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INTRODUCTION TO THE APOLLO COLLECTIONS:

PART I

LUNAR IGNEOUS ROCKS

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PATRICIA E. MCGEE — LOCKHEED ELECTRONICS COMPANY

JEFFREY L. WARNER — LUNAR AND PLANETARY SCIENCE DIVISION

CHARLES H. SIMONDS — LUNAR SCIENCE INSTITUTE

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INTRODUCTION TO THE APOLLO COLLECTIONS

PART I

LUNAR IGNEOUS ROCKS

BY

Patricia McGee, Jeffrey L. Warner, and Charles H. Simonds

Lockheed Electronics Co., Inc.
Lunar and Planetary Sciences Division/NASA-Johnson Space Center
Lunar Science Institute

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INTRODUCTION

During the past few years we have had the task of introducing scores of geoscientists to the Apollo lunar rock and regolith collection. These scientists, who represent the range of visitors to both the Planetary Geoscience Laboratories of the Johnson Space Center and the Lunar Science Institute, had petrographic skills ranging from expert to nil. Many times we felt the need for a pamphlet that contains the basic petrographic, chemical, and age data for a representative suite of lunar samples. This pamphlet is our first attempt to partially meet that requirement.

This pamphlet introduces the igneous rocks from the Moon. A second pamphlet, to be published in about a year, will introduce the impactites (breccias -- the rocks formed by meteorite impacts) from the Moon. These publications are intended as educational tools for students interested in lunar rocks and the geology of the Moon. Also, they should serve a useful role in introducing prospective lunar sample investigators to the Apollo collections and lunar science in general.

Our first task was to select a representative suite of rocks. We have chosen 69 samples: 32 igneous rocks and 37 impactites (breccias). The igneous rocks are listed in Table 1 and the impactites in Table 2. We attempted to choose a suite of rocks that covered all recognized petrographic, chemical, and isotopic groupings. We constrained our list to be more-or-less evenly distributed among the six Apollo missions. A final consideration was an attempt to include samples that have been the subject of detailed scientific investigations. We especially attempted to include rocks that have been dated by the Rb-Sr internal isochron method. The list of 69 samples in Tables 1 and 2 is the result of a detailed review of the Apollo collections and the literature that we conducted in the fall of 1974, followed by an annual review to update the list.

The igneous rocks described in this pamphlet include 26 basalts, four plutonic rocks, and two pyroclastic samples. Several workers have published classifications of the lunar basalts. The classification of Papike et al. (1976) that is based on major element chemistry appears to be the most satisfactory. The assignment of each of our 26 basalts in the Papike et al. scheme is noted in Table 1. The textural-mineralogic name that we have assigned each sample is also included in Table 1.

This pamphlet is divided into three segments: descriptions, tables of rock compositions, and a master reference list.

The description for most rocks occupies two pages. The first page contains the rock name, four sections of text, and mineral chemistry diagrams. The second page contains photographs and a table containing the rock's mode. The rock name reflects the texture of the major silicate minerals.

The first section of text gives the basic information concerning how and where the sample was collected. Reference should be made to a map of the nearside of the Moon (Figure 1) that shows the landing sites for Apollo missions and for the missions in the unmanned Ranger, Surveyor, Luna and Lunokhod series. Landing site maps for all Apollo missions except Apollo 11 are shown in Figures 2, 3, 4, 5, and 6.

The second section of text contains new petrographic descriptions that were made especially for this pamphlet. The descriptions are general and form an internally consistent picture of the lunar rocks. We have not written detailed descriptions of any phenomena of especial interest. The descriptions are intended as a guide for anyone who is attempting to learn the basic petrographic relationships in the lunar rocks.

The third section of text contains radiometric age information where such data are available. We have included crystallization ages obtained by the Rb-Sr internal isochron method and the associated initial Sr isotopic ratio. We have also included plateau ages obtained with the ^{39}Ar-^{40}Ar temperature release method. All age data is referenced to the original work.

The last section of text contains some references that we consider of potential interest to a general audience. This list is not intended to be comprehensive.

Mineral chemistry for each sample is illustrated by a series of plots. Data for pyroxenes are presented in a pyroxene quadrilateral, for olivine (when present at the level of 1 percent or more) on a Fo-Fa bar, and for plagioclase on an An-Ab bar. Data for two-thirds of the rocks were available in the literature and those plots are referenced. We collected new electron microprobe data for those rocks without adequate published data.

The second page of each description contains two photographs and a table. One photograph illustrates the nature of the hand sample for each rock. We chose the best available photograph that would show the rock's texture. Some photographs are from the Lunar Receiving Laboratory's "Mug Shot" set. Other photographs are from the set made by the Curator during the cutting and allocation of the rock.

The second photograph is a general view of a thin section. For several rocks additional photomicrographs were required to illustrate the petrographic description. These photographs are specifically mentioned in the description.

The table contains the mode of the sample. Modes are based on published values supplemented by our observations. The modes generally include a range of values to illustrate the diversity of each rock. References used to compile the ranges of values are included in the fourth section of text.

A three-part table of chemical compositions for all samples is presented after the descriptions and before the master reference list. The first part of this table contains major element analyses that are based on averages calculated from published X-ray fluorescence and gravimetric analyses. The second part of the table contains a suite of minor and trace lithophile elements. These analyses were chosen from the work of a limited set of laboratories in order to achieve internal consistency. The laboratories chosen were the neutron activation laboratory at the Johnson Space Center (L. A. Haskin and D. P. Blanchard), the mass spectrometric isotopic dilution laboratories at the Johnson Space Center (P. W. Gast and N. J. Hubbard) and at the Goddard Space Flight Center (J. A. Philpotts and C. C. Schnetzler). The data from these laboratories were supplemented with data from other laboratories only where omissions were embarrassingly large. The third part of the table contains a suite of minor and trace siderophile and chalcophile elements. Here also we limited the data to a few laboratories in order to achieve internal consistency. The laboratories we chose are the neutron activation laboratories at the University of Chicago (E. Anders) and at the University of California at Los Angeles (J. T. Wasson). All data in these tables are referenced by numbers that refer to the master reference list.

The master reference list contains the complete citation for all studies cited in the descriptions and in the chemical table.

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Table I: IGNEOUS ROCKS

Basalts

Sample Number	Rock Name	Classification after Papike
10003	porphyritic pyroxene basalt	A11 Low K
10017	intersertal basalt	A11 High K
10044	porphyritic pyroxene basalt	A11 Low K
10045	porphyritic pyroxene-olivine basalt	A11 Low K
10049	intersertal basalt	A11 High K
10072	intersertal basalt	A11 High K
12002	porphyritic olivine-pyroxene basalt	A12 olivine
12009	porphyritic olivine-pyroxene basalt	A12 olivine
12021	porphyritic pyroxene basalt	A12 pigeonite
12022	porphyritic olivine-pyroxene basalt	A12 ilmenite
12039	porphyritic pyroxene basalt	
12051	porphyritic pyroxene basalt	A12 ilmenite
12063	porphyritic olivine-pyroxene basalt	A12 ilmenite
12064	sub-ophitic basalt	A12 ilmenite
14053	porphyritic pyroxene basalt	Feldspathic basalt
14072	porphyritic pyroxene basalt	Feldspathic basalt
15016	porphyritic pyroxene-olivine basalt	A15 olivine
15076	porphyritic pyroxene basalt	A15 pigeonite
15475	porphyritic pyroxene basalt	A15 pigeonite
15499	porphyritic pyroxene vitrophyre	A15 pigeonite
15555	porphyritic olivine-pyroxene basalt	A15 olivine
15556	porphyritic pyroxene basalt	A15 olivine
70017	poikilitic plagioclase basalt	A17 Very High Ti
70035	poikilitic plagioclase basalt	A17 Very High Ti
70215	porphyritic olivine-pyroxene basalt	A17 Very High Ti
75055	sub-ophitic basalt	A17 Low K

Plutonic Rocks

Sample Number	Rock Name
15415	Anorthosite
60025	Cataclastic Anorthosite
76535	Troctolite
72415	Cataclastic Dunite

