8.84 g, 3.0 x 1.7 x 1.1 cm

INTRODUCTION

Sample 78577 was collected as part of the large rake sample at Station 8 (Keil et al., 1974). This sample is a coarse-grained, vuggy, ilmenite-rich mare basalt (Fig. 1).

PETROGRAPHY

The texture of mare basalt 78577 was controlled by coprecipitation of pyroxene and plagioclase which surrounded the ilmenite and olivine phenocrysts (Fig. 2).

MINERAL CHEMISTRY

The compositions of minerals in 78577 have not been determined.

WHOLE-ROCK CHEMISTRY

Ma et al. (1979) have reported the chemical composition of 78577 (Table 1 and Fig. 3). This REE pattern is typical of Apollo 17 high-Ti basalts.

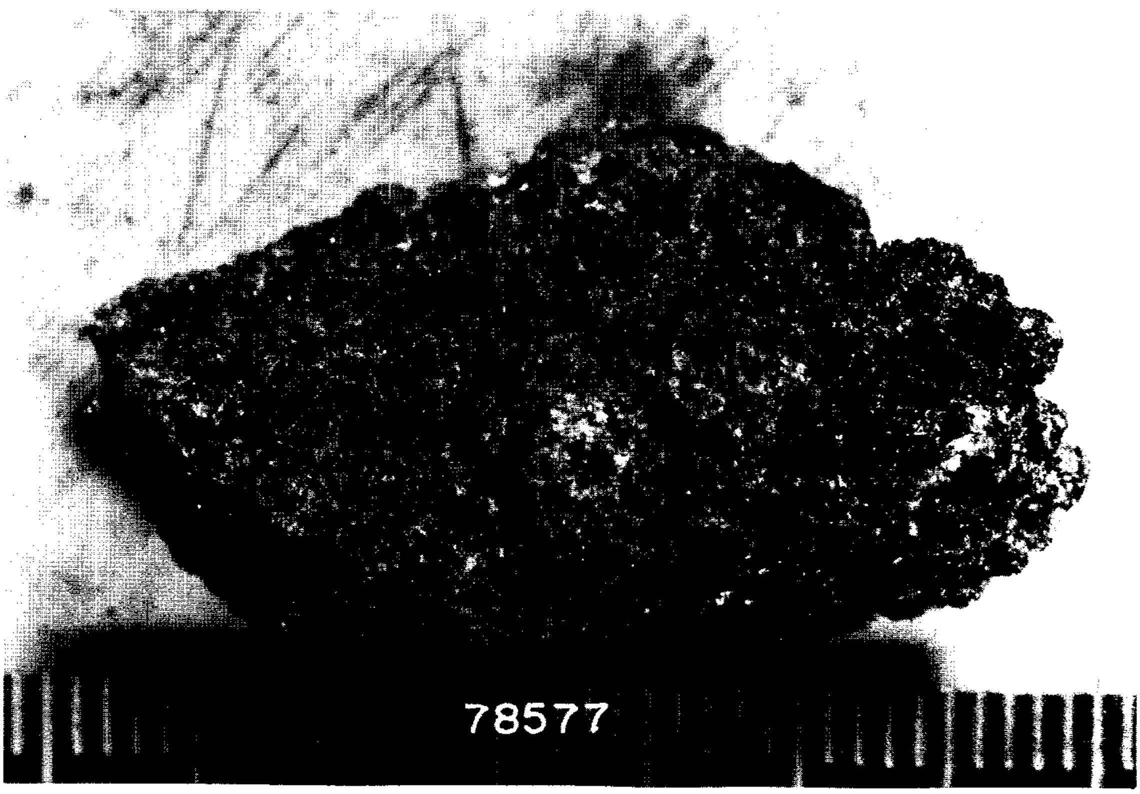


Figure 1: Photograph of 78577. Scale is 1 cm. S73-21034.

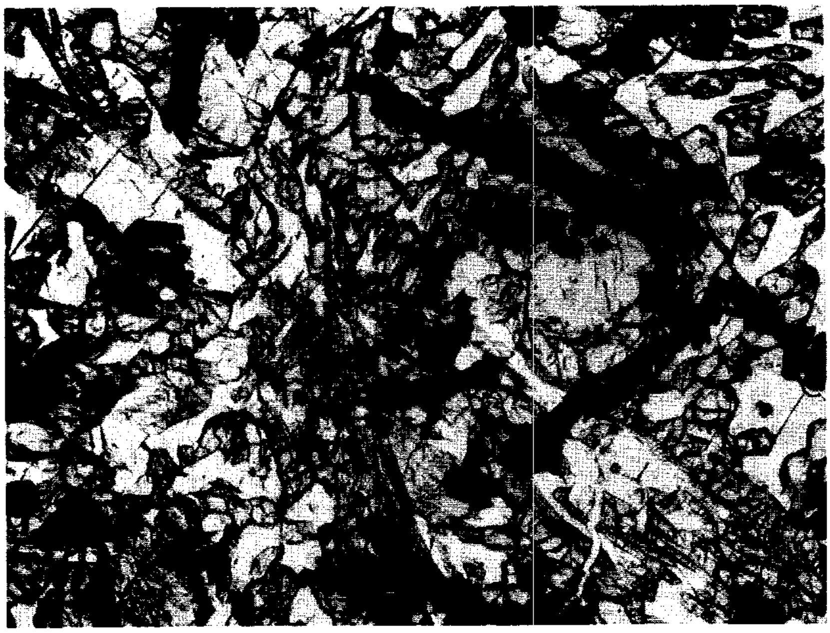


Figure 2: Photomicrograph of thin section 78577,4. Field of view is 3 x 4 mm.

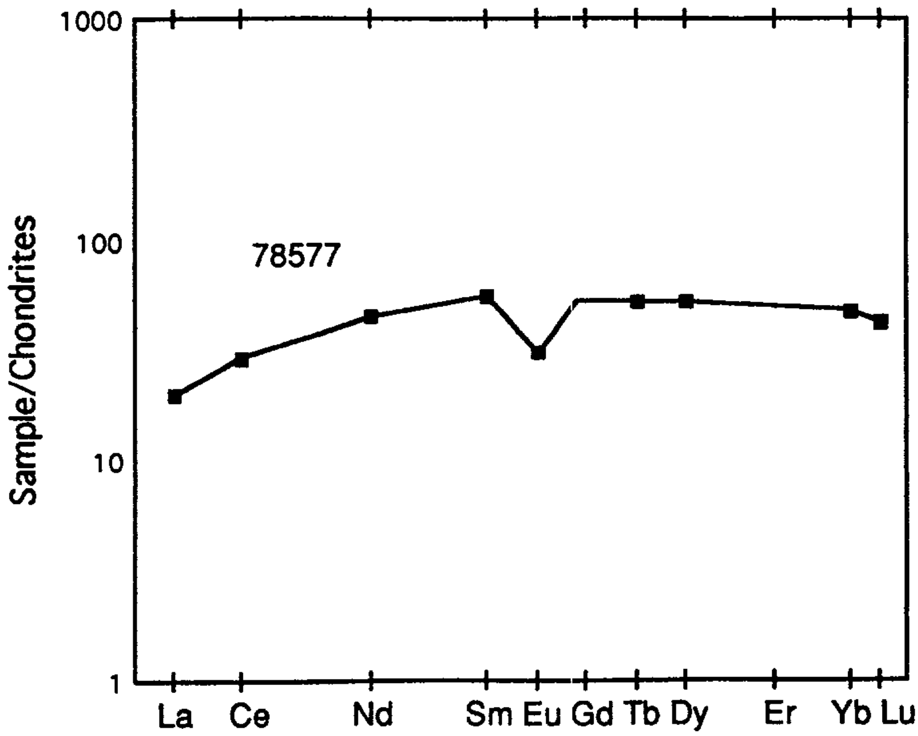


Figure 3: Normalized rare earth element diagram of 78577. Data from Ma et al. (1979).

Table 1: Whole-rock chemistry of 78577.
From Ma et al. (1979).

Split Technique	,1 INAA
SiO_2 (wt%)	–
TiO_2	12.1
Al_2O_3	8.8
Cr_2O_3	0.424
FeO	18.9
MnO	0.244
MgO	9
CaO	10.6
Na_2O	0.416
K_2O	0.051
Nb (ppm)	
Zr	
Hf	7.2
Ta	1.5
Co	20
Sc	82
La	4.7
Ce	18
Nd	21
Sm	8.3
Eu	1.73
Gd	
Tb	1.9
Dy	13
Er	
Yb	7.6
Lu	1.04
Ge (ppb)	
Ir	
Au	

78578
High-Ti Mare Basalt
17.13 g, 3.6 x 1.7 x 1.7 cm

INTRODUCTION

Sample 78578 was collected as part of the large rake sample at Station 8 (Keil et al., 1974). This sample is a coarse-grained, vuggy, ilmenite-rich mare basalt (Fig. 1).

PETROGRAPHY

Fig. 2 illustrates the plagioclase-poikilitic texture of this ilmenite basalt. It has about 51% pyroxene, 28% plagioclase, and 16% ilmenite with a trace of olivine, silica, armalcolite, tranquillityite, and baddeleyite.

MINERAL CHEMISTRY

The mineral compositions were reported in Warner et al. (1978f) (Fig. 3).

WHOLE-ROCK CHEMISTRY

Laul et al. (1975b) and Warner et al. (1975b) have reported the chemical composition of 78578 (Table 1 and Fig. 4). It is a high-Ti basalt with typical REE pattern.

Figure 1: Photograph of 78578. Scale is 1 cm. S73-21032.

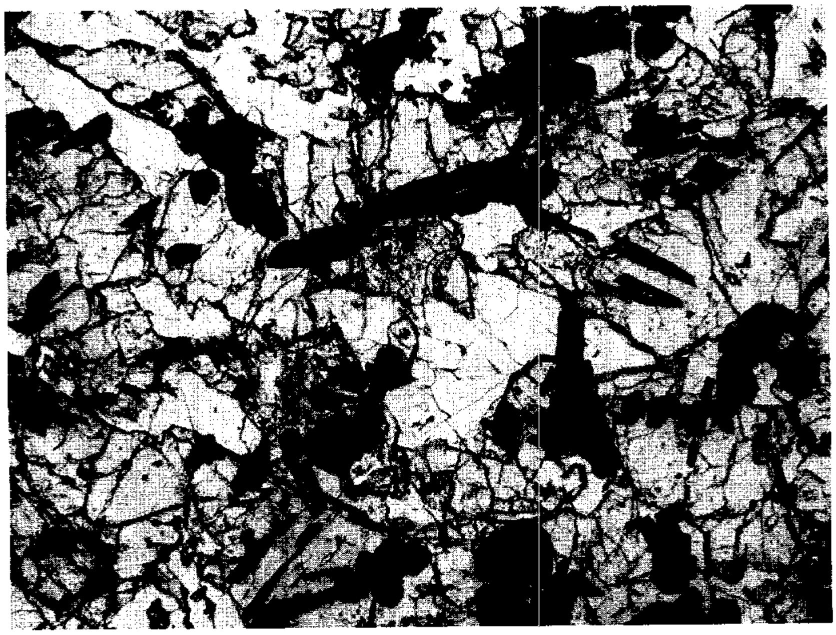


Figure 2: Photomicrograph of thin section 78578,7. Field of view is 3 x 4 mm.

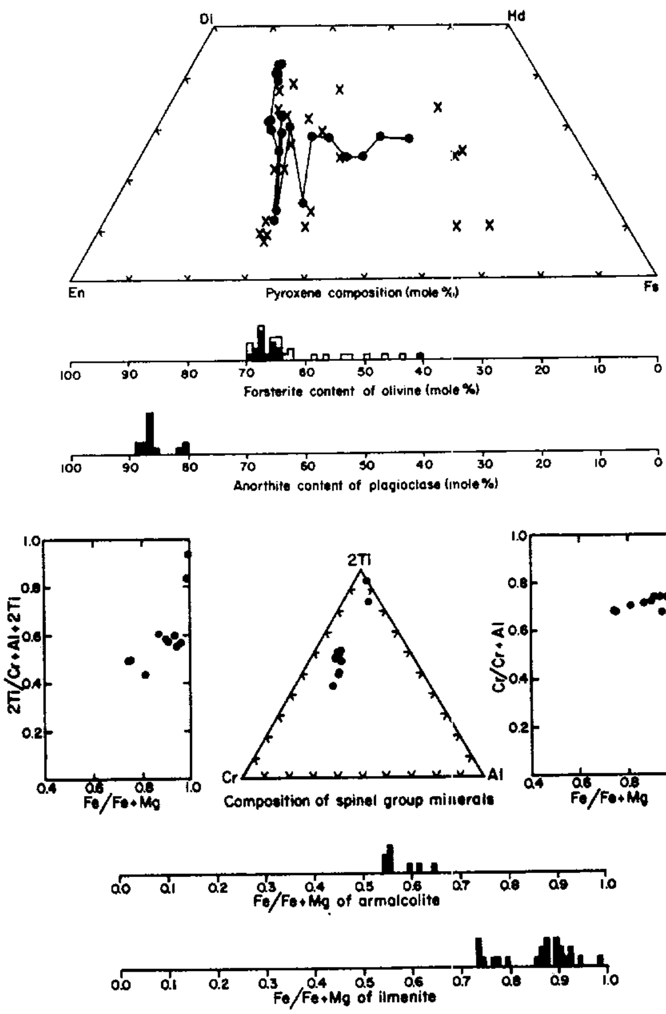


Figure 3: Mineral compositions for 78578. From Warner et al. (1978f).

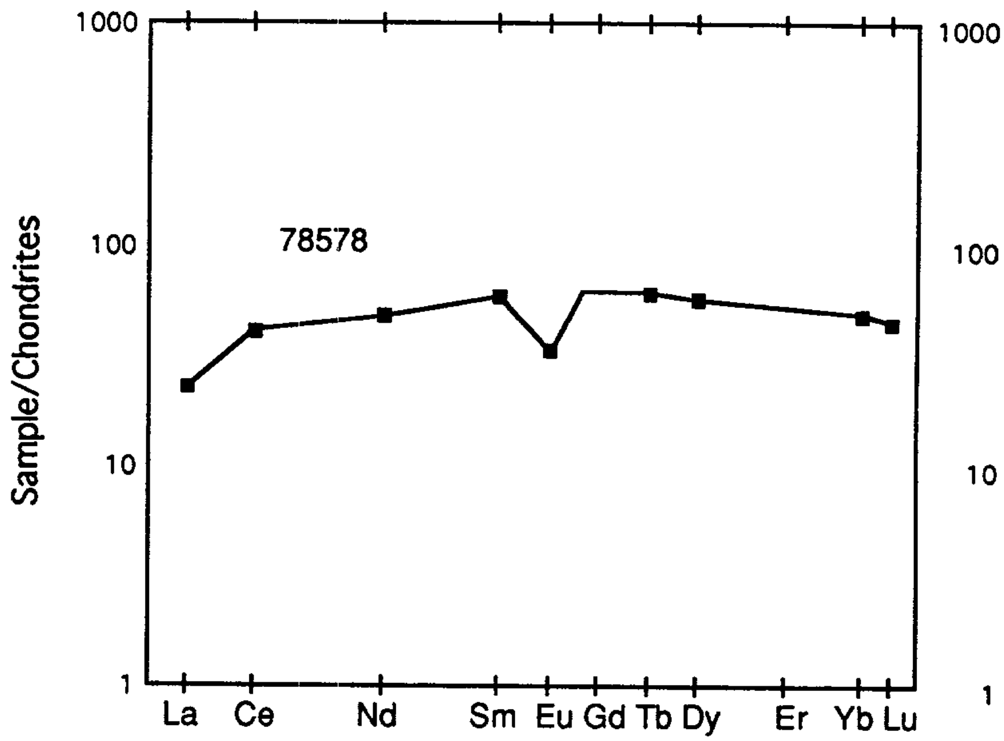


Figure 4: Normalized rare earth element diagram of 78578. Data from Warner et al. (1975b).

Table 1: Whole-rock chemistry of 78578.
From Warner et al. (1975b).

Split Technique	,3 INAA
SiO_2 (wt%)	–
TiO_2	11.2
Al_2O_3	9.0
Cr_2O_3	0.42
FeO	18.6
MnO	0.23
MgO	8.2
CaO	10
Na_2O	0.4
K_2O	0.07
Nb (ppm)	
Hf	7.7
Ta	1.5
Co	19.4
Sc	75
La	5.4
Ce	25
Nd	22
Sm	8.6
Eu	1.9
Gd	
Tb	2.2
Dy	14
Er	
Yb	7.8
Lu	1.1
Ge (ppb)	
Ir	
Au	

78579
High-Ti Mare Basalt
6.07 g, 2.4 x 2.0 x 1.0 cm

INTRODUCTION

Sample 78579 was collected as part of the large rake sample at Station 8 (Keil et al., 1974). This sample is a coarse-grained, vuggy, ilmenite-rich mare basalt (Fig. 1).

PETROGRAPHY

The texture of mare basalt 78579 is transitional between olivine-microporphyritic and plagioclase-poikilitic. The mineralogical mode is ~48% pyroxene, 28% plagioclase, 16% ilmenite, and 4% silica. There is also a trace of olivine, armalcolite, and tranquillityite.

MINERAL CHEMISTRY

Warner et al. (1978f) determined the compositions of all the minerals in 78579 (Fig. 3).

WHOLE-ROCK CHEMISTRY

Murali et al. (1977b) have reported the chemical composition of 78579 (Table 1 and Fig. 4).

Figure 1: Photograph of 78579. Scale is 1 cm. S73-21031.