Pyroclastics

Sample Number	
15426	Green glass
74220	Orange glass

Table II: IMPACTITES (BRECCIAS)

10023	12013	14063	15086	60255	72315
10060	12034	14082	15299	61015	72275
10065	12073	14301	15386	61016	76015
		14304	15405	62235	76215
		14310	15418	62295	76295
		14311	15445	65015	76315
		14312		67015	77017
		14321		68415/416	79135
					79215

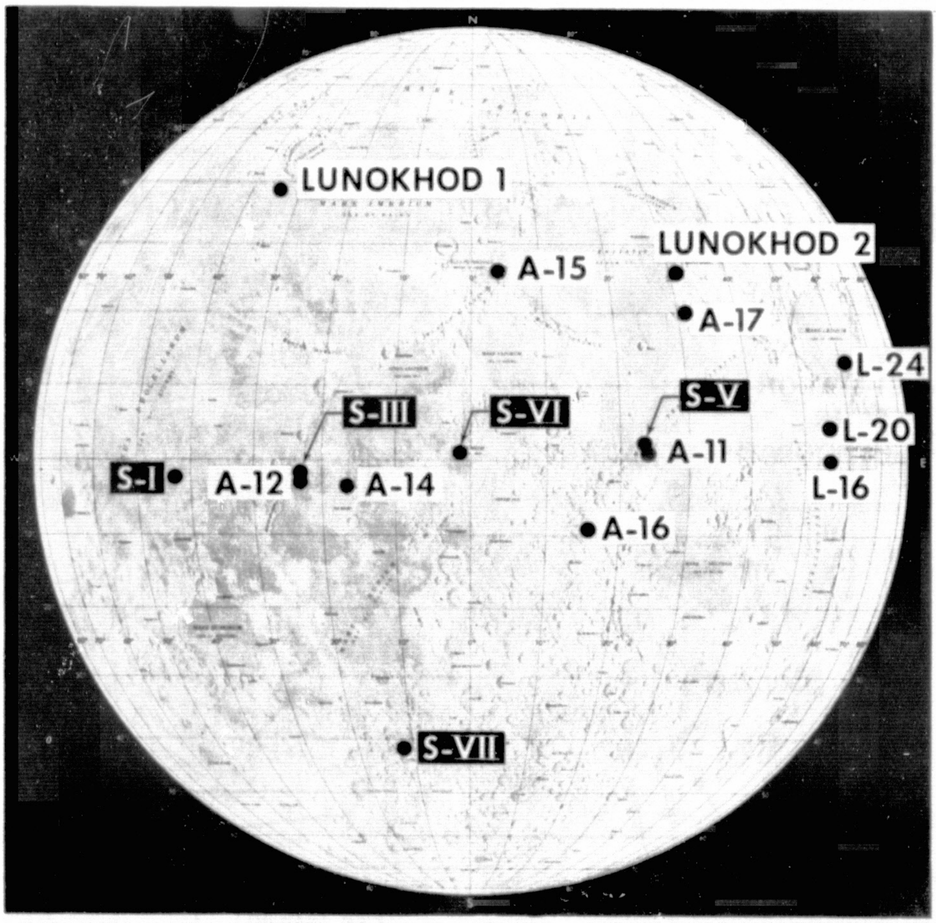


FIGURE 1 LUNAR LANDING SITES

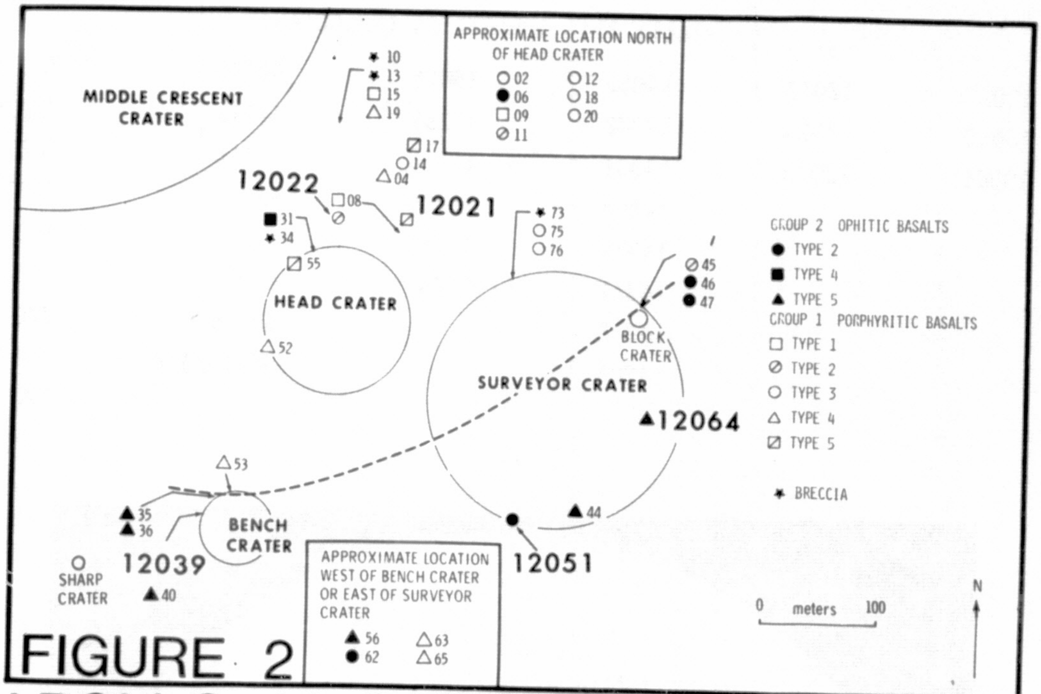


FIGURE 2
APOLLO 12 SAMPLE LOCATION MAP

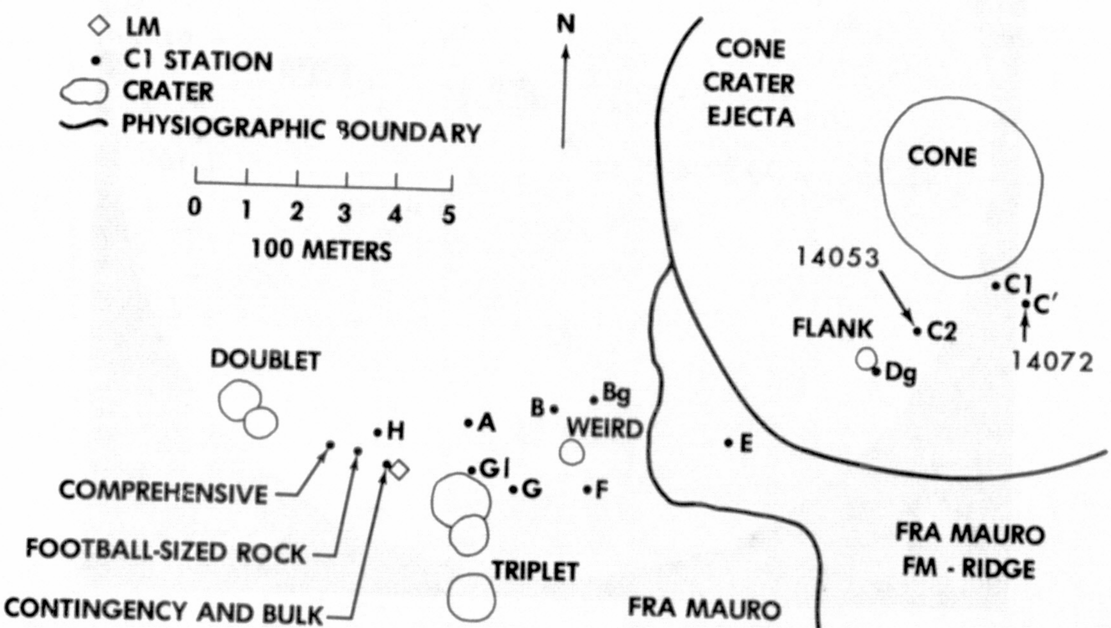


FIGURE 3
APOLLO 14 SAMPLE LOCATION MAP

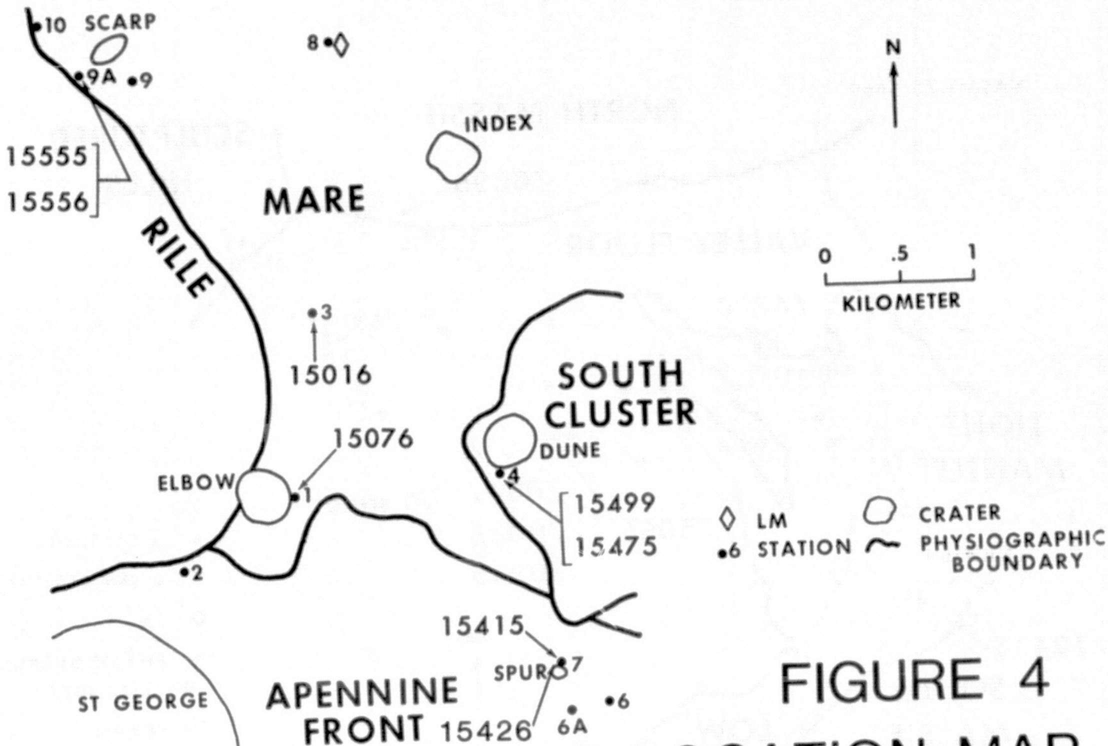


FIGURE 4

APOLLO 15 SAMPLE LOCATION MAP

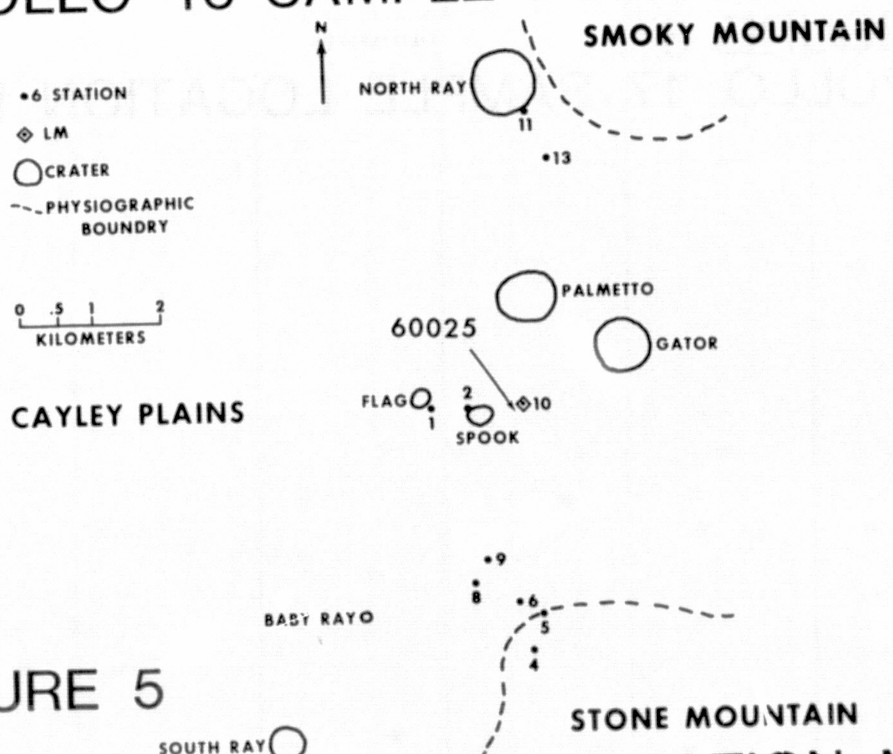


FIGURE 5

APOLLO 16 SAMPLE LOCATION MAP

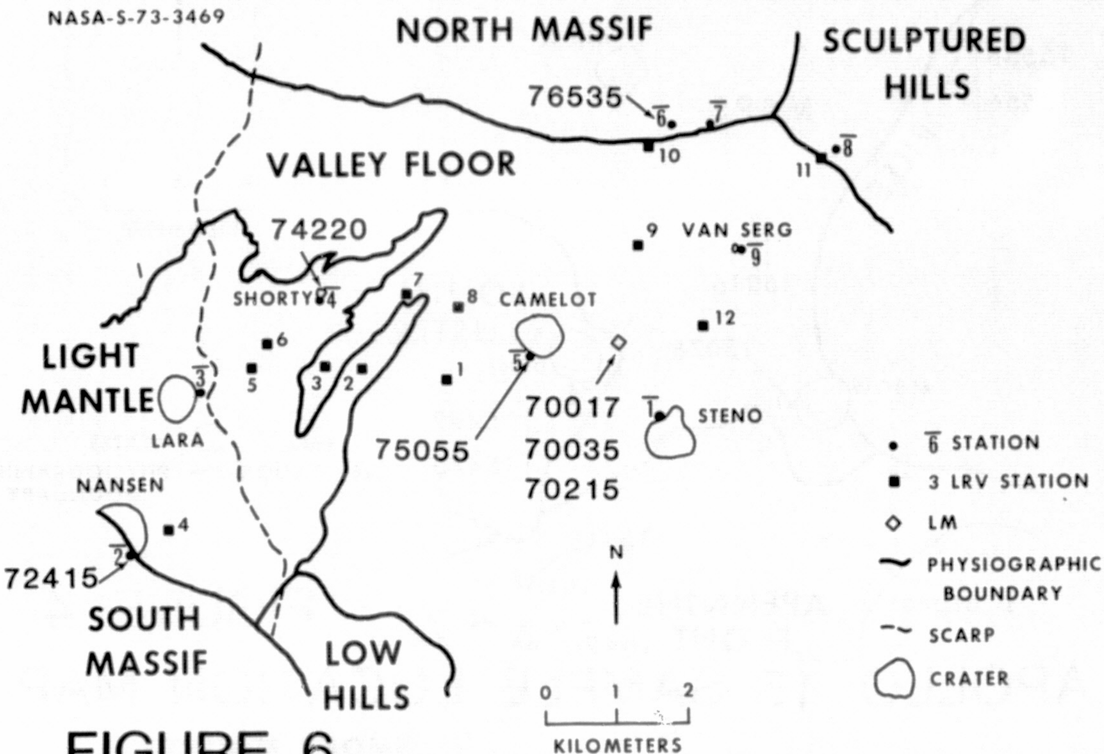


FIGURE 6