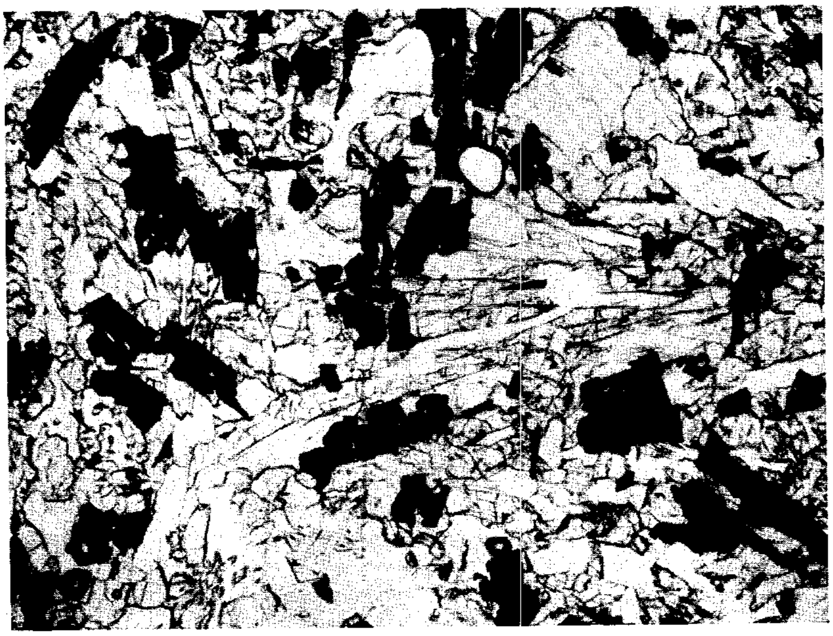


Figure 2: Photomicrograph of thin section 78579,4. Field of view is 3 x 4 mm.

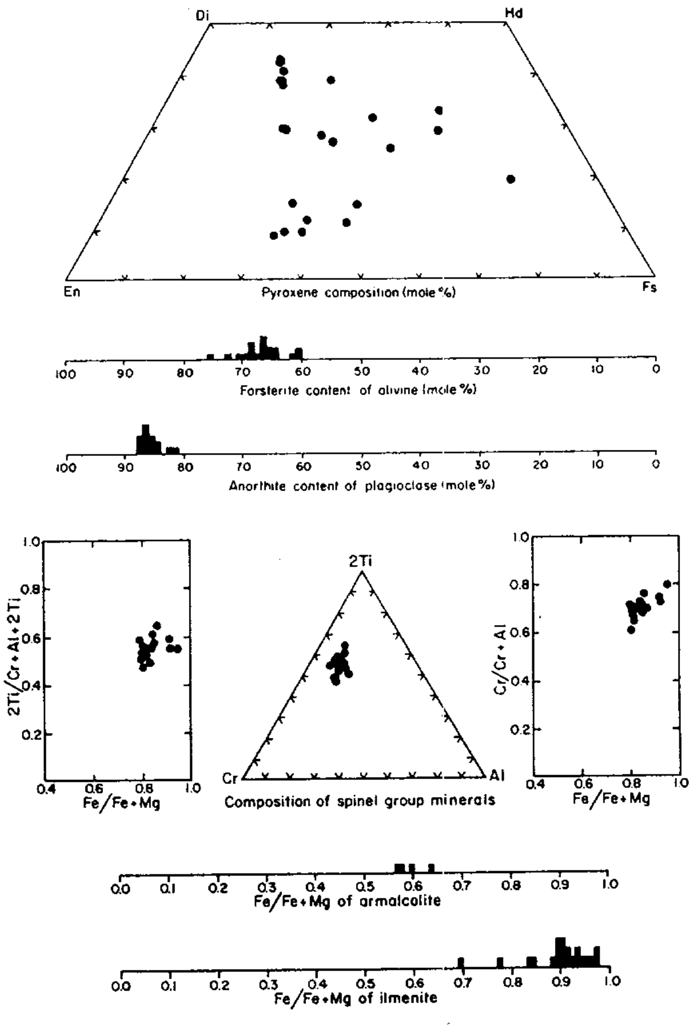


Figure 3: Mineral compositions for 78579. From Warner et al. (1978f).

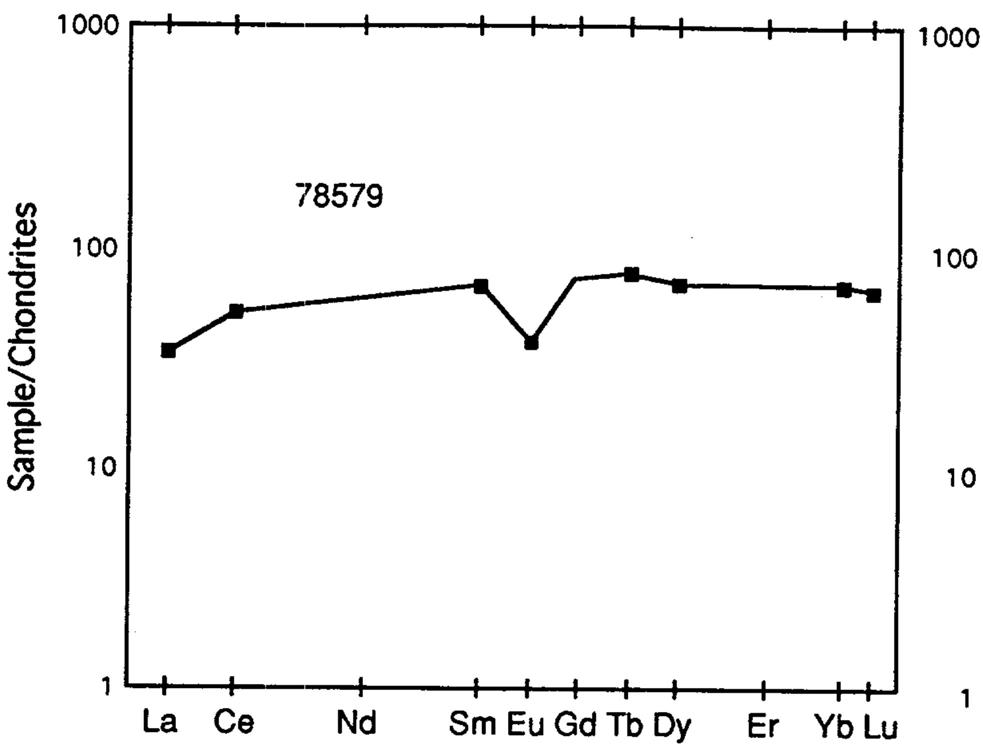


Figure 4: Normalized rare earth element diagram of 78579. Data from Murali et al. (1977b).

Table 1: Whole-rock chemistry of 78579.
From Murali et al. (1977b).

Split Technique	,1 INAA
SiO_2 (wt%)	--
TiO_2	12.0
Al_2O_3	8.5
Cr_2O_3	0.447
FeO	19.8
MnO	0.241
MgO	8.2
CaO	9.9
Na_2O	0.37
K_2O	0.064
Nb (ppm)	
Zr	
Hf	9.7
Ta	1.8
Co	17.9
Sc	77
La	7.9
Ce	31
Nd	
Sm	9.9
Eu	2.14
Gd	
Tb	2.8
Dy	17
Er	
Yb	11.1
Lu	1.54
Ge (ppb)	
Ir	
Au	

78585
High-Ti Mare Basalt
44.60 g, ~3.0 x 3.5 x 4.0 cm

INTRODUCTION

Sample 78585 is a dark black, aphanitic mare basalt from the large rake sample at Station 8 (Fig. 1).

In hand specimen, one surface of 78585 appears to have a large brown clast, but this is a cavity filled with regolith dirt.

PETROGRAPHY

Butler (1973) describes 78585 as a very fine-grained mare basalt. In thin section it is opaque with ~10% thin chains of skeletal olivine (Fig. 2). Since it has high TiO_2 (11.8%), the opaqueness is due to fine ilmenite, which commonly nucleates on olivine (Fig. 3).

MINERAL CHEMISTRY

Mineral compositions have not been determined. This sample was not studied by Warner et al. (1978f).

WHOLE-ROCK CHEMISTRY

Ma et al. (1977) have reported the chemical composition of 78585 (Table 1 and Fig. 4). The rare earth element pattern is similar to those of the other Apollo 17 basalts. Rhodes and Blanchard (1983) also performed an analysis of 78585, but give no data.

The low Hf content indicates that 78585 is a Type B Apollo 17 basalt (see appendix).

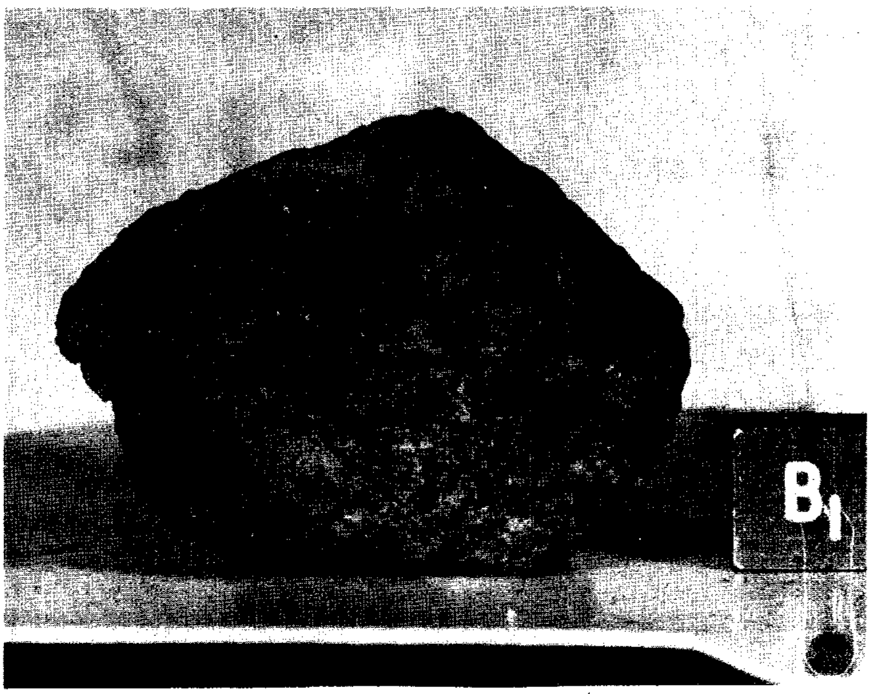


Figure 1: Photograph of mare basalt 78585. Scale is 1 cm. S73-21400.

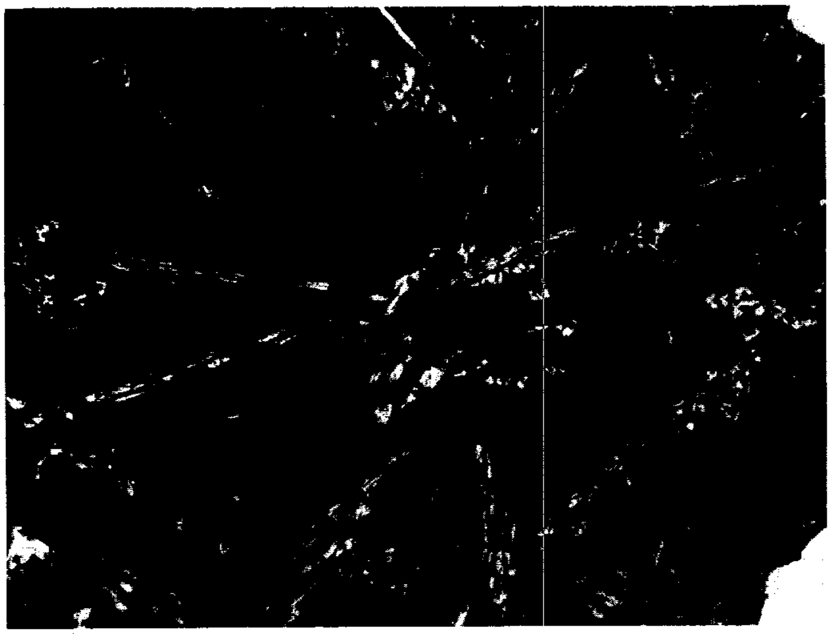


Figure 2: Photomicrograph of thin section 78585,5. Field of view is 3 x 4 mm.

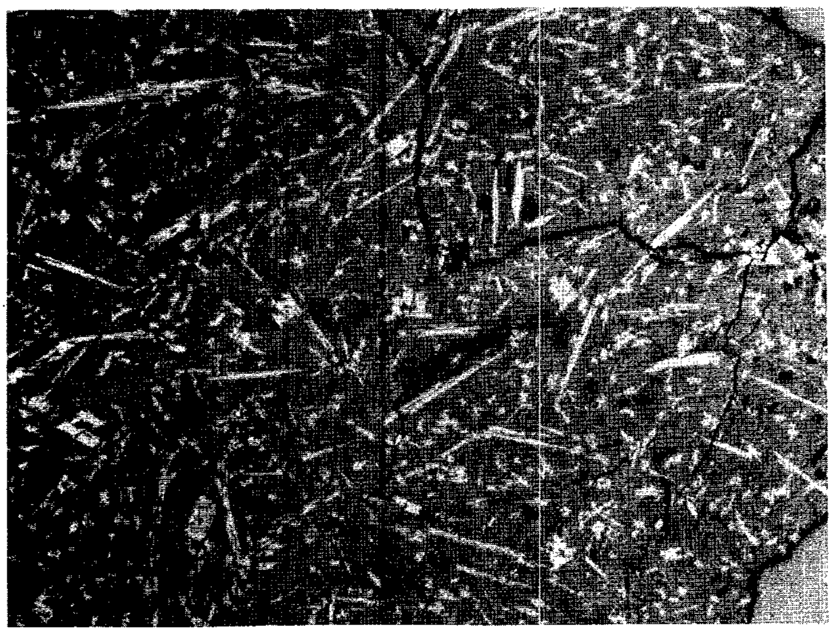


Figure 3: Reflected light photomicrograph of same area as Fig. 2.

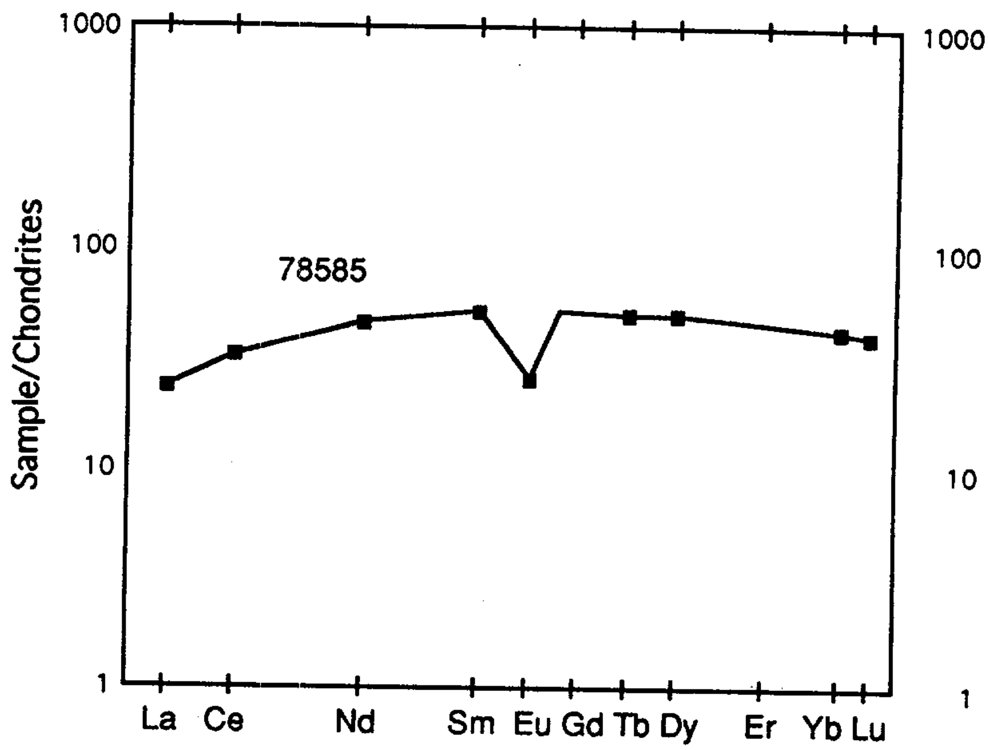


Figure 4: Normalized rare earth element diagram of 78585. Data from Ma et al. (1977).

Table 1: Whole-rock chemistry of 78585.
From Ma et al. (1977).

Split	**,7**
Technique	**INAA**
SiO_2 (wt%)	--
TiO_2	12.2
Al_2O_3	9.1
Cr_2O_3	0.361
FeO	19.6
MnO	0.245
MgO	7
CaO	11
Na_2O	0.396
K_2O	0.041
Nb (ppm)	
Hf	6.4
Ta	1.6
Co	21
Sc	86
La	5.6
Ce	20
Nd	21
Sm	7.5
Eu	1.42
Gd	
Tb	1.8
Dy	12
Er	
Yb	6.9
Lu	0.97
Ge (ppb)	
Ir	
Au	

78586
High-Ti Mare Basalt
10.73 g, 2.6 x 1.8 x 1.5 cm

INTRODUCTION

Sample 78586 is a dark black, aphanitic mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Keil et al. (1974) and Warner et al. (1978f) describe the texture of 78586 as vitrophyric (Fig. 2). Skeletal olivine and acicular ilmenite crystals exist in a groundmass of arcuate, feathery pyroxene crystals and glassy mesostasis. Minor armalcolite phenocrysts are reported by Warner et al. (1978f).

MINERAL CHEMISTRY

Warner et al. (1978f) have determined the compositions of minerals in 78586 (Fig. 3).

WHOLE-ROCK CHEMISTRY

Laul et al. (1975b) and Warner et al. (1975b) have reported the chemical composition of 78586 (Table 1 and Fig. 4).

The low Hf indicates that 78586 is a Type B basalt (see appendix).

RADIOGENIC ISOTOPES

Paces et al. (1991) have studied the Rb-Sr and Sm-Nd for whole-rock samples of 78586 (Table 2) and classify it as a Type B2 Apollo 17 mare basalt because the Sr and Nd isotopes do not fall on the whole-rock isochrons for other Apollo 17 mare basalt samples. This may indicate a different source region.

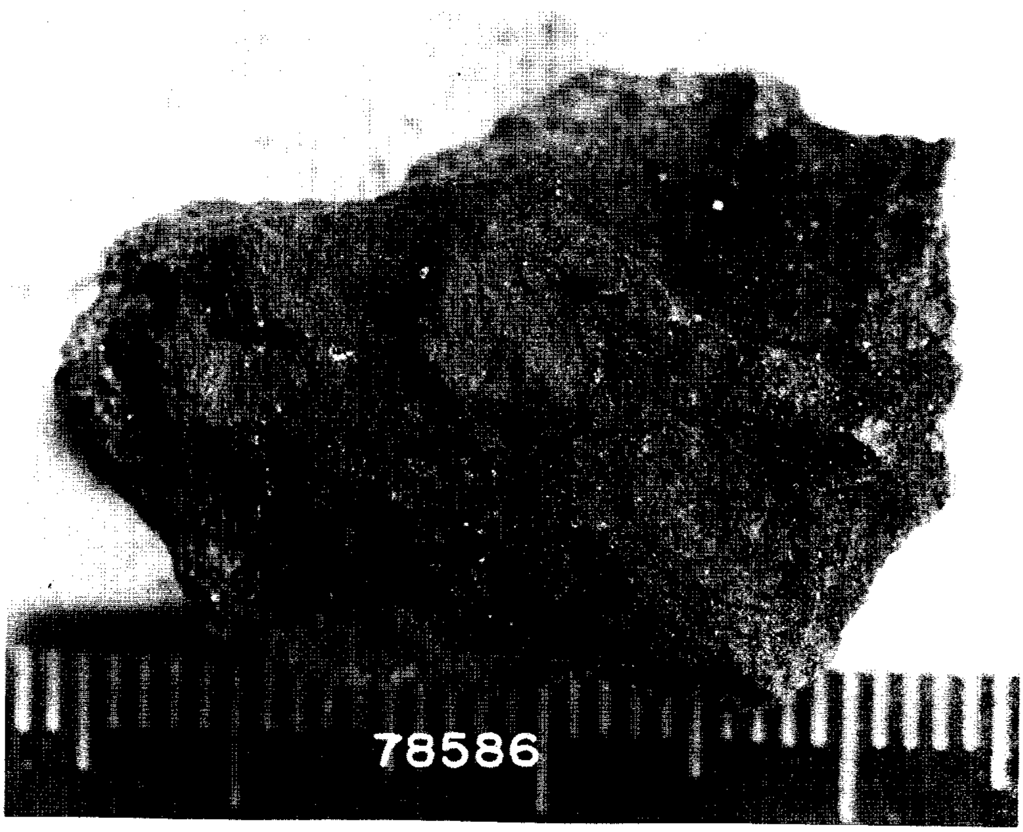


Figure 1: Photograph of 78586. Scale is 1 cm. S73-21029.

Figure 2: Photomicrograph of thin section 78586,5. Field of view is 3 x 4 mm.

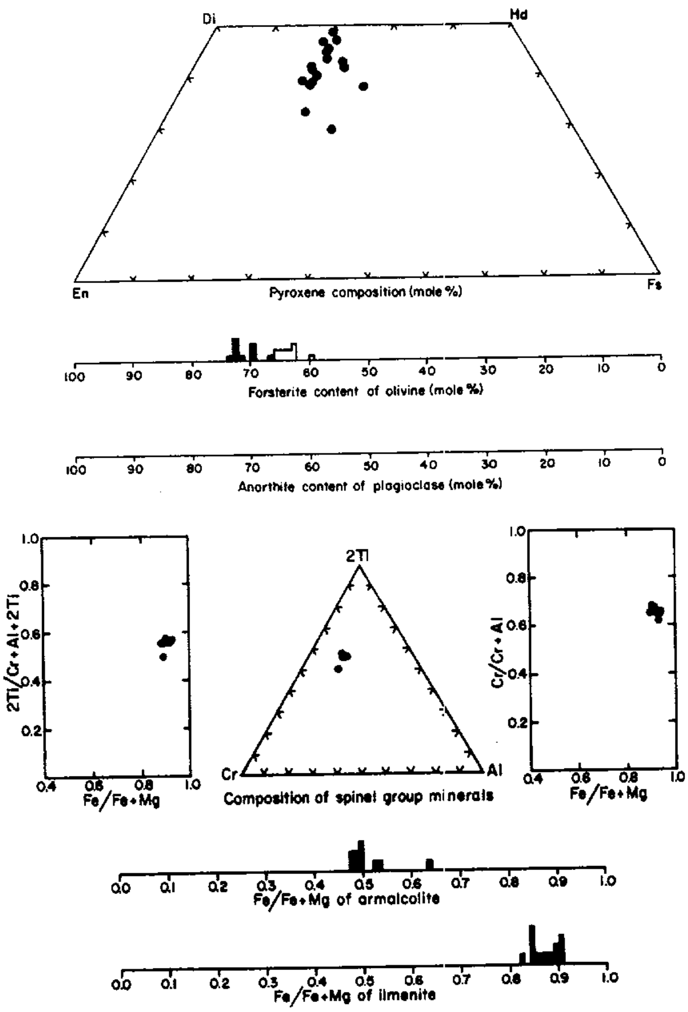


Figure 3: Mineral compositions for 78586. From Warner et al. (1978f).

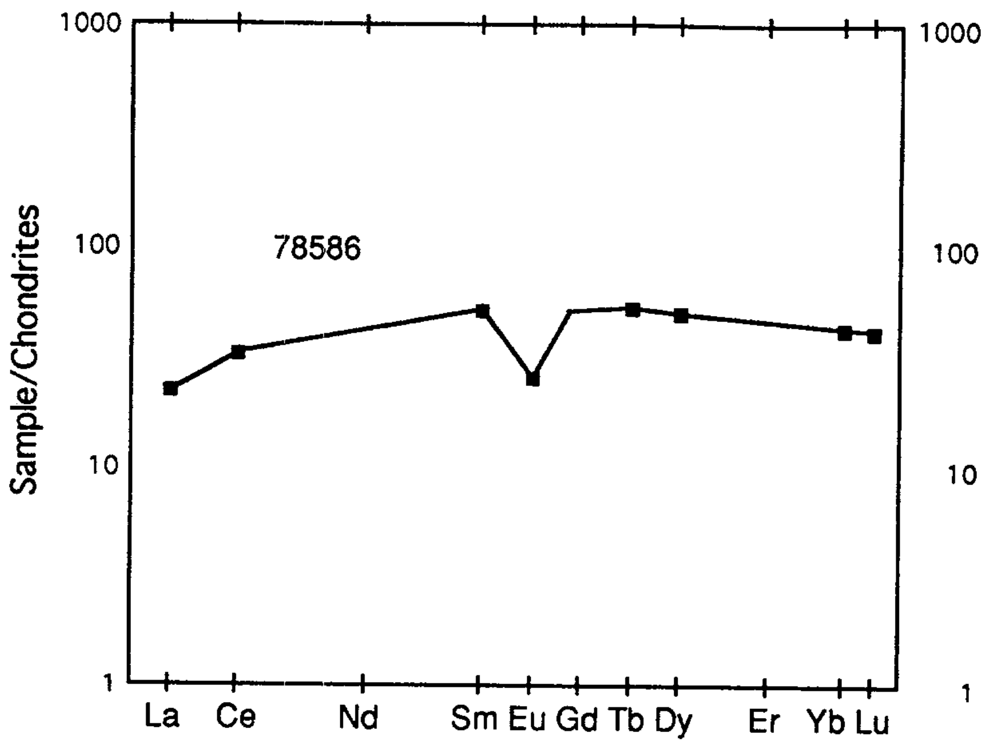


Figure 4: Normalized rare earth element diagram of 78586. Data from Warner et al. (1975b).

Table 1: Whole-rock chemistry of 78586.
From Warner et al. (1975b).

Split **Technique**	**,3** **INAA**	**Split** **Technique**	**,3** **INAA**
SiO_2 (wt%)	–	La	5.2
TiO_2	12.5	Ce	20
Al_2O_3	8.7	Nd	
Cr_2O_3	0.37	Sm	7.5
FeO	19.4	Eu	1.44
MnO	0.25	Gd	
MgO	7.4	Tb	1.9
CaO	10.3	Dy	12
Na_2O	0.41	Er	
K_2O	0.055	Yb	6.9
Nb (ppm)		Lu	1.0
Hf	6.2	Ge (ppb)	
Ta	1.6	Ir	
Co	20.8	Au	
Sc	82		

Table 2: Rb-Sr and Sm-Nd composition of 78586.
Data from Paces et al. (1991).

Sample	**78586,7**
wt (mg)	46.81
Rb (ppm)	0.389
Sr (ppm)	129
$^{87}Rb/^{86}Sr$	0.008637 ± 86
$^{87}Sr/^{86}Sr$	0.699704 ± 18
Sm (ppm)	7.58
Nd (ppm)	18.6
$^{147}Sm/^{144}Nd$	0.24637 ± 49
$^{143}Nd/^{144}Nd$	0.513989 ± 10

78587
High-Ti Mare Basalt
11.48 g, 2.5 x 2.0 x 1.2 cm

INTRODUCTION

Sample 78587 is a dark black, aphanitic mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Keil et al. (1974) describe sample 78587 as very fine-grained and rich in opaques. Warner et al. (1978f) classify this sample as olivine-microporphyritic ilmenite basalt. It has skeletal olivine and skeletal, acicular ilmenite microphenocrysts in an extremely fine-grained, wholly crystalline groundmass (Fig. 2). Sparse microphenocrysts of armalcolite and chromian ulvospinel are present (Fig. 3).

MINERAL CHEMISTRY

The mineral compositions were reported in Warner et al. (1978f) (Fig. 4).

WHOLE-ROCK CHEMISTRY

Warner et al. (1975b) have analyzed 78587 (Table 1 and Fig. 5). It has high Ti and typical rare earth element abundance.

The low Hf content of 78587 indicates that it is a Type B Apollo 17 basalt (see appendix).

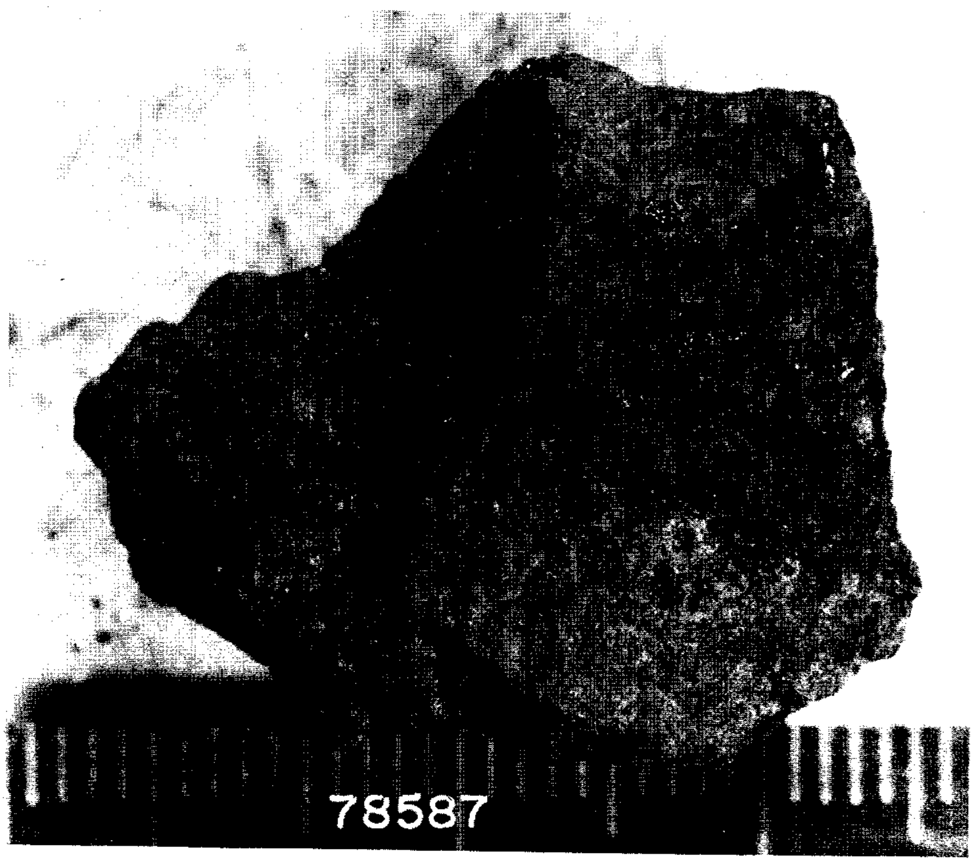


Figure 1: Photograph of 78587. Scale is 1 cm. S73-21030.

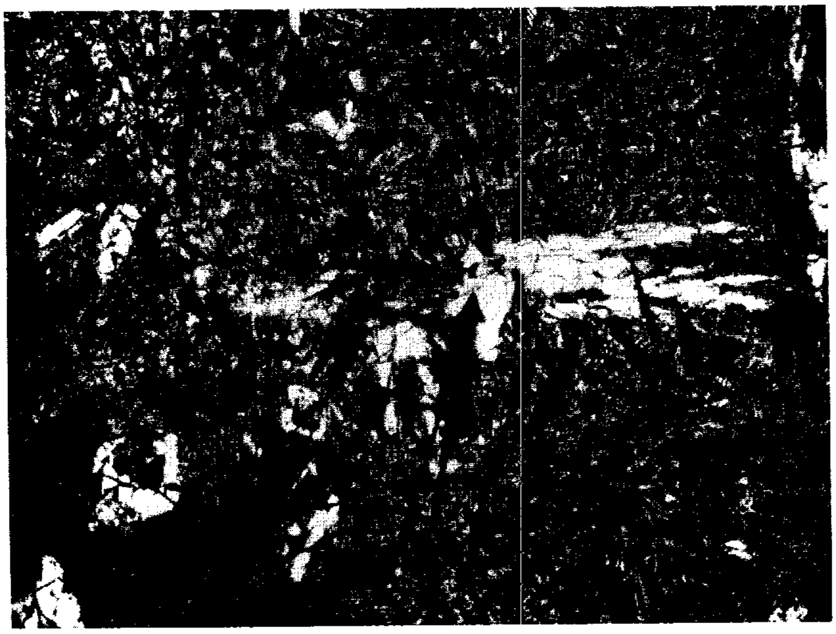


Figure 2: Photomicrograph of thin section 78587,6. Field of view is 3 x 4 mm.

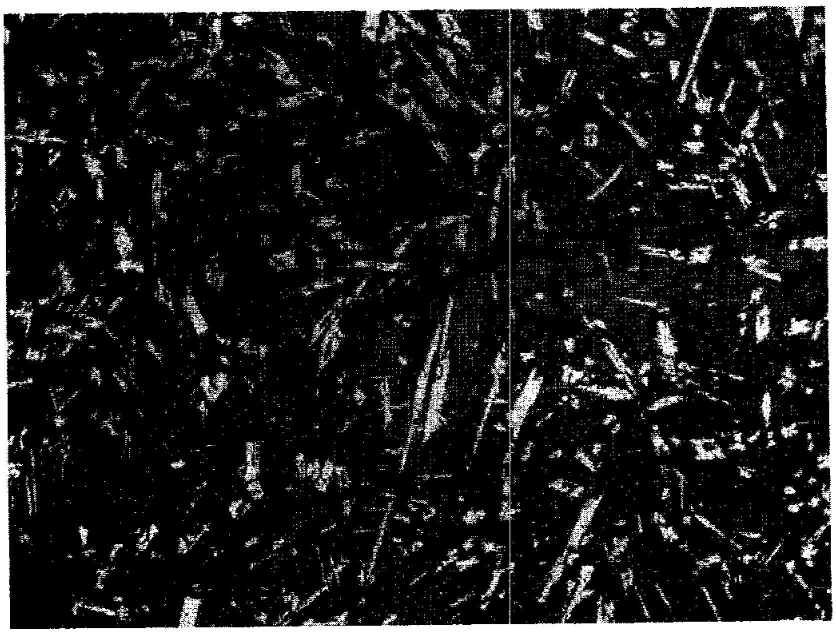


Figure 3: Photomicrograph in reflected light of same area as Fig. 2.