APOLLO 17 SAMPLE LOCATION MAP

ROCK DESCRIPTIONS

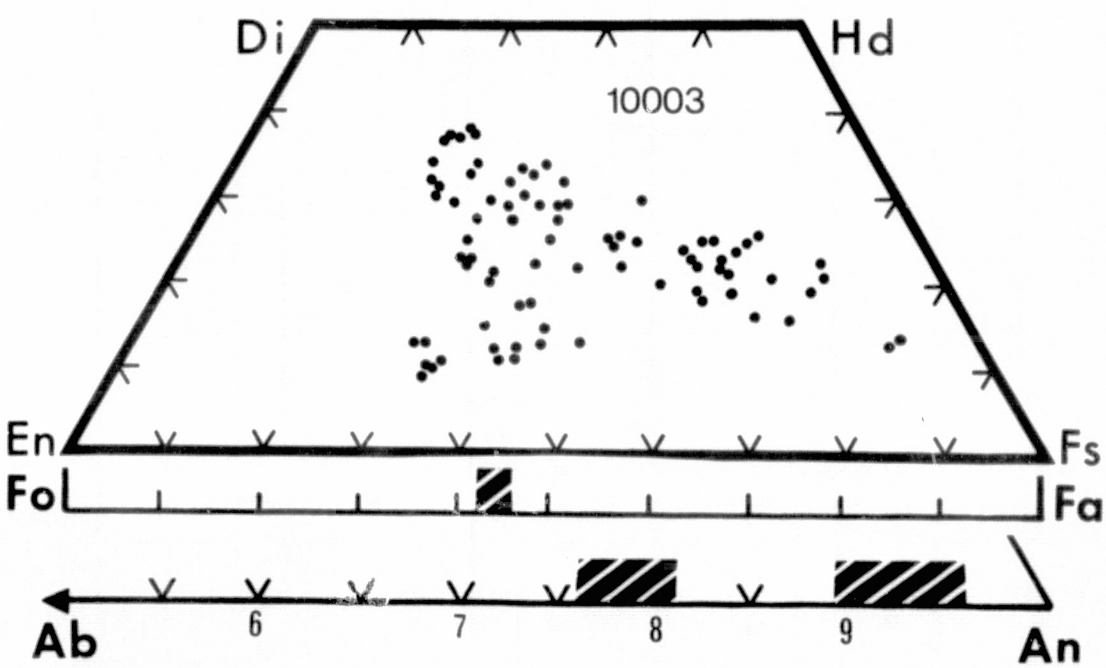
10003 Porphyritic Pyroxene Basalt

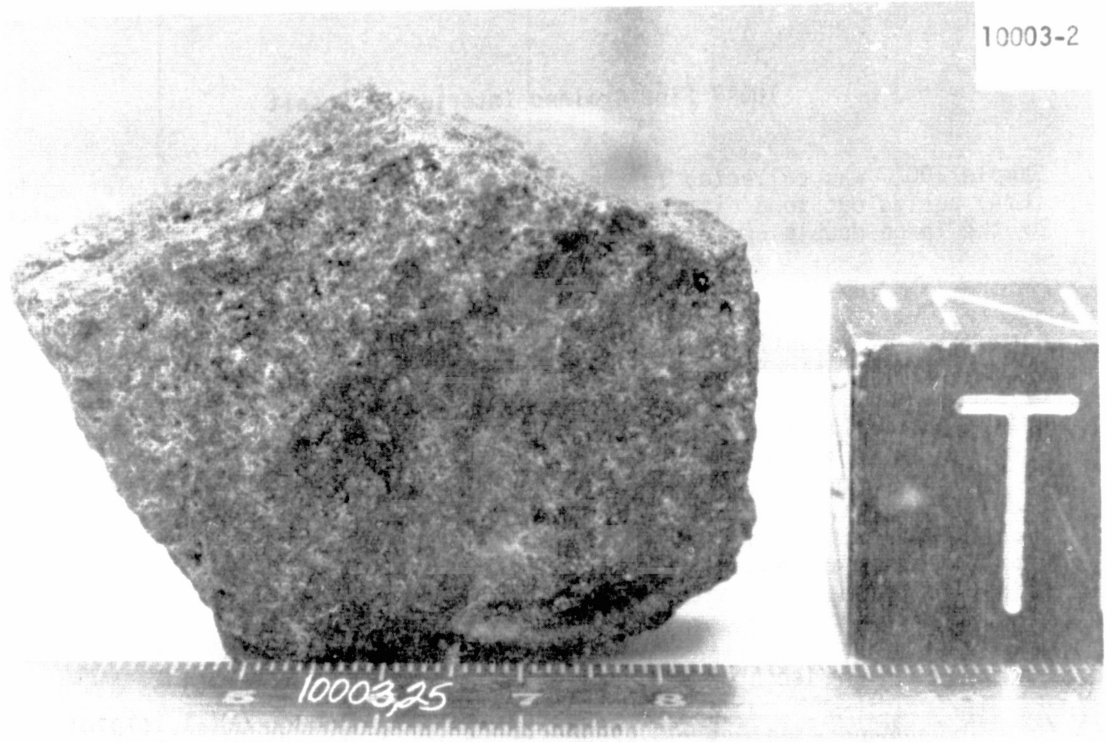
The exact collection site for sample 10003 is not documented; it is believed to have been collected in an area between the Lunar Module (LM) and the double elongate crater to the southwest of the LM.

Sample 10003 is a medium grained porphyritic pyroxene basalt characterized by anhedral phenocrysts of pyroxene (1.0-2.7mm) set in a subophitic matrix of plagioclase, pyroxene, and ilmenite. Interstitial areas are filled with cristobalite, glassy mesostasis, and a small amount of irregularly shaped pore space. Plagioclase is typically tablet shaped (0.1-0.6mm), euhedral to subhedral, and occurs both subophitically intergrown with pyroxene phenocrysts and as an interstitial phase between the phenocrysts. Ilmenite is the major opaque phase, typically occurring as blocky, irregularly shaped bodies (0.5-1.0mm) intergrown with pyroxene and plagioclase, and less commonly as rounded laths (0.1-0.3mm) which are present as inclusions in pyroxene phenocrysts. Troilite, with Fe-Ni metal inclusions, is present as blebs intergrown with ilmenite or associated with the mesostasis.

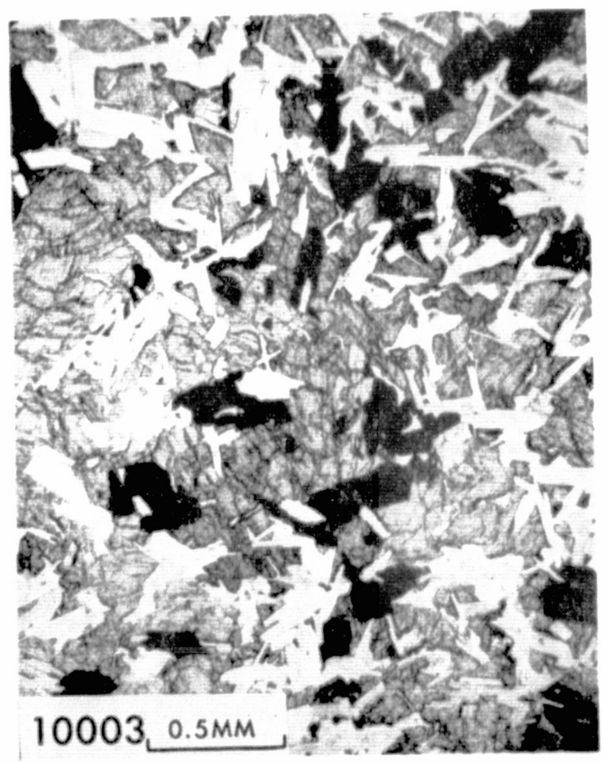
AGE DATA: $^{40}Ar-^{39}Ar$ plateau - 3.92 ± .07 AE Turner (1970)
3.91 ± .03 AE Stettler et al. (1974)
3.84 ± .08 AE Papanastassiou and Wasserburg (1975)
Rb-Sr isochron - 3.84 ± .08 AE } Papanastassiou et al. (1970)
I_{Sr} - 0.69909 ± 4 }

ADDITIONAL REFERENCES: Bailey et al.,(1970); Haggerty et al. (1970); James and Jackson (1970).