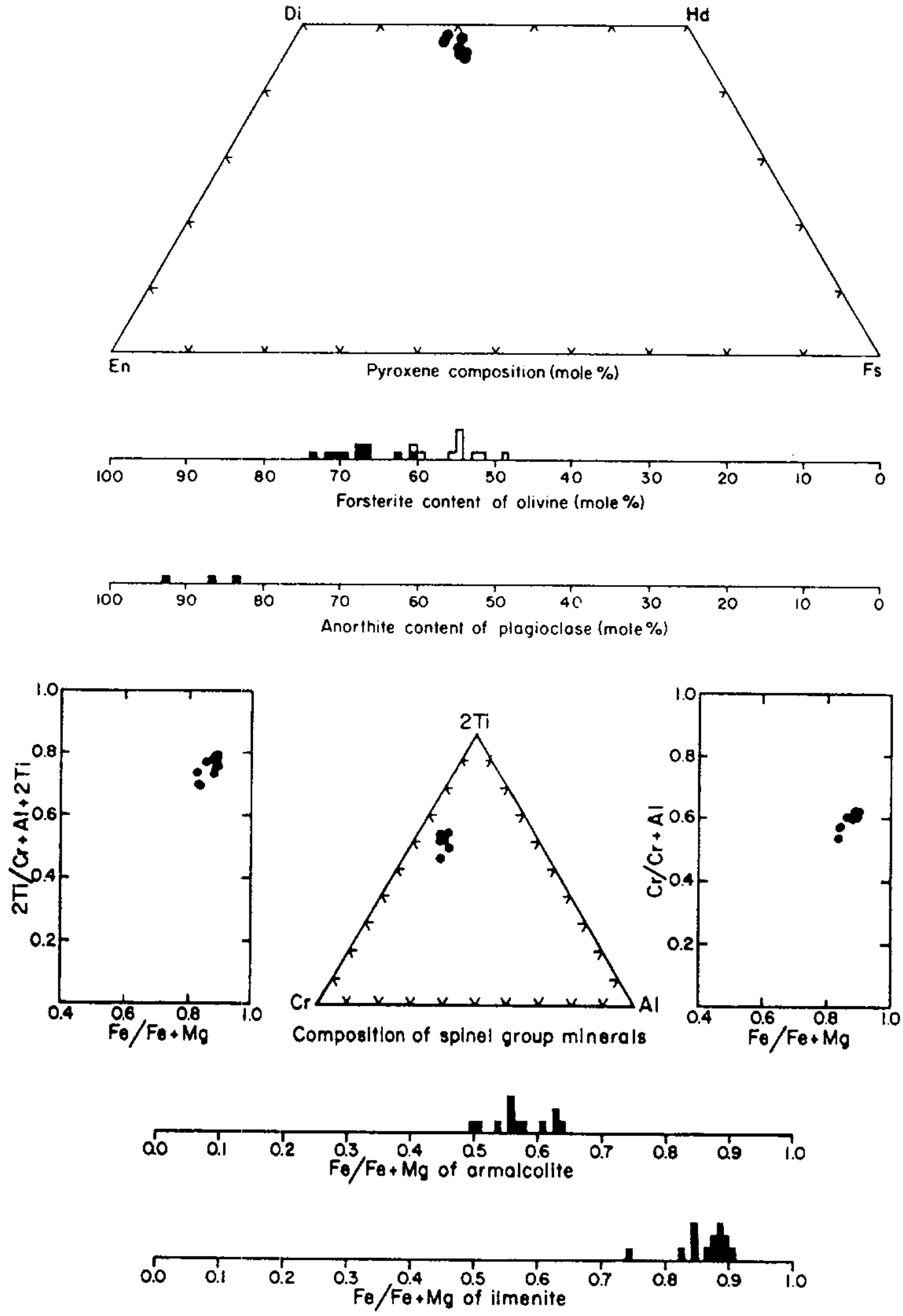


Figure 4: Mineral compositions for 78587. From Warner et al. (1978f).

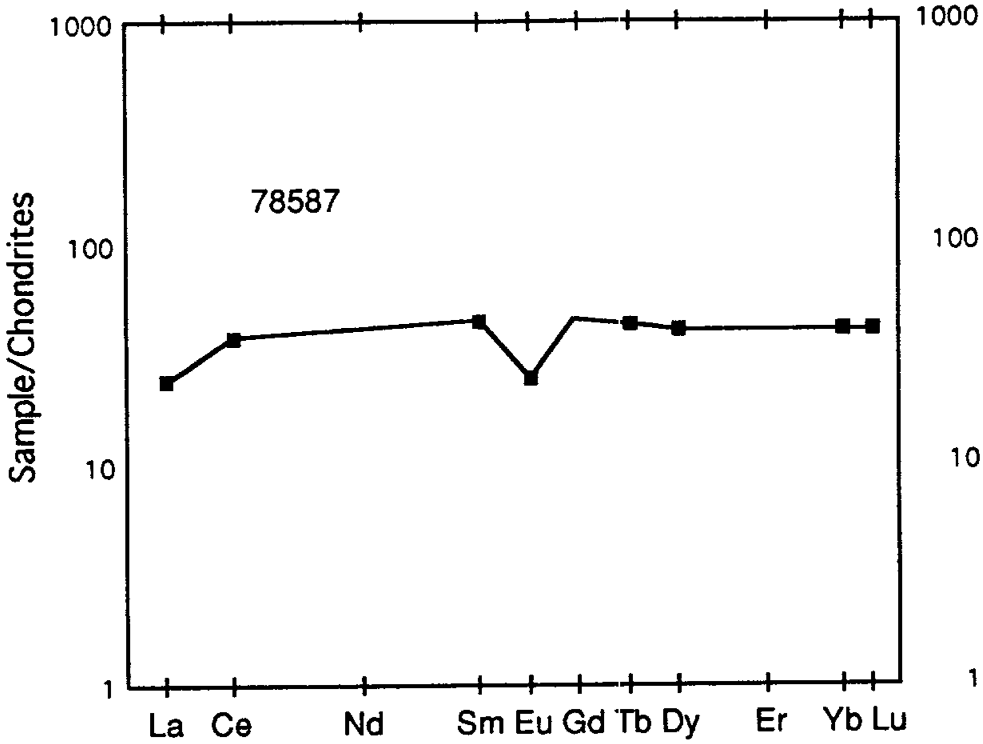


Figure 5: Normalized rare earth element diagram of 78587. Data from Warner et al. (1975b).

Table 1: Whole-rock chemistry of 78587.
From Warner et al. (1975b).

Split **Technique**	**,3** **INAA**
SiO_2 (wt%)	–
TiO_2	12.2
Al_2O_3	8.8
Cr_2O_3	0.375
FeO	19.4
MnO	0.235
MgO	7.0
CaO	10.3
Na_2O	0.37
K_2O	0.046
Nb (ppm)	
Hf	6.0
Ta	1.6
Ni	
Co	20.3
Sc	81
La	5.7
Ce	23
Nd	
Sm	6.6
Eu	1.41
Gd	
Tb	1.6
Dy	10
Er	
Yb	6.7
Lu	1.0
Ge (ppb)	
Ir	
Au	

78588
High-Ti Mare Basalt
3.77 g, 1.4 x 1.2 x 0.9 cm

INTRODUCTION

Sample 78588 is a dark grey mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Warner et al. (1978f) describe 78588 as an olivine-microporphyritic ilmenite basalt (Fig. 2). A modal count shows ~6.5% olivine, 43% pyroxene, 28% plagioclase, 16% ilmenite, and ~5% silica.

MINERAL CHEMISTRY

The minerals in 78588 have been analyzed during the cataloging process by Warner et al. (1978f) (Fig. 3).

WHOLE-ROCK CHEMISTRY

Murali et al. (1977b) have reported the chemical composition of 78588 (Table 1 and Fig. 4). The Ce analysis needs to be checked again.

The relatively high Hf content indicates that 78588 is a Type A basalt (see appendix).

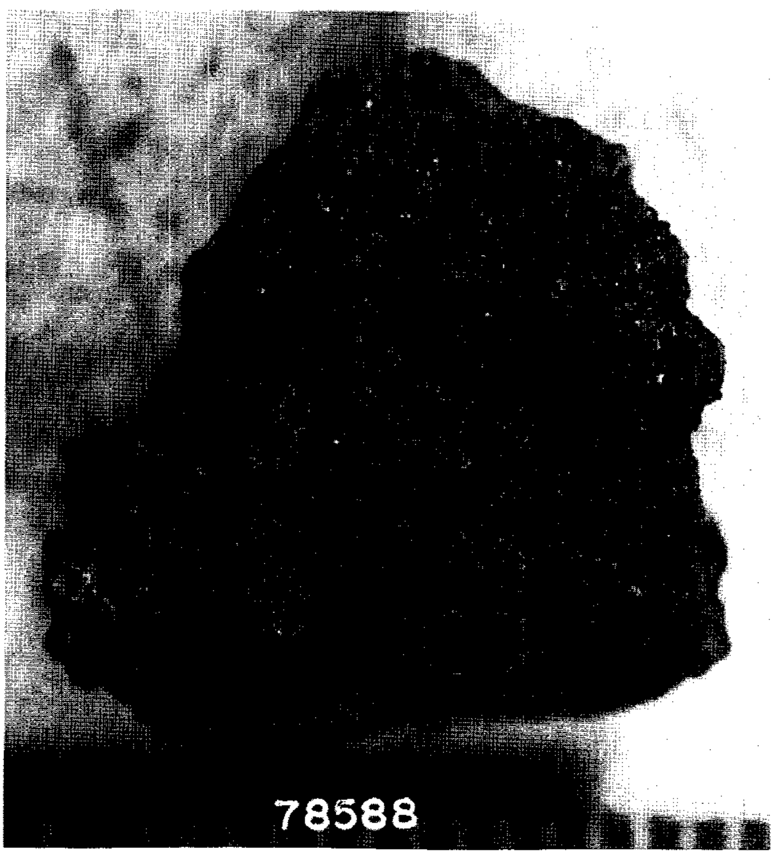


Figure 1: Photograph of 78588. Scale is 1 cm. S73-21023.

Figure 2: Photomicrograph of thin section 78588,5. Field of view is 3 x 4 mm.

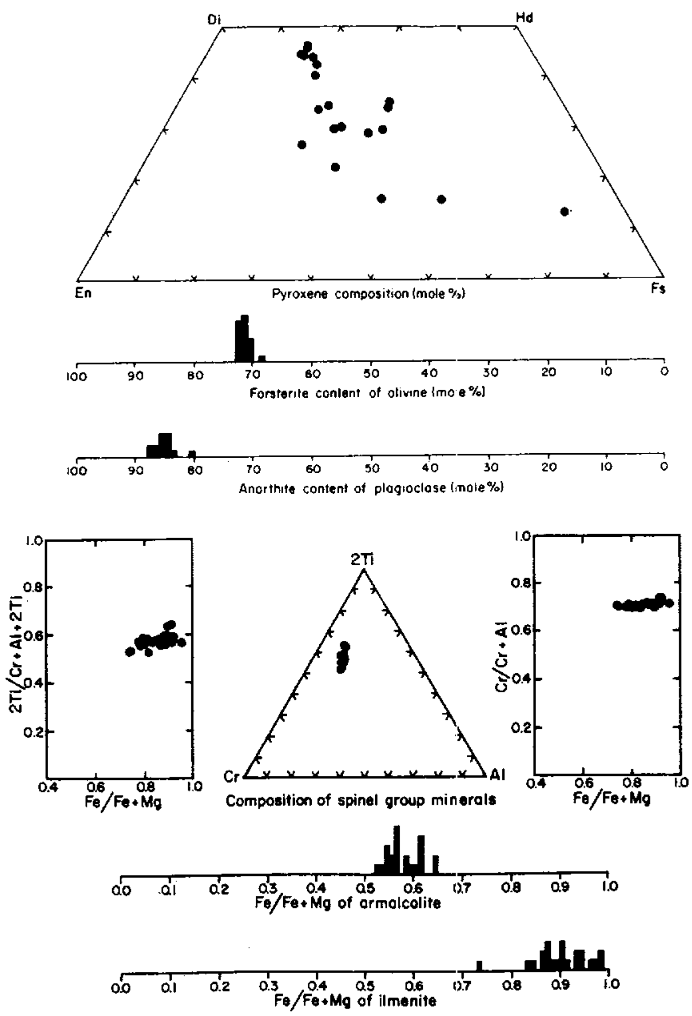


Figure 3: Mineral compositions for 78588. From Warner et al. (1978f).

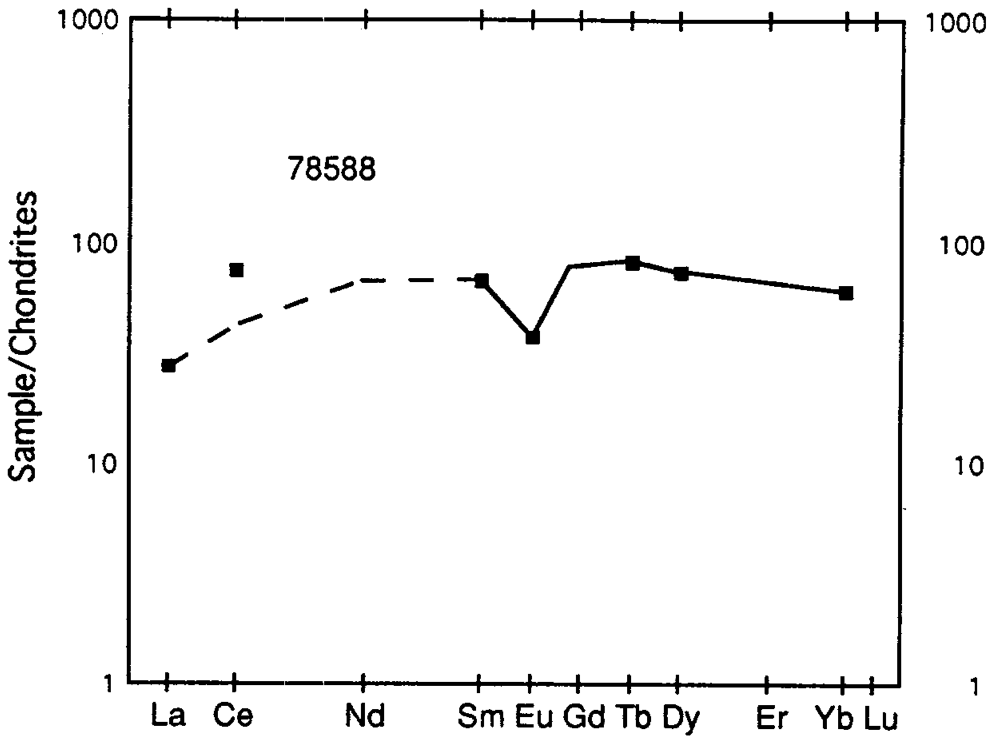


Figure 4: Normalized rare earth element diagram of 78588. Data from Murali et al. (1977b).

Table 1: Whole-rock chemistry of 78588.
From Murali et al. (1977b).

Split Technique	,1 INAA
SiO_2 (wt%)	--
TiO_2	13.0
Al_2O_3	8.9
Cr_2O_3	0.469
FeO	20.3
MnO	0.25
MgO	8.9
CaO	9.9
Na_2O	0.38
K_2O	0.69
Nb (ppm)	
Hf	10.8
Ta	1.9
Co	18.6
Sc	76
La	6.6
Ce	(46)
Nd	
Sm	9.9
Eu	2.15
Gd	
Tb	3
Dy	18
Er	
Yb	9.8
Lu	1.44
Ge (ppb)	
Ir	
Au	

78589

High-Ti Mare Basalt
4.10 g, 1.8 x 1.4 x 1.2 cm

INTRODUCTION

Sample 78589 is a dark grey, fine-grained mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Warner et al. (1978f) describe the texture of 78589 as predominantly very fine-grained, with subequant, sometimes skeletal, olivine and skeletal, often acicular, ilmenite microphenocrysts in a variolitic groundmass (Fig. 2).

MINERAL CHEMISTRY

Warner et al. (1978f) have determined the chemical compositions of the minerals in 78589 (Fig. 3).

WHOLE-ROCK CHEMISTRY

Murali et al. (1977b) have reported the chemical composition of 78589 (Table 1 and Fig. 4). The analysis for Ce needs to be checked.

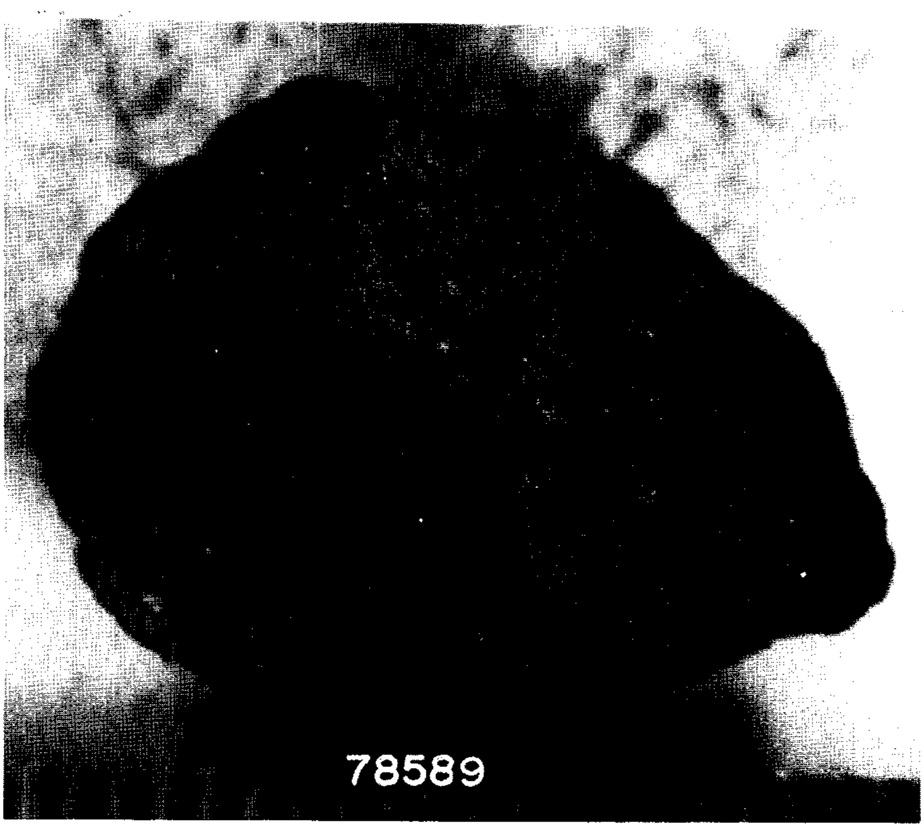


Figure 1: Photograph of 78589. Scale is 1 cm. S73-21024.

Figure 2: Photomicrograph of thin section 78589,5. Field of view is 3 x 4 mm.