10003 MODAL ANALYSIS (%)	
PYROXENE	49-52
OLIVINE	0.5
PLAGIOCLASE	29-35
ILMENITE	14-18
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	—
METAL	—
TROILITE	0.5
CRISTOBALITE	0.3-1.0
TRIDYMITE	—
MESOSTASIS	—
PORE SPACE	0.5
PHOSPHATE	0.2
OTHERS	—



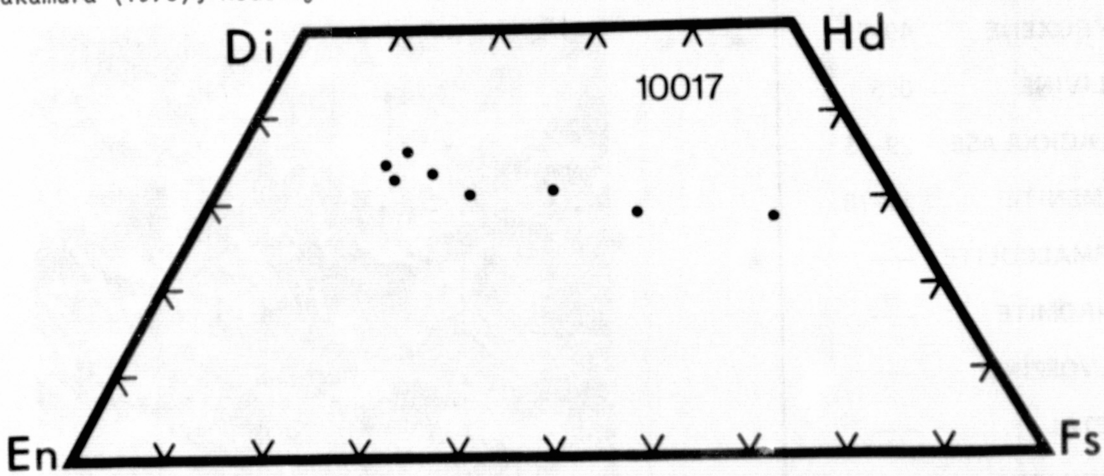
10017 Fine Grained Intersertal Basalt

Sample 10017 was collected in the final minutes of the extravehicular activity (EVA) period out to a distance of 10 to 15 meters in the area near the east rim of the large double crater.

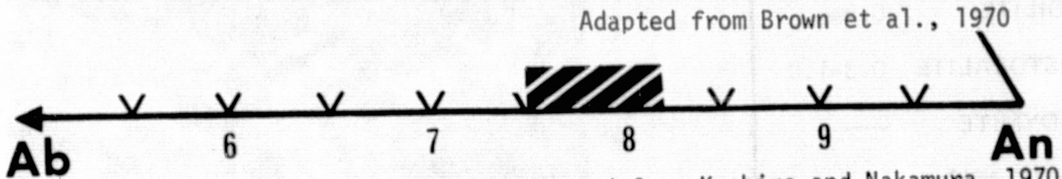
Sample 10017 is a fine grained intersertal basalt characterized by a mesh-like assemblage of essentially equal size (0.05-0.30mm) anhedral pyroxene and ilmenite crystals with interstitial plagioclase megacrysts (0.3x1.5mm), anhedral cristobalite, and glassy mesostasis. Several small vesicles (0.2-0.5mm) are present. Plagioclase megacrysts are typically poikilitic and enclose anhedral pyroxene and ilmenite crystals. Some ilmenite is present as rounded laths (0.2mm) but anhedral shapes are the typical form. Rare crystals of anhedral tranquillityite, 10μ and less, are present in the mesostasis and several plagioclase megacrysts contain rod-shaped inclusions of tranquillityite. Troilite blebs are abundant in the mesostasis and commonly contain inclusions of native iron. Fe-Ni metal also occurs in association with ilmenite.

AGE DATA: Rb-Sr isochron - 3.80 ± .11 AE Compston et al. (1970)
3.59 ± .05 AE } Papanastassiou et al. (1970)
I_{Sr} - 0.69932 ± 5 }

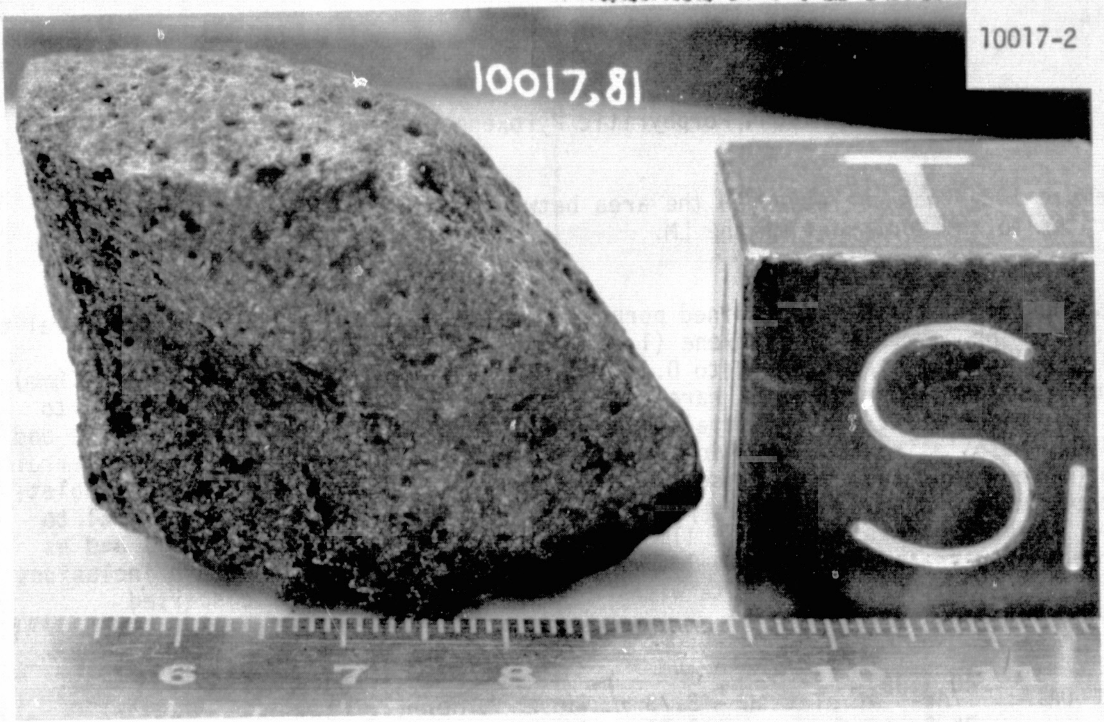
ADDITIONAL REFERENCES: O'Hara et al. (1970); Brown et al. (1970); Kushiro and Nakamura (1970); Housley et al. (1970); James and Jackson (1970).



Adapted from Brown et al., 1970

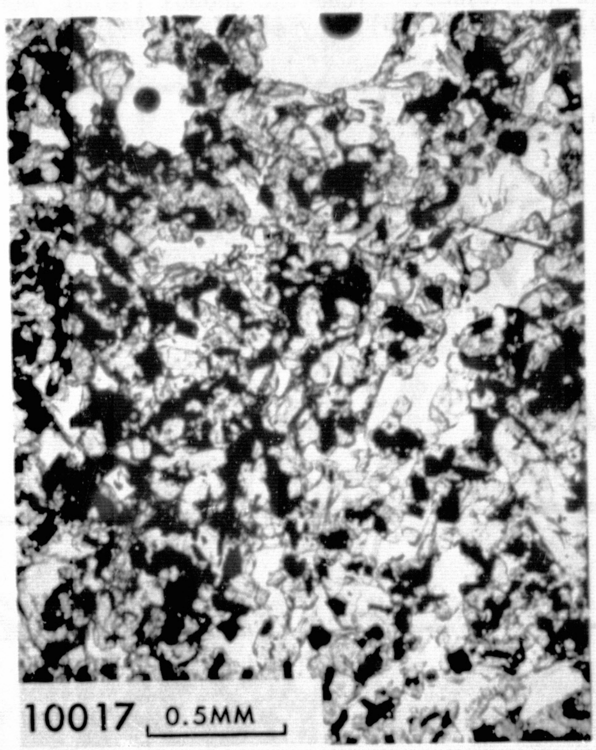


Adapted from Kushiro and Nakamura, 1970



10017
MODAL ANALYSIS (%)

PYROXENE	48-59
OLIVINE	—
PLAGIOCLASE	18-27
ILMENITE, ARMALCOLITE, CHROMITE, ULVOSPINEL	14-24
METAL	tr-0.2
TROILITE	0.3-1.0
CRISTOBALITE	1-2
TRIDYMITE	—
MESOSTASIS	6-8
PORE SPACE	—
PHOSPHATE	tr
OTHERS	—



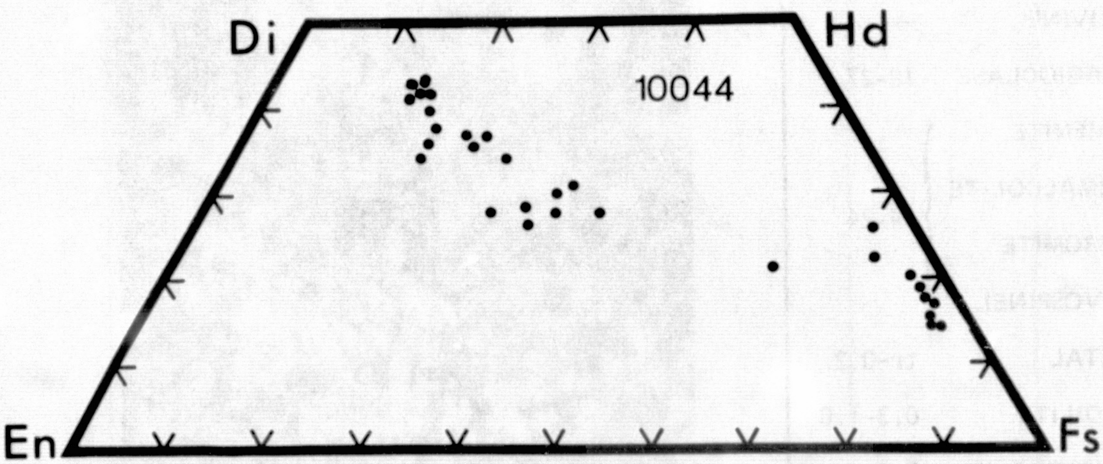
10044 Porphyritic Pyroxene Basalt

Sample 10044 was collected in the area between the LM and the double elongate crater to the southwest of the LM.

Sample 10044 is a coarse grained porphyritic basalt which consists of subhedral to anhedral phenocrysts of pyroxene (1.0-2.0mm) set in a subophitic matrix of plagioclase tablets (0.2x1.0 to 0.4x2.0mm), anhedral pyroxene grains (0.6-0.8mm), and ilmenite. Pore space is rare and occurs as irregularly shaped vugs 0.2 to 0.3mm in diameter. Interstitial areas are filled with anhedral cristobalite and glassy mesostasis, some of which is present as a clear green glass. Pyroxferroite was observed on the edges of several pyroxene grains. Several deep red, tablet-shaped minerals (0.01-0.02mm), possibly tranquillityite, occur interstitial to the larger silicate minerals. Ilmenite is present as laths (0.3-0.8mm) and as irregularly shaped bodies (0.4-1.6mm), both of which commonly contain inclusions of silicate minerals. Troilite with Fe-Ni metal inclusions is dispersed throughout the matrix.

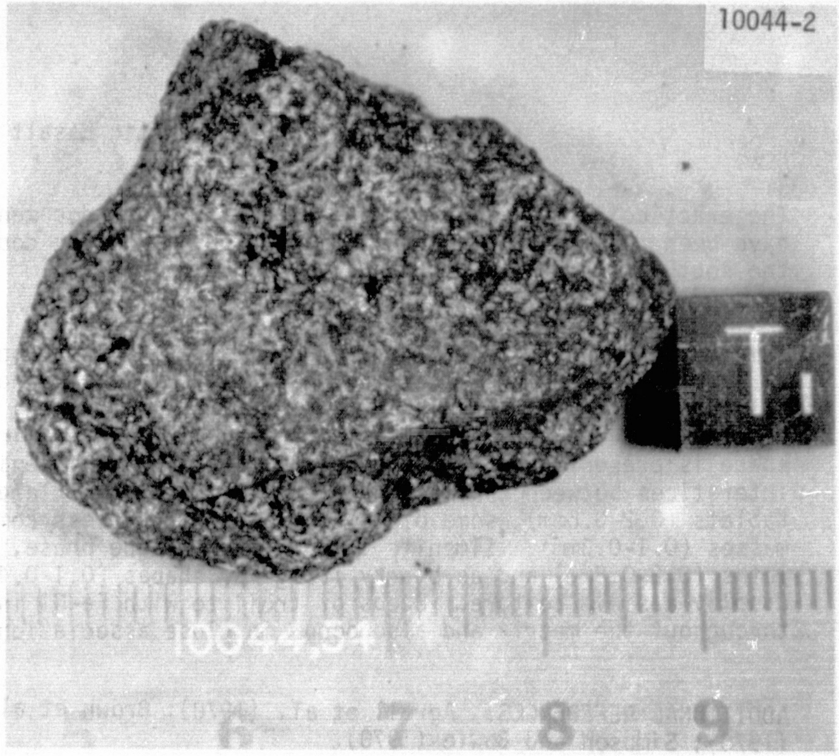
AGE DATA: $^{40}Ar-^{39}Ar$ plateau - 3.73 ± .05 AE Turner (1970)
Rb-Sr isochron - 3.71 ± .11 AE } Papanastassiou et al. (1970)
I_{Sr} - 0.69909 ± 6 }

ADDITIONAL REFERENCES: Albee and Chodos (1970); Agrell et al. (1970); Bailey et al. (1970) Cameron (1970); Gay et al. (1970).

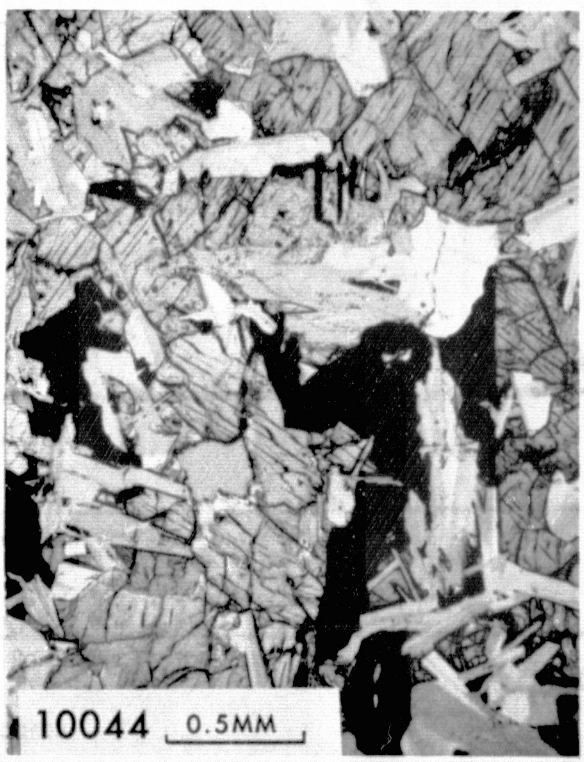


Adapted from Albee et al., 1970

Adapted from Albee et al., 1970



10044 MODAL ANALYSIS (%)	
PYROXENE	45-59
OLIVINE	—
PLAGIOCLASE	33-37
ILMENITE	6-12
ARMALCOLITE	—
CHROMITE	0.2
ULVOSPINEL	
METAL	tr
TROILITE	tr-0.5
CRISTOBALITE	4-6
TRIDYMITE	—
MESOSTASIS	—
PORE SPACE	1.0
PHOSPHATE	tr
OTHERS	—