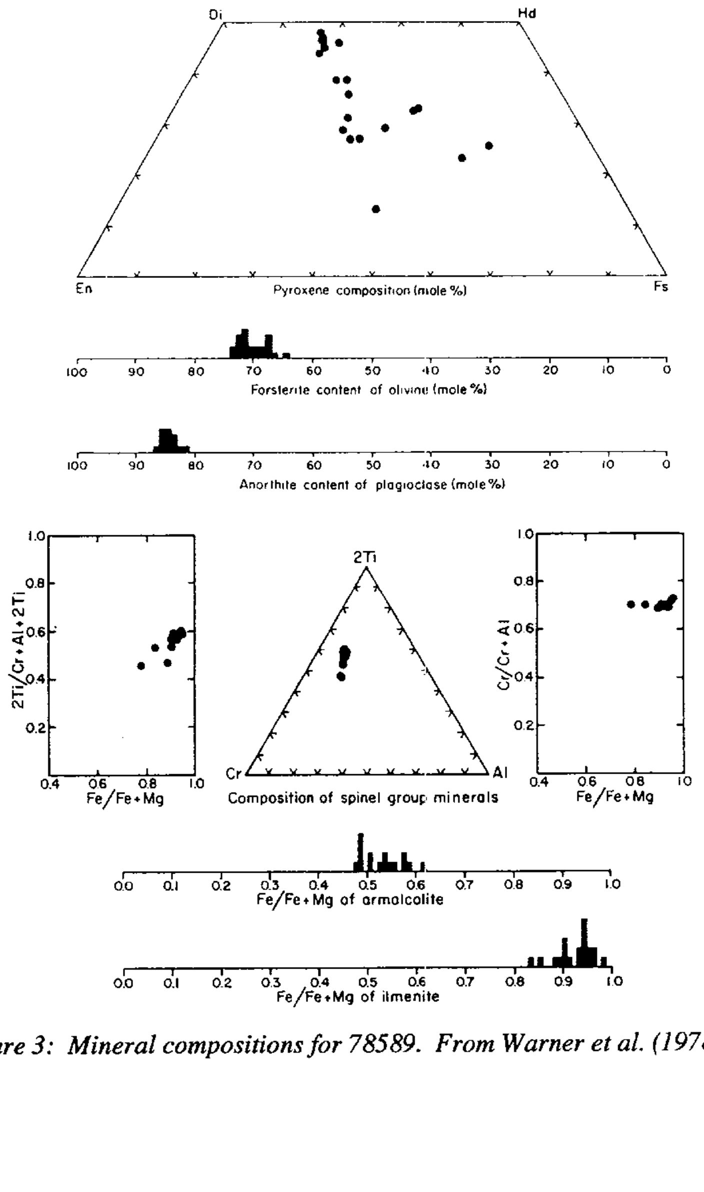


Figure 3: Mineral compositions for 78589. From Warner et al. (1978f).

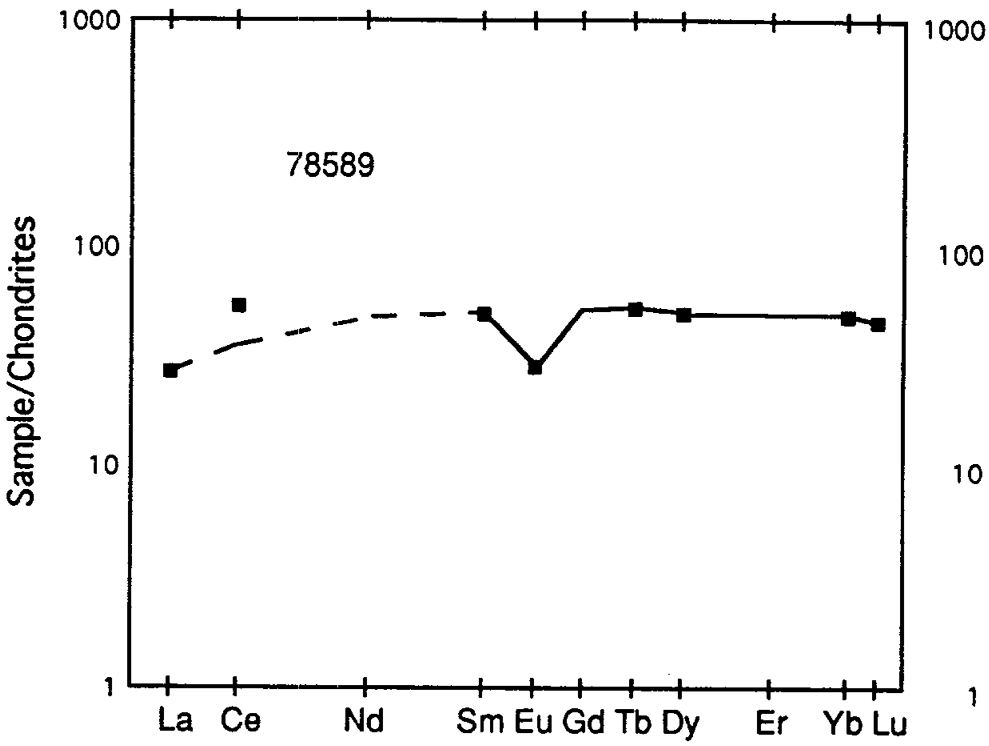


Figure 4: Normalized rare earth element diagram of 78589. Data from Murali et al. (1977b).

Table 1: Whole-rock chemistry of 78589.
From Murali et al. (1977b).

Split **Technique**	**,1** **INAA**
SiO_2 (wt%)	–
TiO_2	12.6
Al_2O_3	9.2
Cr_2O_3	0.324
FeO	20.4
MnO	0.25
MgO	7.9
CaO	11.4
Na_2O	0.4
K_2O	0.047
Nb (ppm)	
Hf	7.7
Ta	1.6
Co	19.2
Sc	83
La	6.3
Ce	33
Nd	
Sm	7.4
Eu	1.59
Gd	
Tb	1.9
Dy	12
Er	
Yb	7.9
Lu	1.12
Ge (ppb)	
Ir	
Au	

78595
High-Ti Mare Basalt
4.19 g, 1.3 x 1.4 x 1.2 cm

INTRODUCTION

Sample 78595 is a medium dark grey, fine-grained mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Sample 78595 has slightly resorbed equant olivine phenocrysts. The fine-grained groundmass has a variolitic texture (Fig. 2).

MINERAL CHEMISTRY

Warner et al. (1978f) have determined the chemical compositions of the minerals in 78595 (Fig. 3). Pyroxenes are chemically zoned.

WHOLE-ROCK CHEMISTRY

Warner et al. (1975a) have reported the chemical composition of 78595 (Table 1 and Fig. 4).

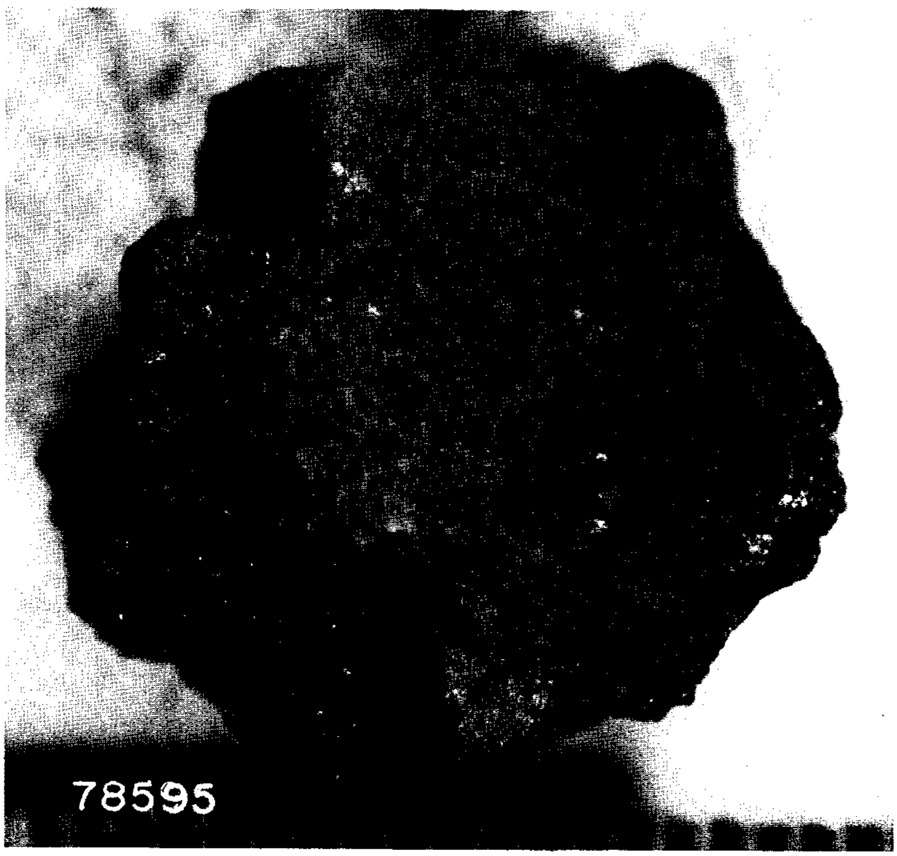


Figure 1: Photograph of 78595. Scale is 1 cm. S73-21025.

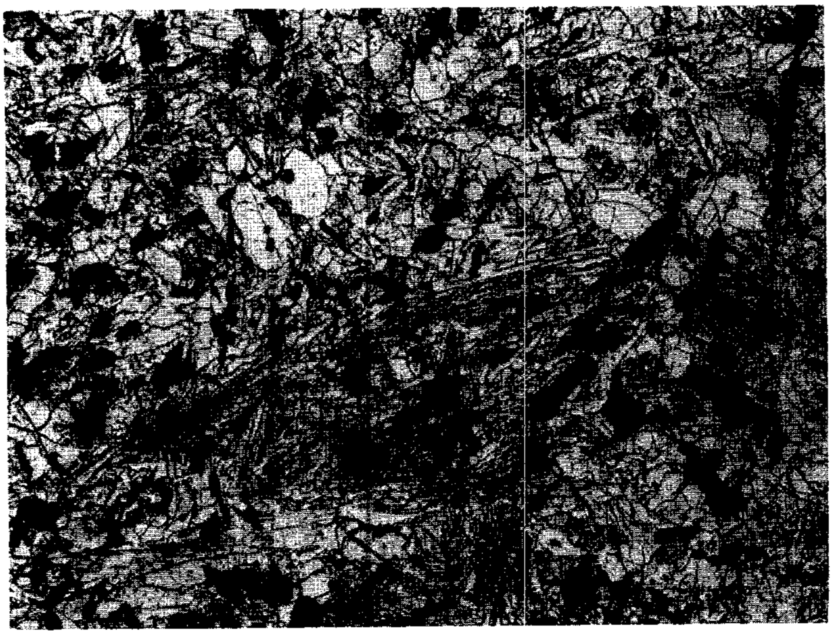


Figure 2: Photomicrograph of thin section 78595,6. Field of view is 3 x 4 mm.

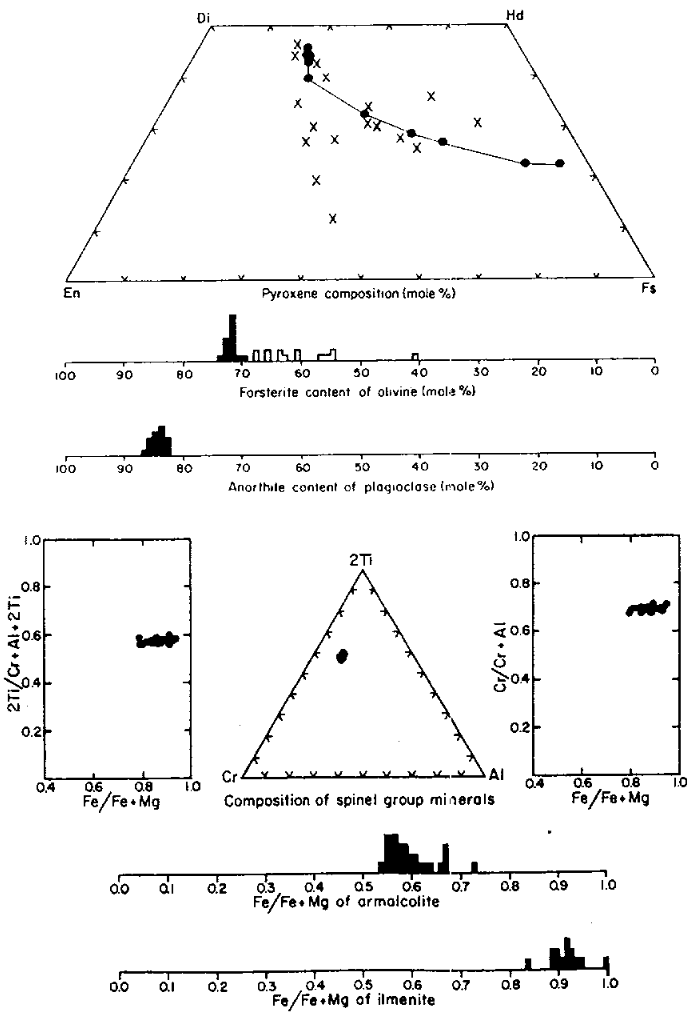


Figure 3: Mineral compositions for 78595. From Warner et al. (1978f).

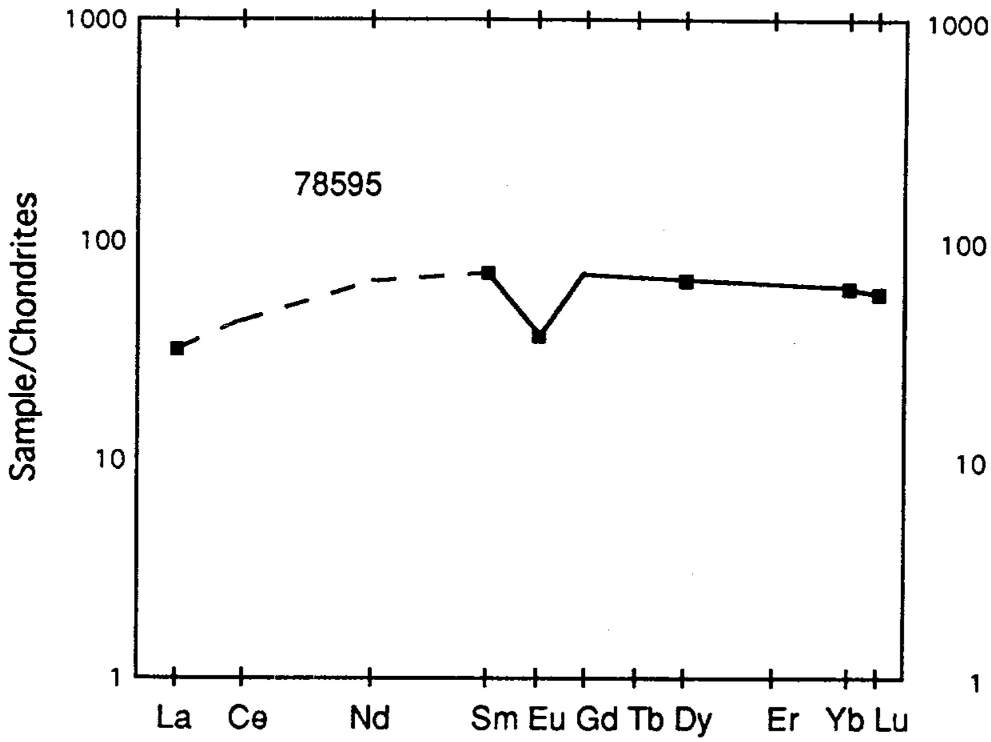


Figure 4: Normalized rare earth element diagram of 78595. Data from Warner et al. (1975a).

Table 1: Whole-rock chemistry of 78595.
From Warner et al. (1975a).

Split Technique	,3 INAA
SiO_2 (wt%)	-
TiO_2	12.8
Al_2O_3	9.0
Cr_2O_3	0.443
FeO	19.9
MnO	0.253
MgO	9.1
CaO	11.0
Na_2O	0.387
K_2O	0.063
Nb (ppm)	
Ni	
Co	20.5
Sc	86
La	7.5
Ce	
Nd	
Sm	10.5
Eu	2.05
Gd	
Tb	
Dy	16
Er	
Yb	9.9
Lu	1.4
Ge (ppb)	
Ir	
Au	

78596
High-Ti Mare Basalt
7.55 g, 2.0 x 1.5 x 1.5 cm

INTRODUCTION

Sample 78596 is a dark grey, fine-grained mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Sample 78596 has slightly resorbed equant olivine phenocrysts. The fine-grained groundmass has a variolitic texture (Fig. 2).

MINERAL CHEMISTRY

Warner et al. (1978f) have determined the chemical compositions of the minerals in 78596 (Fig. 3).

WHOLE-ROCK CHEMISTRY

Murali et al. (1977b) have reported the chemical composition of 78596 (Table 1 and Fig. 4). This analysis may need to be repeated because the Ce seems too high.

Sample 78596 is a Type A Apollo 17 basalt (see appendix).

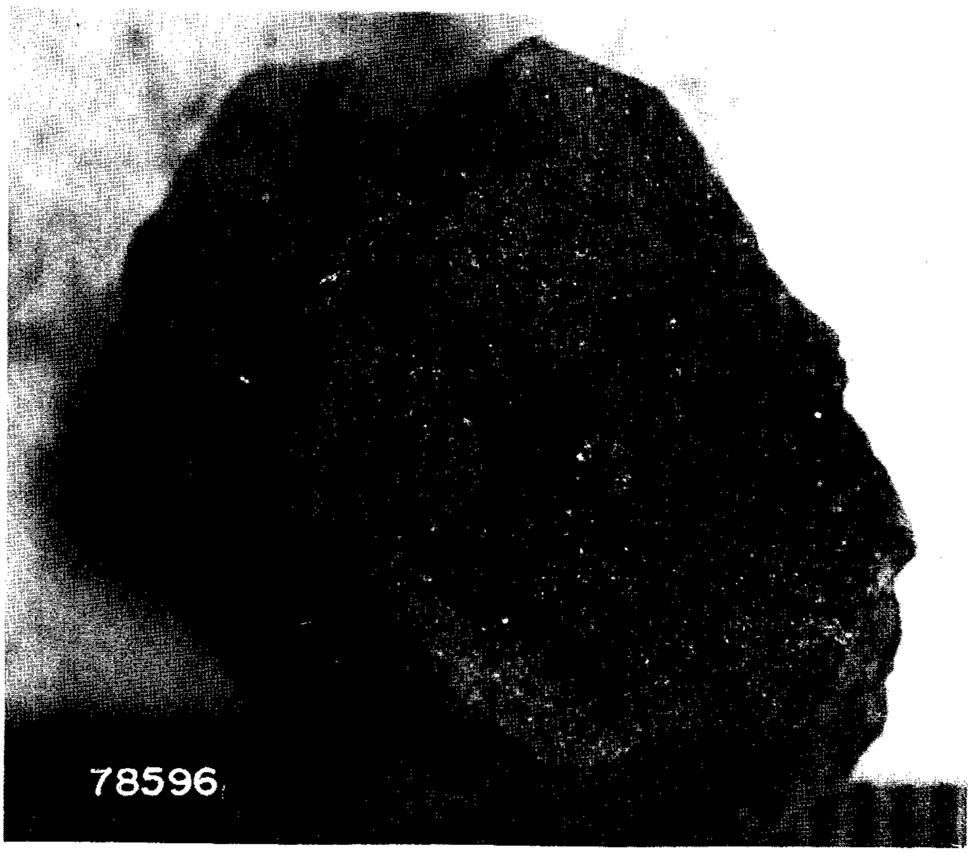


Figure 1: Photograph of 78596. Scale is 1 cm. S73-21037.