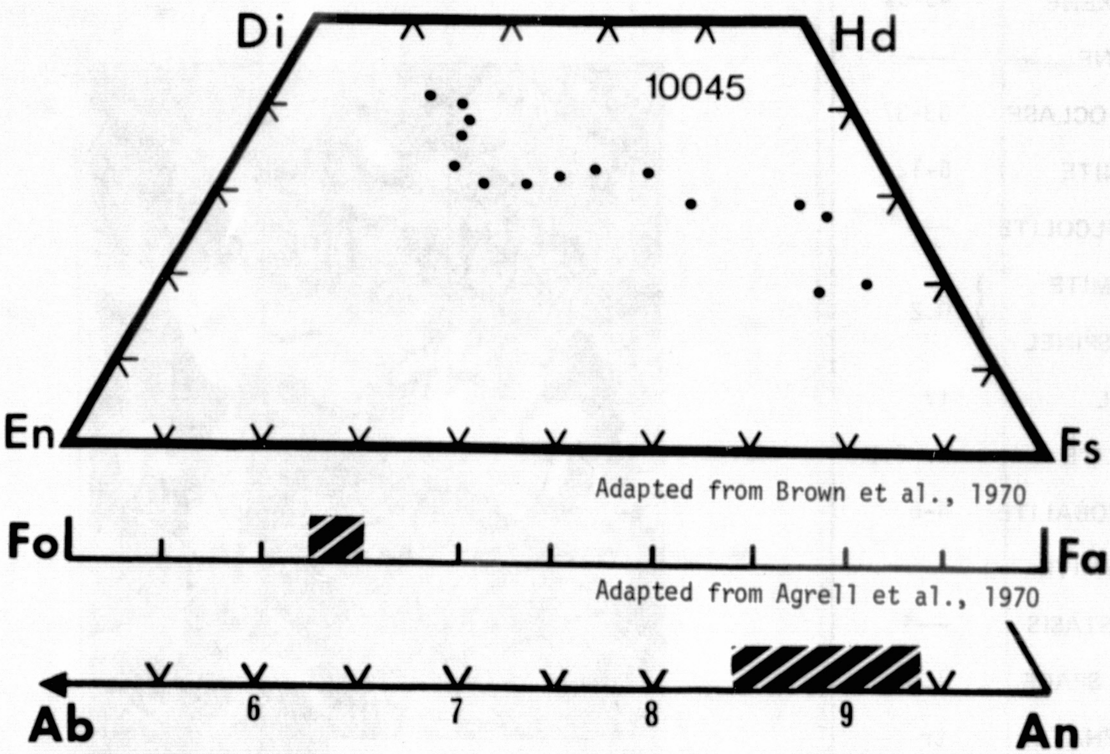


10045 Porphyritic, Subophitic Basalt

The exact collection site for sample 10045 is not documented; it is believed to have been collected in an area between the LM and the double elongate crater to the southwest of the LM.

Sample 10045 is a fine grained porphyritic, subophitic basalt which is characterized by subhedral pyroxene phenocrysts (0.8-1.3mm) and several rounded olivine phenocrysts (0.8mm) intergrown with plagioclase, anhedral pyroxene crystals (0.45-0.6mm) and ilmenite. A small amount of irregularly shaped pore space is present enclosed by silicate minerals and ilmenite. Cristobalite fills interstices between the matrix intergrowths. Plagioclase occurs typically as tablets (0.2-0.6mm), some of which are bent, and less commonly as anhedral masses (0.1-0.3mm). Ilmenite is the major opaque phase, occurring as rounded laths (0.2-0.8mm) and as blocky irregular shapes (0.1-0.4mm) which commonly display a sieve texture. Blebs of troilite with Fe-Ni inclusions are dispersed throughout the matrix and also occur in close association with ilmenite.

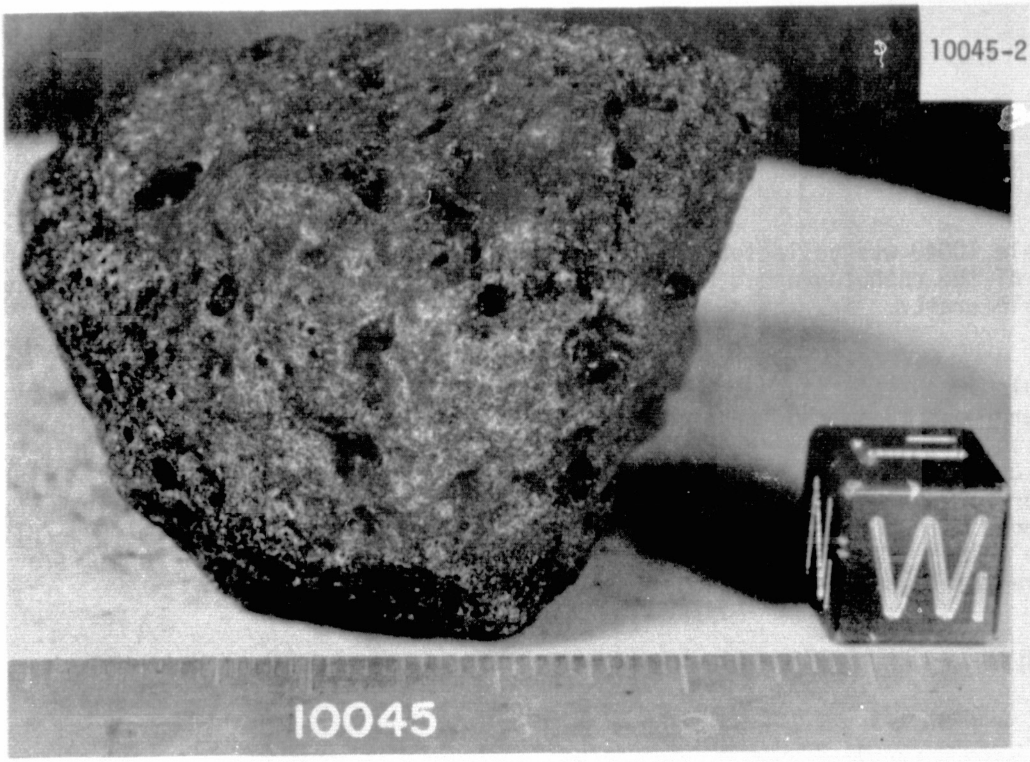
ADDITIONAL REFERENCES: Agrell et al. (1970); Brown et al. (1970); Gay et al. (1970); Simpson and Bowie (1970).



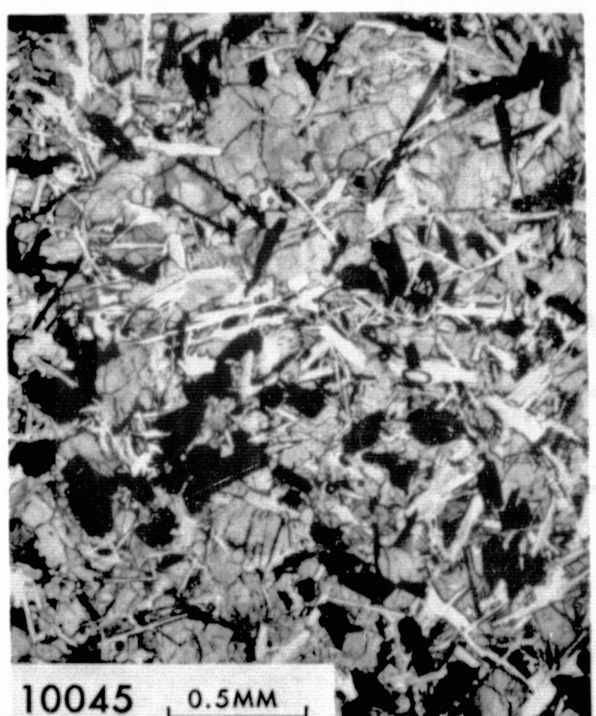
Adapted from Brown et al., 1970

Adapted from Agrell et al., 1970

Adapted from Keil et al., 1970



10045 MODAL ANALYSIS (%)	
PYROXENE	53-61
OLIVINE	3.0
PLAGIOCLASE	27
ILMENITE	7-11
ARMALCOLITE	—
CHROMITE } ULVOSPINEL	0.2
METAL	0.2
TROILITE	tr-1.0
CRISTOBALITE	2.0
TRIDYMITE	—
MESOSTASIS	—
PORE SPACE	—
PHOSPHATE	—
OTHERS	—