Figure 2: Photomicrograph of thin section 78596,6. Field of view is 3 x 4 mm.

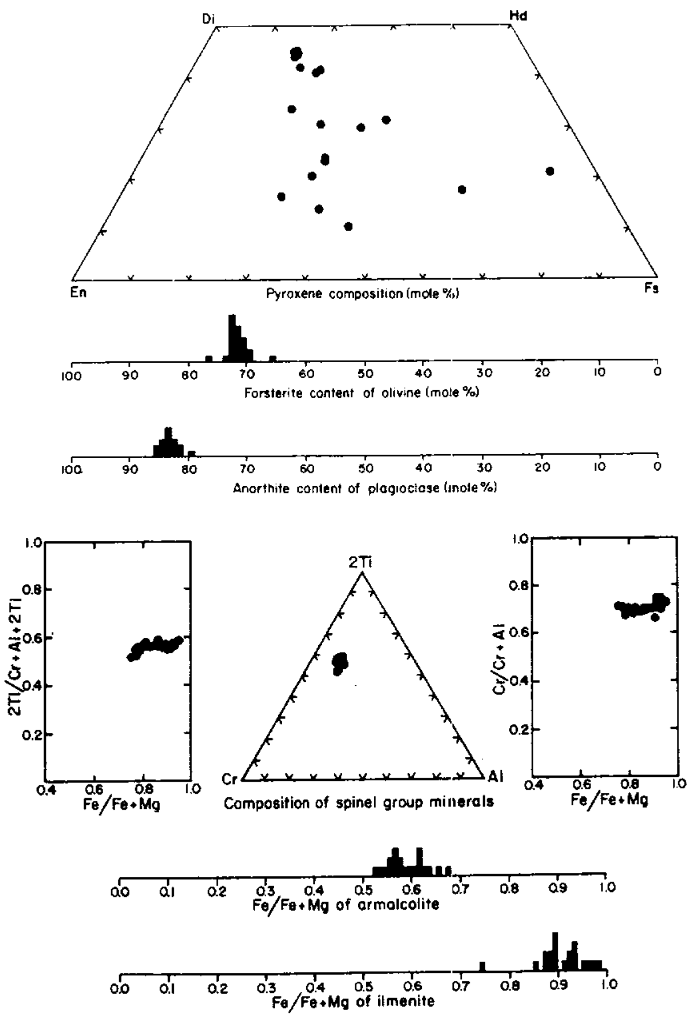


Figure 3: Mineral compositions for 78596. From Warner et al. (1978f).

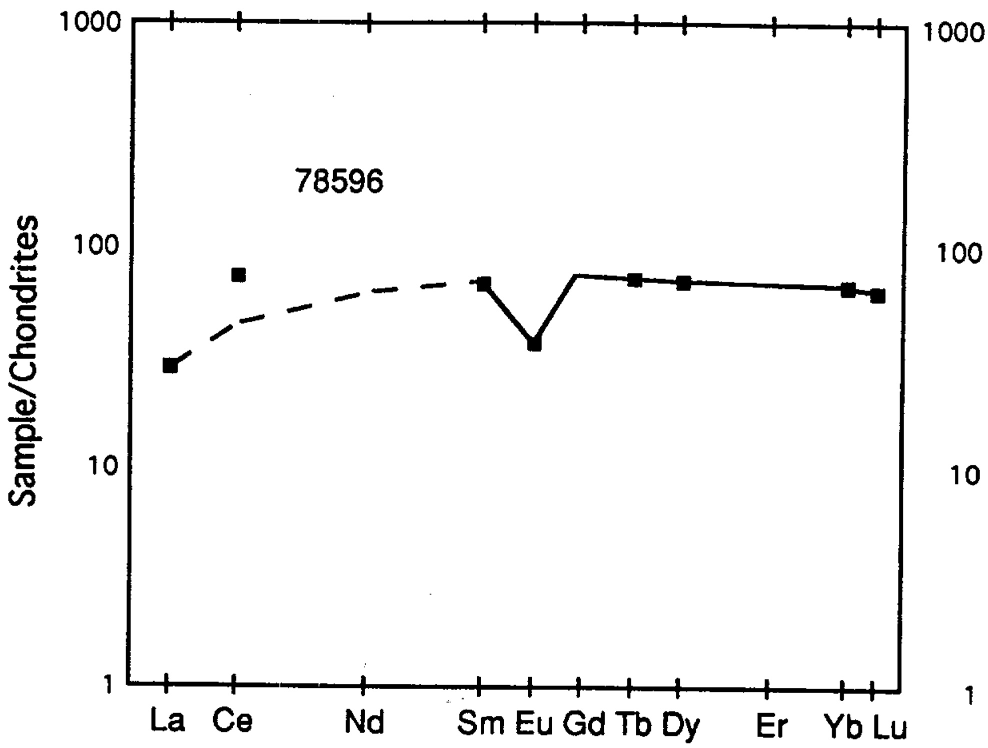


Figure 4: Normalized rare earth element diagram of 78596. Data from Murali et al. (1977b).

Table 1: Whole-rock chemistry of 78596.
From Murali et al. (1977b).

Split Technique	,4 INAA
SiO_2 (wt%)	–
TiO_2	11.5
Al_2O_3	8.4
Cr_2O_3	0.424
FeO	19.5
MnO	0.24
MgO	8.1
CaO	10.4
Na_2O	0.37
K_2O	0.065
Nb (ppm)	
Hf	9.6
Ta	1.8
Co	18.2
Sc	79
La	6.8
Ce	45
Nd	
Sm	10.1
Eu	2.08
Gd	
Tb	2.6
Dy	17
Er	
Yb	10.6
Lu	1.51
Ge (ppb)	
Ir	
Au	

78597
High-Ti Mare Basalt
319.1 g, 6.7 x 5.7 x 5.0 cm

INTRODUCTION

Sample 78597 is a dark grey, medium-grained mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

This basalt has a porphyritic texture with relatively large olivine phenocrysts. The groundmass has a variolitic texture with intergrown pyroxene and plagioclase needles in radial clusters (Fig. 2). The plagioclase laths have a well-developed intrafasiculate texture.

Sample 78597 has a network of interconnecting vugs.

MINERAL CHEMISTRY

Warner et al. (1978f) have determined the chemical compositions of the minerals in 78597 (Fig. 3).

WHOLE-ROCK CHEMISTRY

Laul et al. (1975b) and Warner et al. (1975b) have reported the chemical composition of 78597 (Table 1). Rhodes et al. (1976a) have also reported the chemical composition of 78597 (Fig. 4). Please note that the isotope dilution mass spectroscopy data give a superior view of the true shape of the rare earth element pattern of these Apollo 17 basalts, as compared with the poorly defined instrumental neutron activation analysis data.

Gibson et al. (1976) determined the sulfur content.

RADIOGENIC ISOTOPES

Nyquist et al. (1976) have reported Rb-Sr data for the whole rock (Table 2).

O'Kelley et al. (1974a) used the induced radioactivity of 78597 to study the solar flare of August 1972 (Table 3).

Figure 1: Photograph of 78597. Scale is 1 cm. S73-21424.

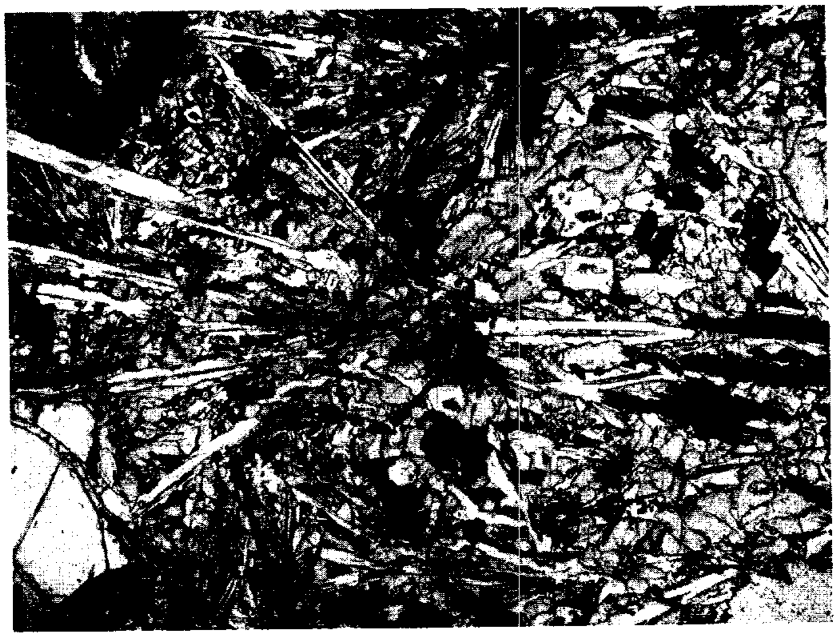


Figure 2: Photomicrograph of thin section 78597,11. Note the hollow plagioclase laths. Field of view is 3 x 4 mm.

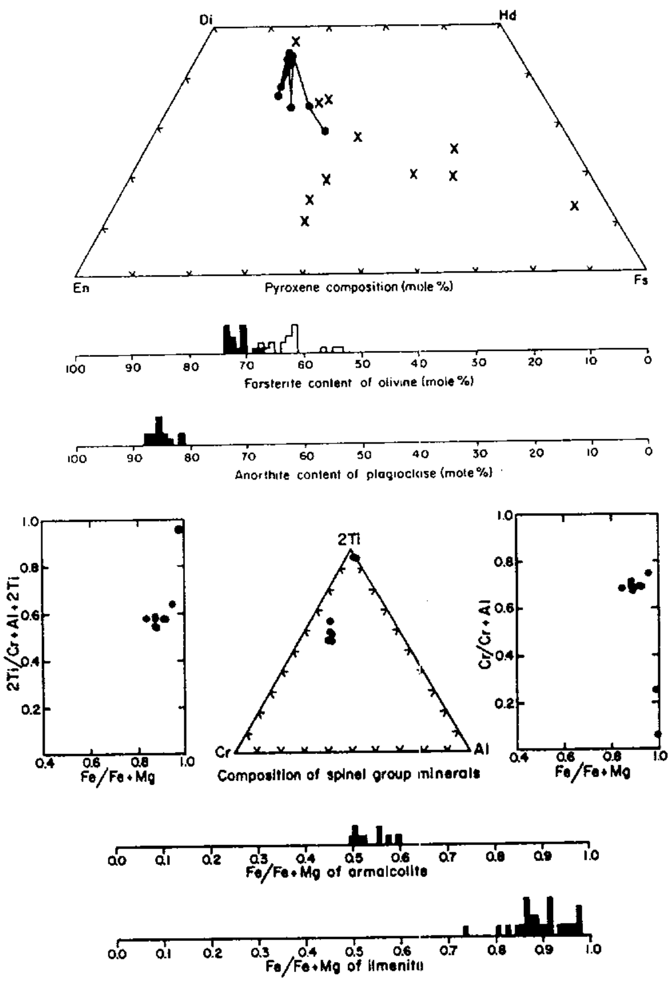


Figure 3: Mineral compositions for 78597. From Warner et al. (1978f).

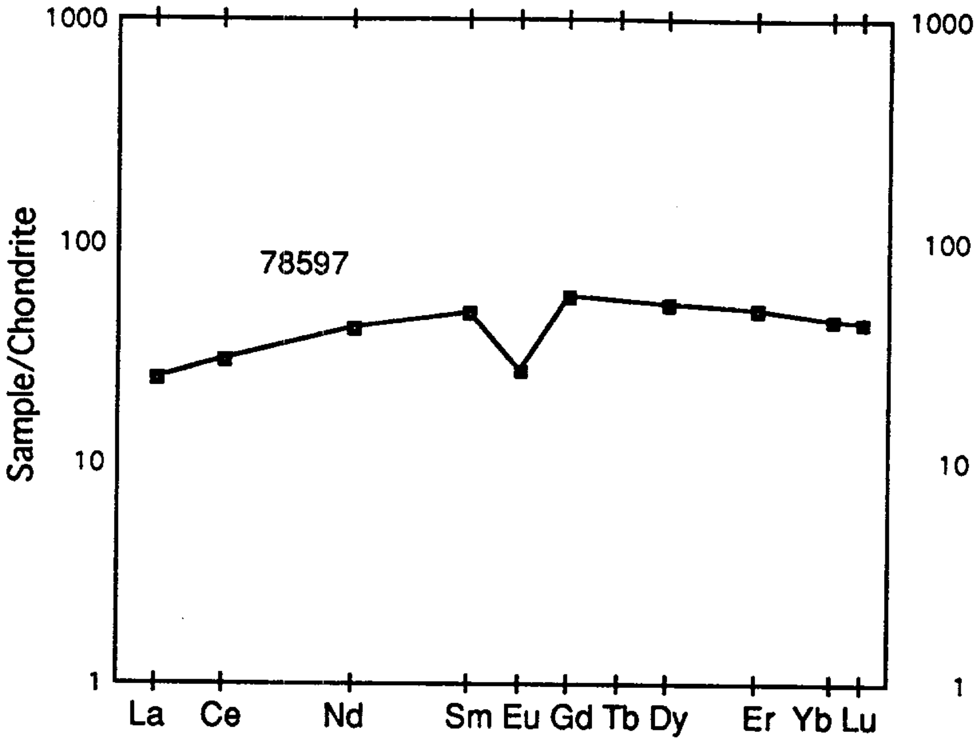


Figure 4: Normalized rare earth element diagram of 78597. Data from Rhodes et al. (1976a).

Table 1: Whole-rock chemistry of 78597.
a) Warner et al. (1975b); b) Rhodes et al. (1976a)

Split Technique	,1 (a) INAA	,4 (b) XRF, IDMS, *INAA*
SiO_2 (wt%)	–	38.54
TiO_2	11.8	12.39
Al_2O_3	9.0	8.85
Cr_2O_3	0.348	0.32
FeO	18.0	19.67
MnO	0.24	0.29
MgO	7.1	7.83
CaO	10.7	10.94
Na_2O	0.42	0.39
K_2O	0.06	0.04
P_2O_5		0.11
S		0.19
Nb (ppm)		
Hf	6.2	*6.8*
Ta	1.5	
Sr		130
Rb		0.37
Li		9.9
Ba		60.6
Co	18.5	*20.7*
Sc	75	*85*
La	5.3	5.67
Ce	18	17.9
Nd		18.8
Sm	7.3	7.17
Eu	1.4	1.48
Gd		11.2
Tb	1.9	
Dy	12	13
Er		7.94
Yb	6.7	7.37

Table 1: (Concluded).

Split Technique	,1 (a) INAA	,4 (b) XRF, IDMS, *INAA*
Lu	1.0	*1.07*
Ge (ppb)		
Ir		
Au		

Table 2: Rb-Sr composition of 78597.
Data from Nyquist et al. (1976).

Sample	78597,4
wt (mg)	61
Rb (ppm)	0.370
Sr (ppm)	130
$^{87}Rb/^{86}Sr$	0.0082 ± 3
$^{87}Sr/^{86}Sr$	0.69954 ± 6
T_B	3.76 ± 0.66
T_L	4.34 ± 0.66

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

Table 3: Solar flare induced activity.
From O'Kelley et al. (1974a).

	78597 (a)
dpm/Kg	
^{26}Al	48 ± 4
^{22}Na	33 ± 4
^{54}Mn	80 ± 10
^{56}Co	80 ± 20
^{46}Sc	25 ± 10
^{48}V	

78598
High-Ti Mare Basalt
224.1 g, 8.6 x 4.5 x 4.5 cm

INTRODUCTION

Sample 78598 is a dark grey, aphanitic mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Thin sections of 78598 reveal a dendritic network of evenly spaced, fine ilmenite crystals separated by feathery pyroxene crystals and glassy mesostasis (Figs. 2 and 3).

MINERAL CHEMISTRY

Warner et al. (1978f) have determined the chemical compositions of the minerals in 78598 (Fig. 4).

WHOLE-ROCK CHEMISTRY

Laul et al. (1975b) and Warner et al. (1975b) have reported the chemical composition of 78598 (Table 1 and Fig. 5).

The high Hf content indicates that 78598 is a Type A Apollo 17 basalt (see appendix).

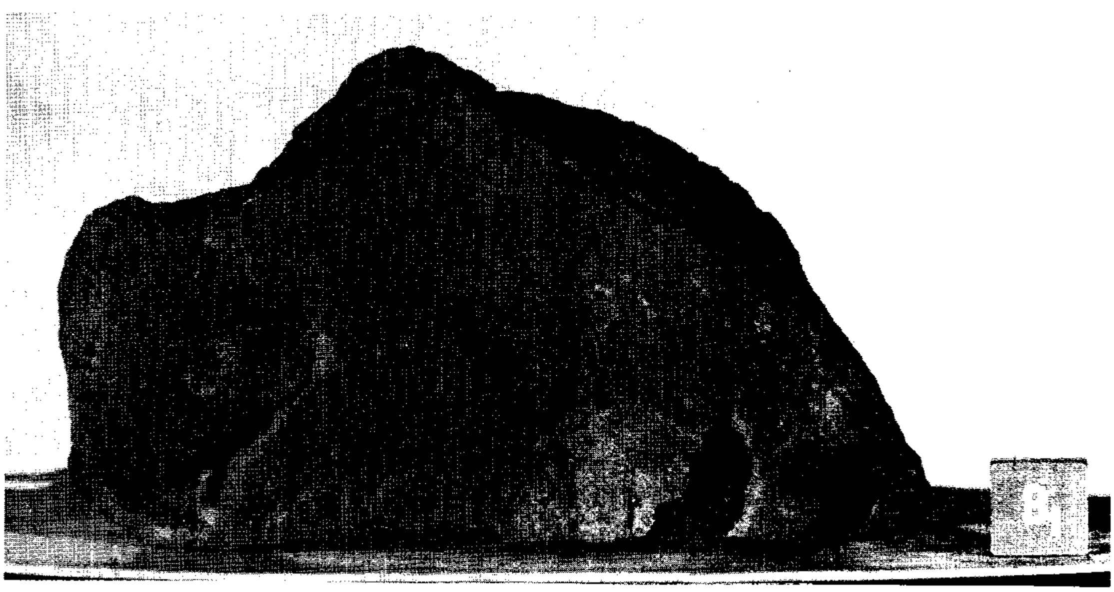


Figure 1: Photograph of 78598. Scale is 1 cm. S73-21770.

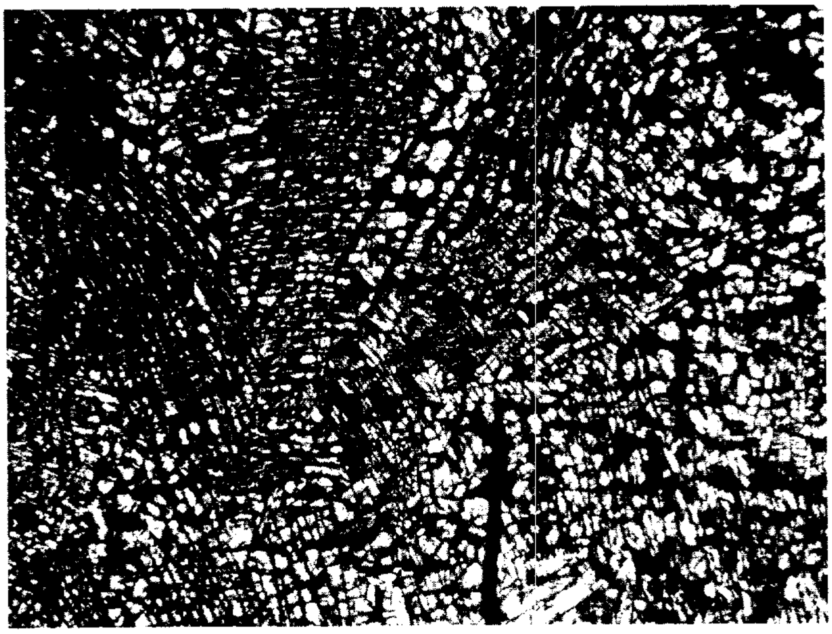


Figure 2: Photomicrograph of thin section 78598,5. Field of view is 3 x 4 mm.

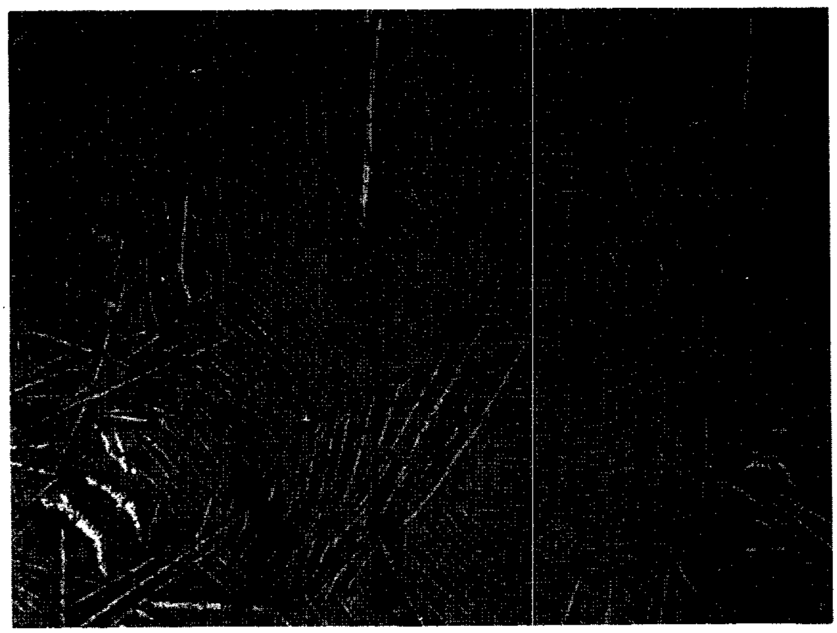


Figure 3: Photomicrograph in reflected light of same area as Fig. 2.

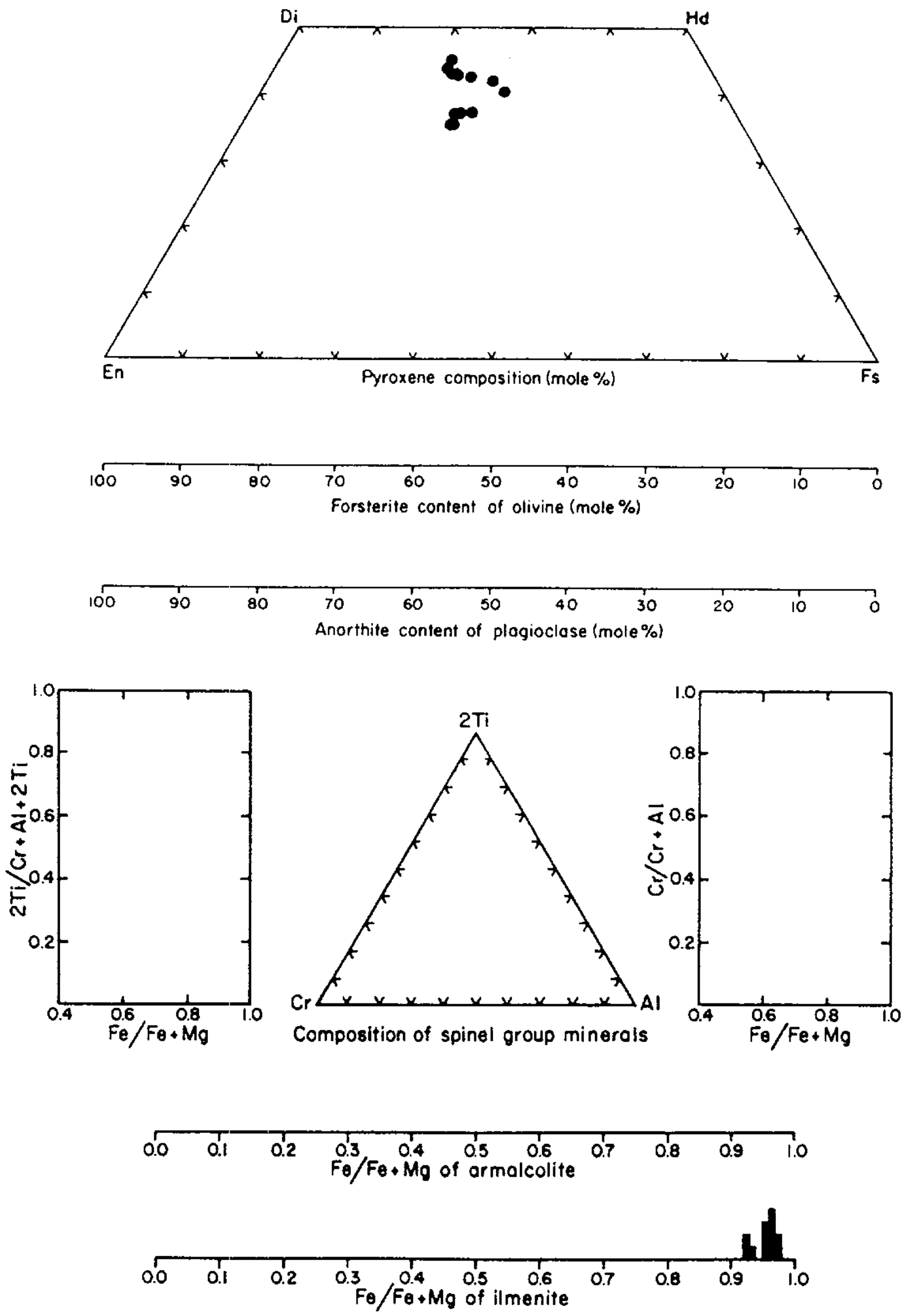


Figure 4: Mineral compositions for 78598. From Warner et al. (1978f).

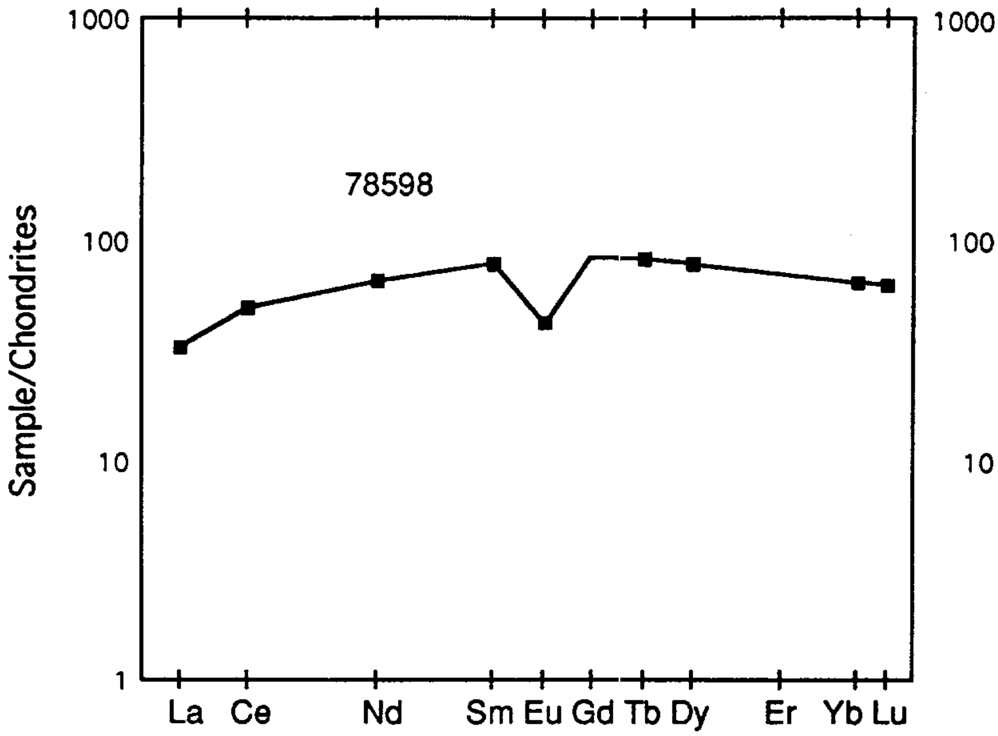


Figure 5: Normalized rare earth element diagram of 78598. Data from Warner et al. (1975b).

Table 1: Whole-rock chemistry of 78598.
From Warner et al. (1975b).

Split **Technique**	**,3** **INAA**
SiO_2 (wt%)	–
TiO_2	8.9
Al_2O_3	10
Cr_2O_3	0.2
FeO	18.5
MnO	0.246
MgO	5.2
CaO	11.5
Na_2O	0.44
K_2O	0.075
Nb (ppm)	
Hf	9.7
Ta	1.8
Co	15
Sc	72
La	7.8
Ce	30
Nd	30
Sm	11.6
Eu	2.4
Gd	
Tb	3
Dy	19
Er	
Yb	10.3
Lu	1.5
Ge (ppb)	
Ir	
Au	

78599
High-Ti Mare Basalt
198.6 g, 7.2 x 4.7 x 3.0 cm

INTRODUCTION

Sample 78599 is a dark black, fine-grained mare basalt from the large rake sample at Station 8 (Fig. 1).

PETROGRAPHY

Sample 78599 is a fine-grained basalt with small phenocrysts of olivine and ilmenite in a fine-grained groundmass with a variolitic texture (Fig. 2).

MINERAL CHEMISTRY

Warner et al. (1978f) have determined the chemical compositions of the minerals in 78599 (Fig. 3).

WHOLE-ROCK CHEMISTRY

Warner et al. (1975b) and Rhodes et al. (1976a) report the chemical composition of 78599 (Table 1 and Fig. 4). Gibson et al. (1976) determined the sulfur content of 78599.

Trace element data indicate that 78599 is a Type A Apollo 17 basalt (see appendix).

RADIOGENIC ISOTOPES

Nyquist et al. (1976) have reported Rb-Sr data for the "whole rock" (Table 2).

SURFACE STUDIES

Micrometeorite craters are abundant on at least one surface.

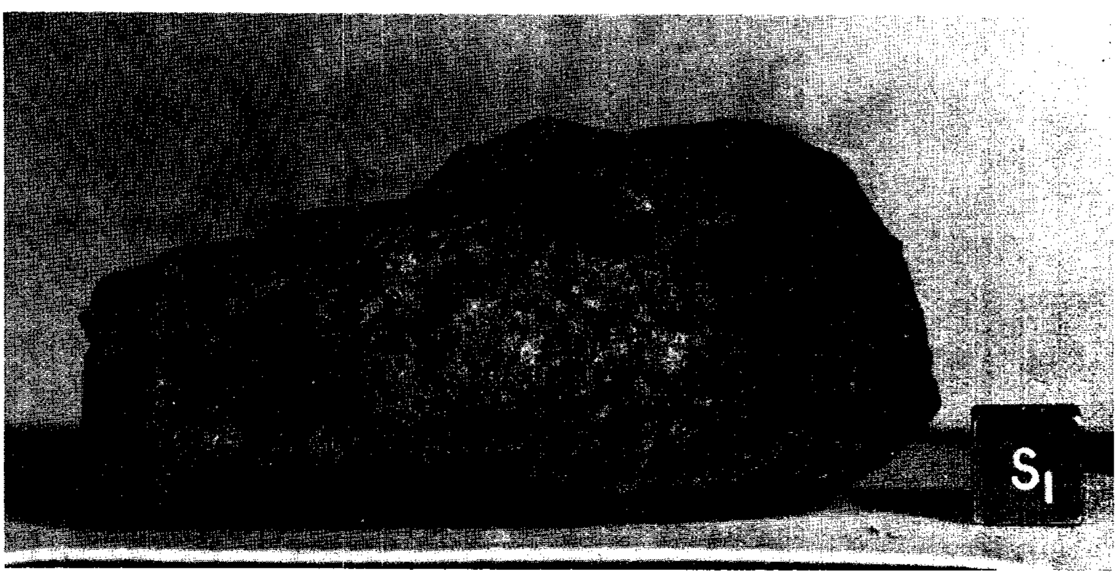


Figure 1: Photograph of 78599. Scale is 1 cm. S73-21392.

Figure 2: Photomicrograph of thin section 78599,6. Field of view is 3 x 4 mm.

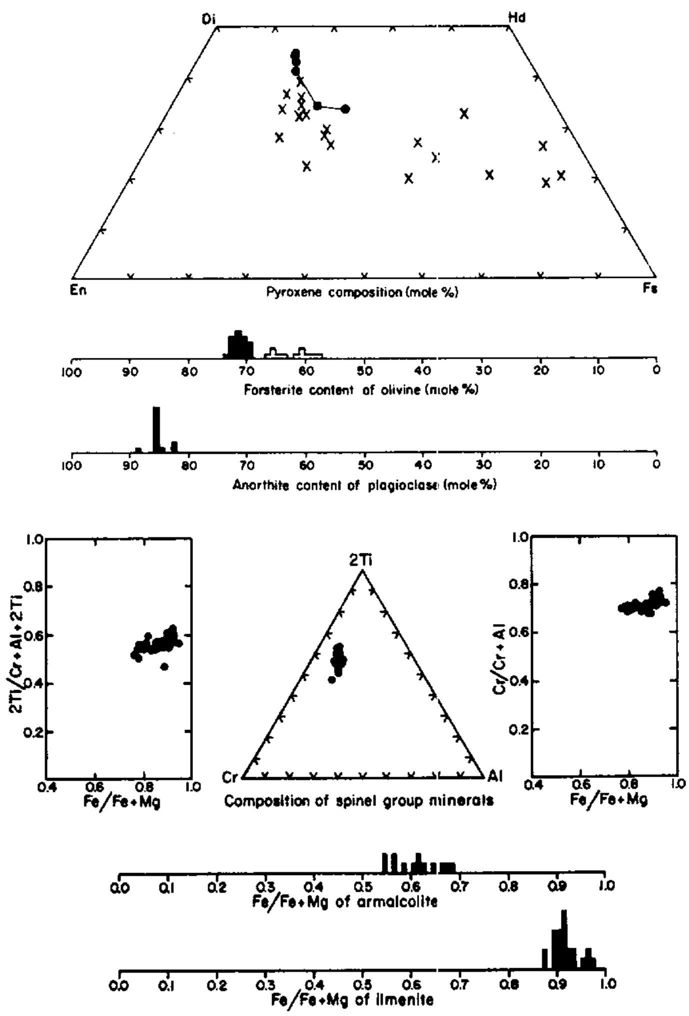


Figure 3: Mineral compositions for 78599. From Warner et al. (1978f).

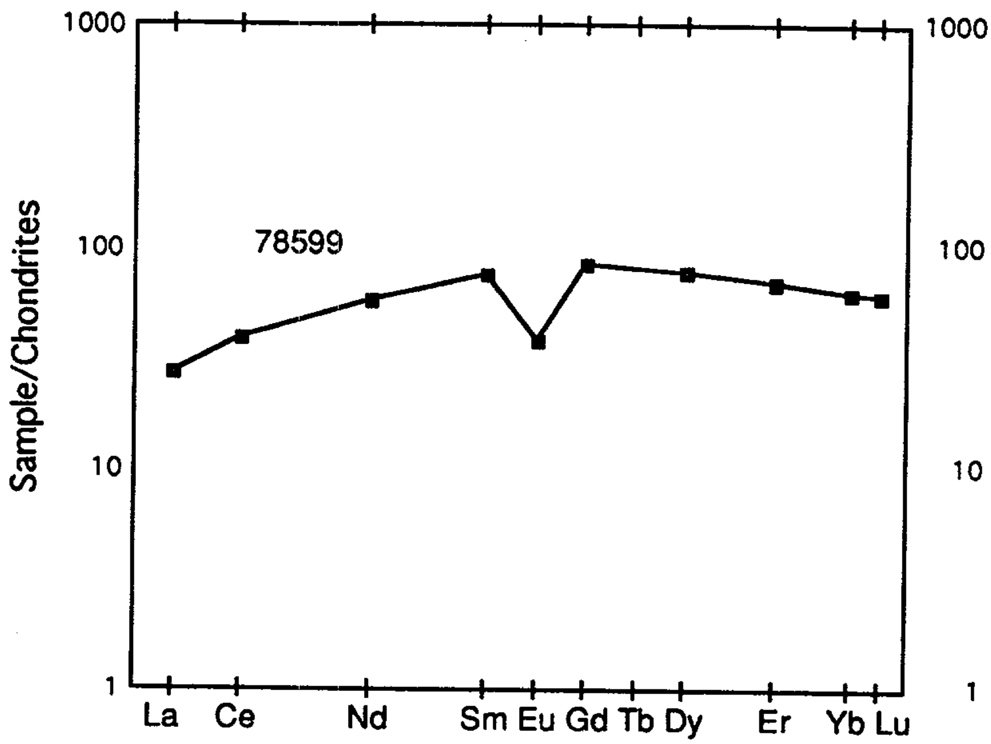


Figure 4: Normalized rare earth element diagram of 78599. Data from Rhodes et al. (1976a).

Table 1: Whole-rock chemistry of 78599.
a) Warner et al. (1975b); b) Rhodes et al. (1976a)

Split **Technique**	**,4 (a)** **INAA**	**,3 (b)** **XRF, IDMS, *INAA***
SiO_2 (wt%)	–	38.44
TiO_2	13.0	12.52
Al_2O_3	9.2	8.67
Cr_2O_3	0.5	0.43
FeO	20.2	19.14
MnO	0.234	0.28
MgO	7.8	8.47
CaO	10.4	10.48
Na_2O	0.41	0.38
K_2O	0.076	0.06
P_2O_5		0.04
S		0.18
Nb (ppm)		
Hf	9.6	*10.1*
Ta	2.1	
Sr		190
Rb		0.71
Li		10.4
Ba		83.2
Co	20.6	*18.4*
Sc	84	*79*
La	7.1	6.45
Ce	27	23.7
Nd		25.8
Sm	10.2	11
Eu	2.2	2.12
Gd		16.6
Tb	2.5	
Dy	16	18.8
Er		11.2
Yb	9.4	10.2
Lu	1.6	*1.46*
Ge (ppb)		
Ir		
Au		

Table 2: Rb-Sr composition of 78599.
Data from Nyquist et al. (1976).

Sample	78599,3-2
wt (mg)	50
Rb (ppm)	0.707
Sr (ppm)	190
$^{87}Rb/^{86}Sr$	0.0108 ± 3
$^{87}Sr/^{86}Sr$	0.69978 ± 5
T_B	4.39 ± 0.45
T_L	4.83 ± 0.45

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)

APPENDIX
On the Classification of High-Ti Mare Basalts from Apollo 17

All the large Apollo 17 basalts have very high TiO_2 contents (8-14%). On the basis of differences in trace element concentrations (quality data from large splits of fine-grain-size samples), Rhodes et al. (1976) recognized three types (A, B and C). They found the Ba/Rb ratio to be especially useful (Fig. 1). Since then, other authors (Lindstrom and Haskin, 1978; Pratt et al., 1978) have proceeded to continue to classify the high-Ti mare basalts (often on the basis of data from sample splits as small as 50 mg). Some authors (Warner et al., 1978) have used petrographic differences to distinguish "olivine porphyritic ilmenite basalt" from "plagioclase-poikilitic ilmenite basalt," but these differences are mostly due to variable cooling rates of the volcanic liquid.

Neal and Taylor (1992) have recently reviewed the petrogenesis of lunar basalts. On the basis of La versus La/Sm and Hf versus Cr/La plots, Neal et al. (1990) have distinguished Types A and B Apollo 17 basalts. Figs. 2 and 3 plot the data for the basalt samples included in this volume.

Isotopic data have also been used to help classify the Apollo 17 basalts (Fig. 4, Paces et al., 1991). However, for those samples whose ages have not been determined by internal isochron technique, classification based on isotopic data is model dependent assuming an age of ~3.7 b.y.!

Very low Ti basalt (VLT), a rare but important rock type at Apollo 17, is found only in the core tubes and as clasts in some of the breccias (Fig. 5, Vaniman and Papike, 1977; Wentworth et al., 1979; Lindstrom et al., 1994). The only large sample of VLT basalt is the glass breccia 78526.

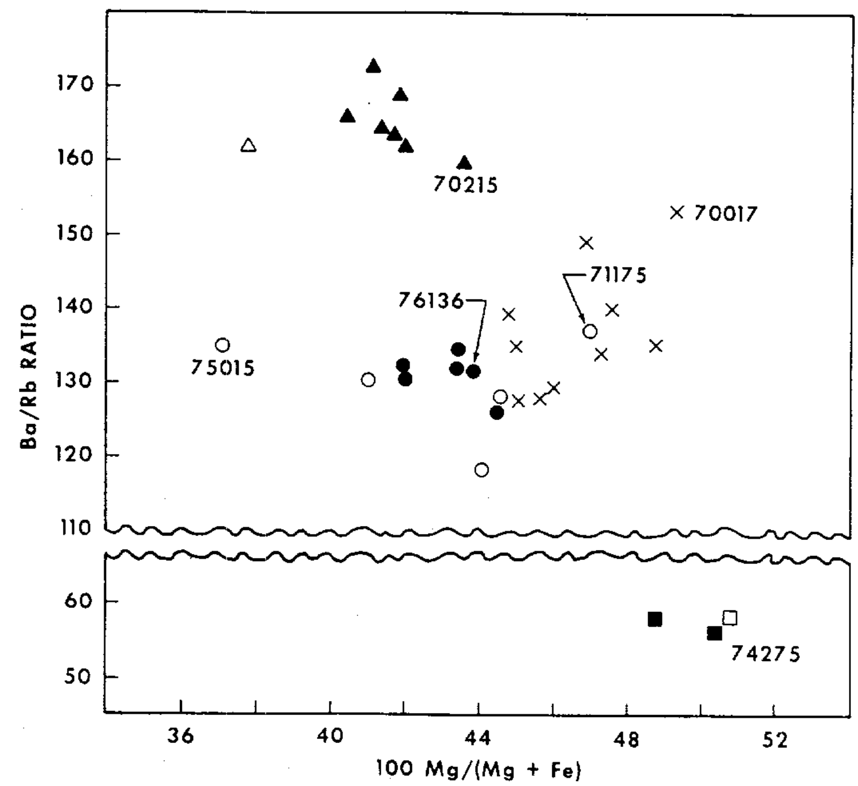


Figure 1: Ba/Rb ratios for some Apollo 17 basalts (from Rhodes et al., 1976). In this diagram the circles are Type A, triangles are Type B, and squares are Type C.

CAUTIONARY NOTE

The quality of analytical data depend critically on sample size versus grain size, analytical technique, and cleanliness of sample. Basalts that were clasts in breccias, or have regolith attached, will not accurately provide the composition of the original basaltic liquid. Sample splits that are too small with respect to their grain size will yield questionable data (Clanton and Fletcher, 1976).

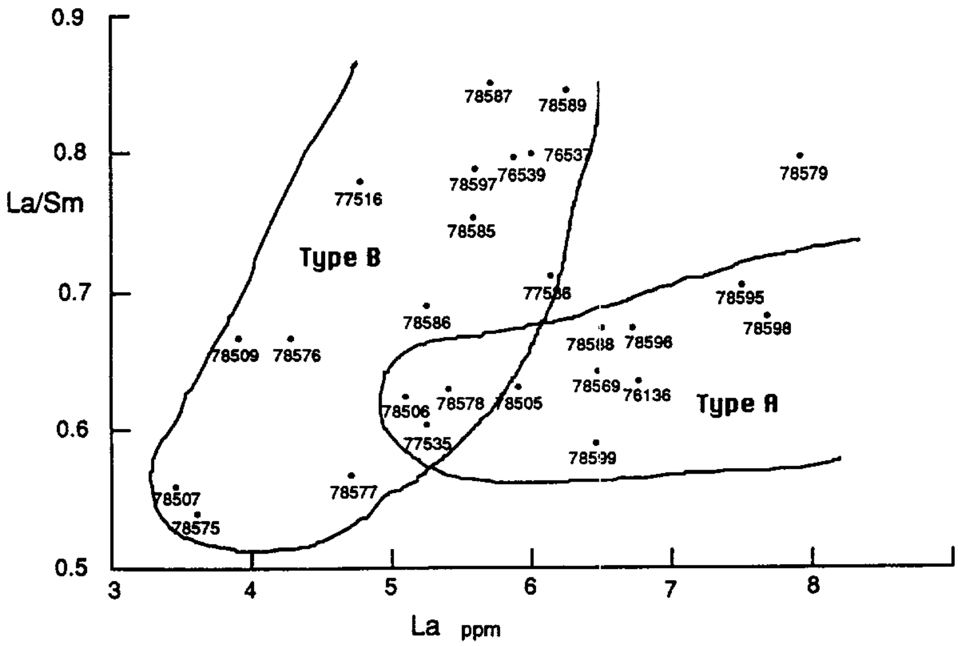


Figure 2: La versus La/Sm for Apollo 17 basalts (this volume only). Fields from Neal et al. (1992).

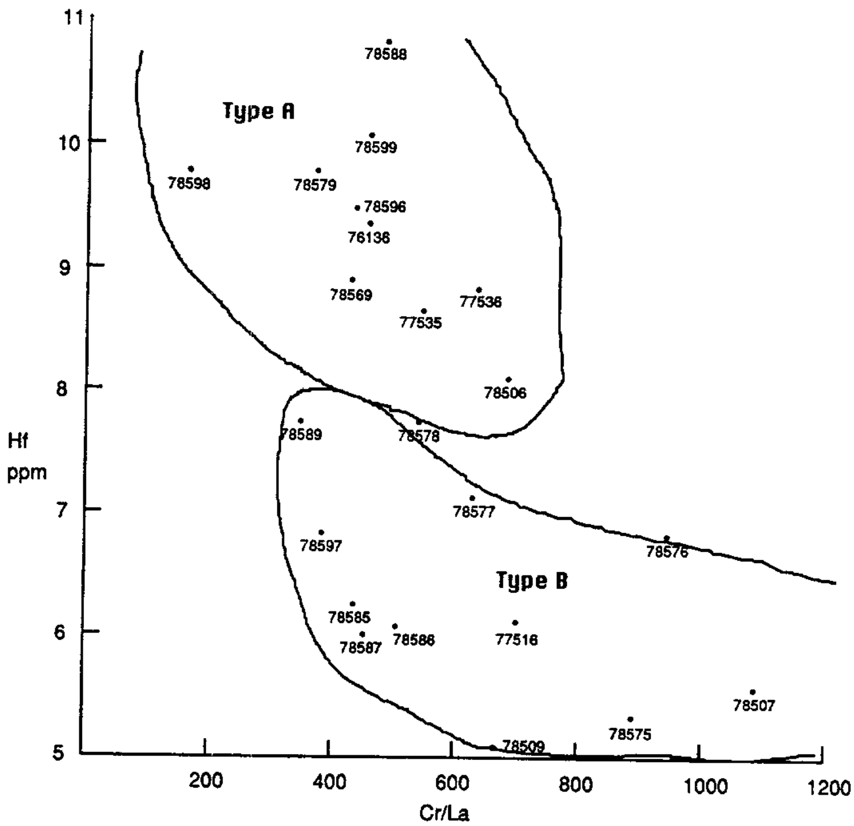


Figure 3: Hf versus Cr/La for Apollo 17 basalts (this volume only). Fields from Neal et al. (1992).

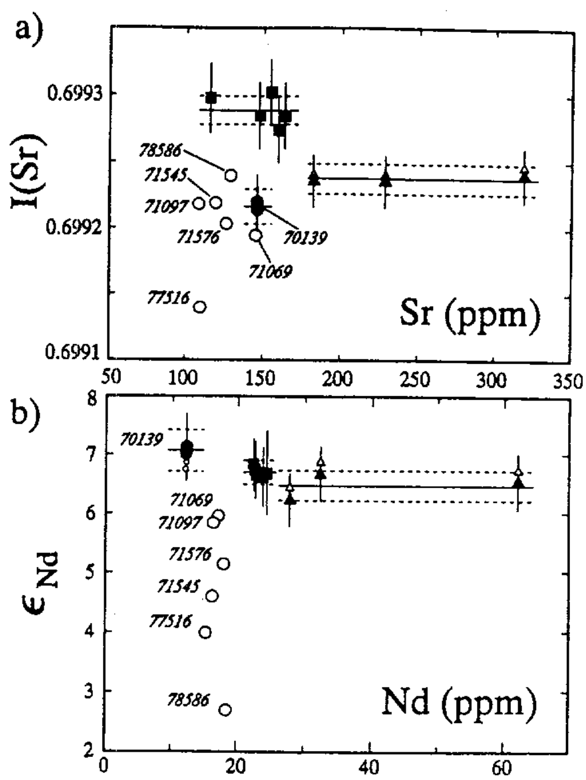


Figure 4: Initial isotopic ratio (calculated at the age of presumed eruption) versus element plots for some Apollo 17 basalts. From Paces et al. (1991).

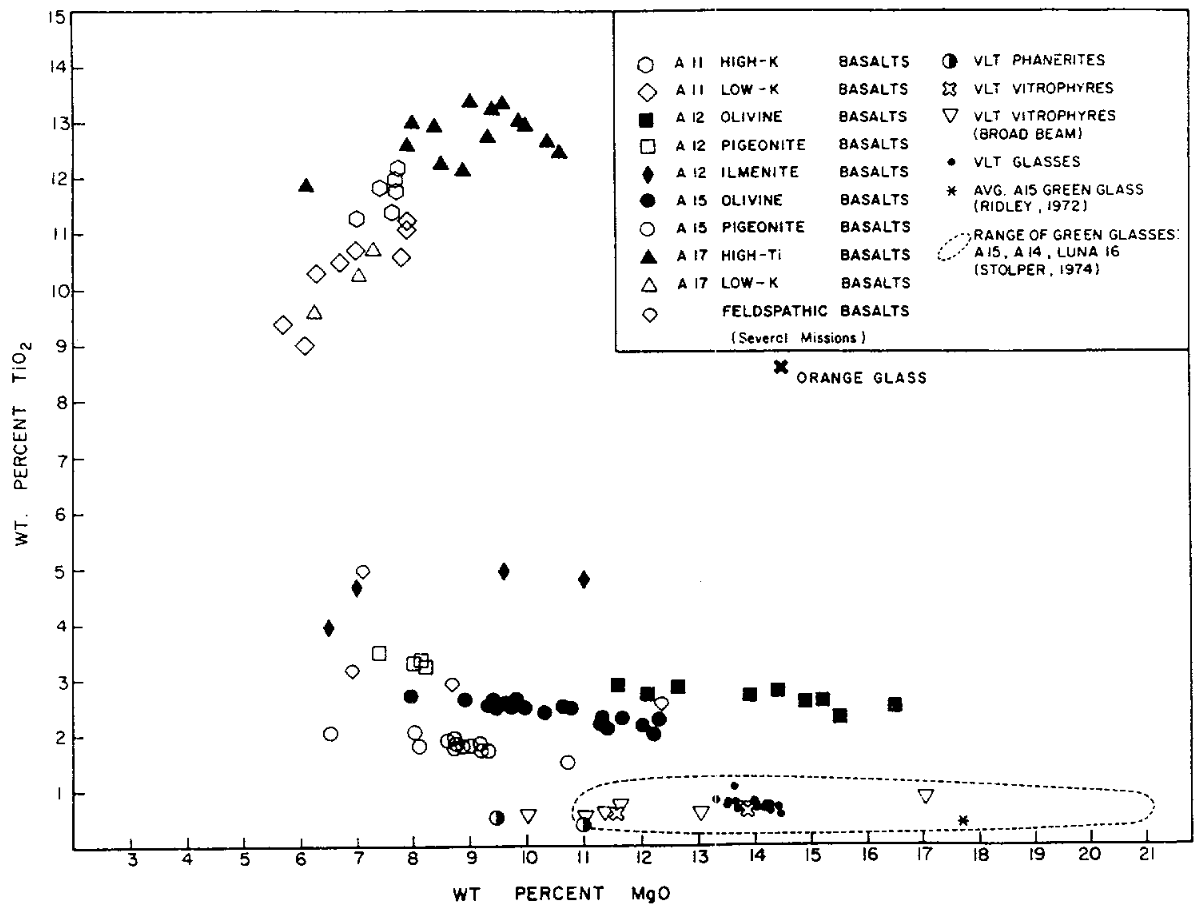


Figure 5: MgO versus TiO_2 for lunar basalts. Field of very low Ti basalt is shown. From Vaniman and Papike (1977).

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Note: LS and LPS refer to the abstract volumes of the annual Lunar Science and Lunar and Planetary Science Conferences. These abstract volumes were issued by the Lunar and Planetary Science Institute, Houston.

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