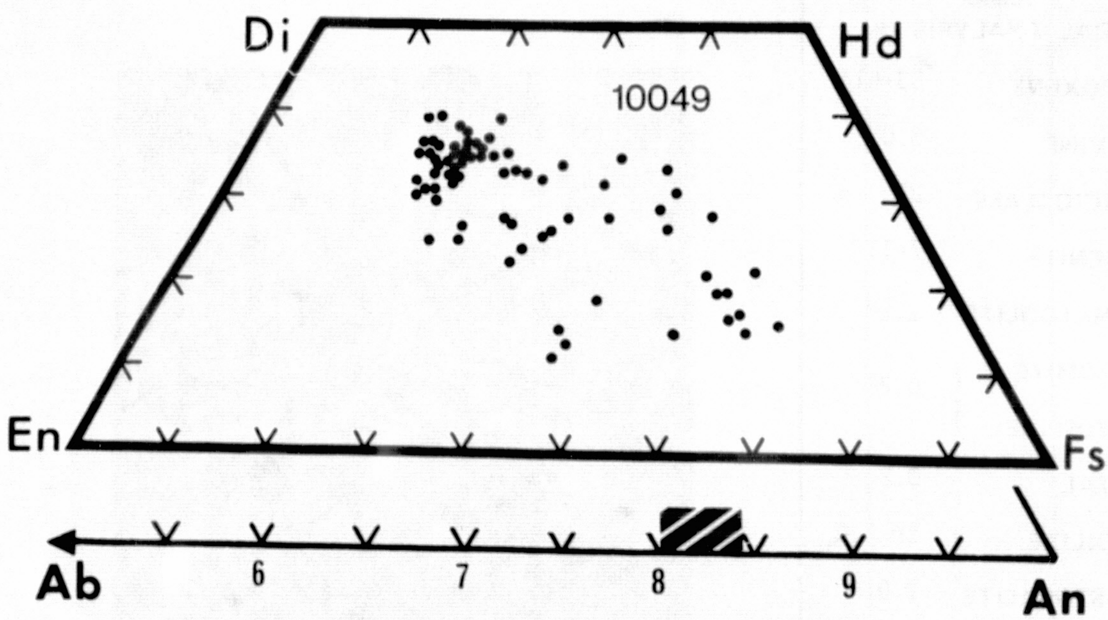


10049 Fine Grained Intersertal Basalt

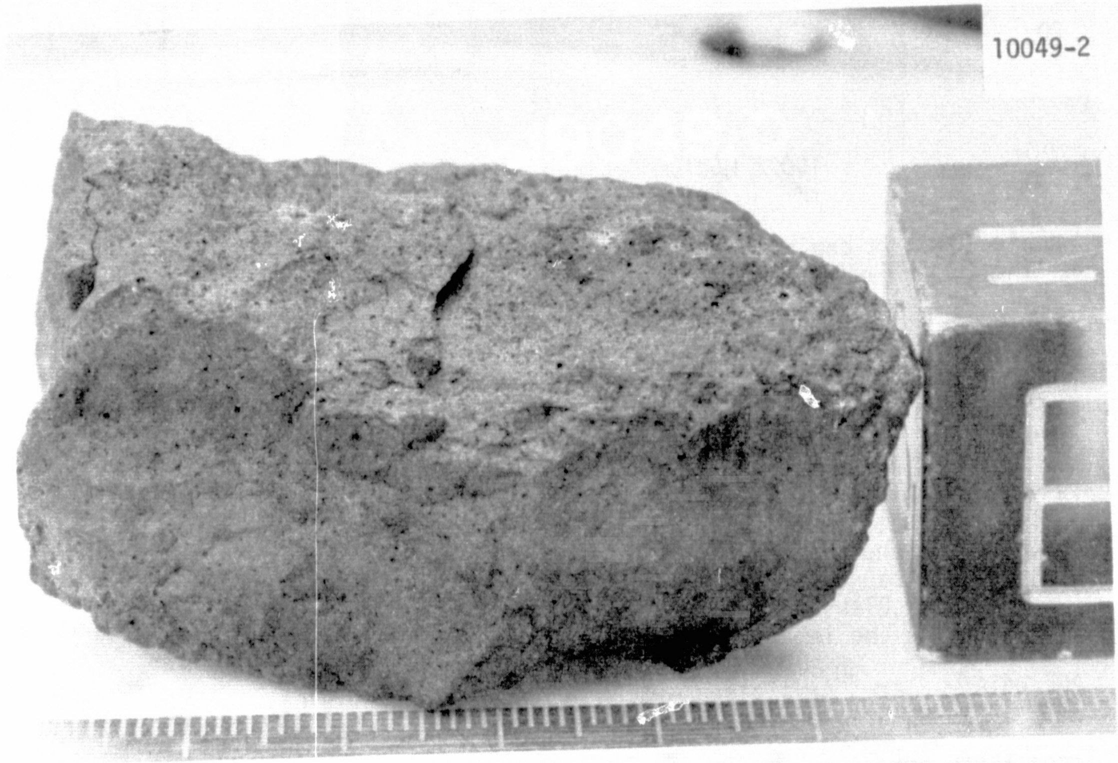
Sample 10049 was collected by Armstrong in the final minutes of the EVA. It is one of the unphotographed grab samples collected near the east rim of the large double crater.

Sample 10049 is a fine grained intersertal basalt which consists of a network of intergrown crystals of anhedral pyroxene (0.02-0.08mm), plagioclase (0.03-1.10mm), possible rare olivine grains (0.04mm), and opaque minerals. Vesicles (0.10-0.35mm) are common and minor amounts of glassy mesostasis fill interstices in the tightly intergrown network. Ilmenite is the major opaque phase and occurs typically as rounded laths (0.01-0.10mm), although rare irregularly shaped bodies (0.01-0.20mm) also occur. Troilite blebs, with and without inclusions of Fe-Ni metal, are present in the mesostasis and in association with ilmenite.

ADDITIONAL REFERENCES: Cameron (1970).

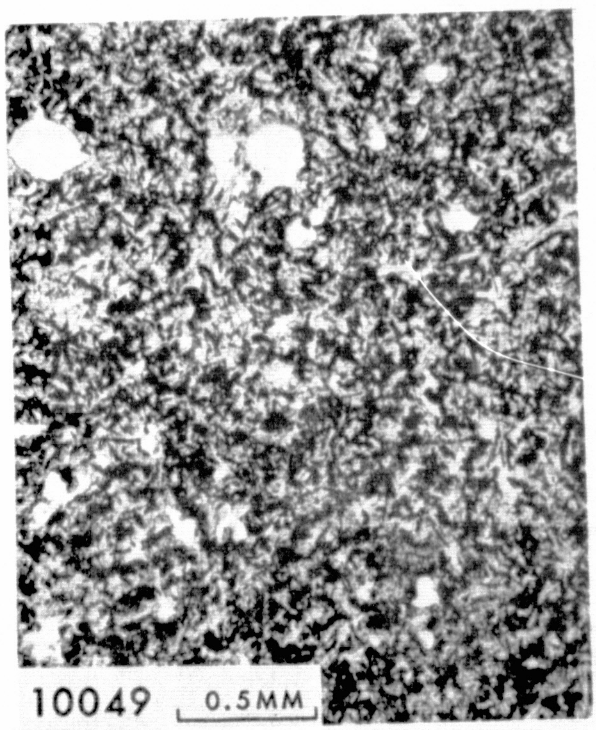


10049-2



10049
MODAL ANALYSIS (%)

PYROXENE	47
OLIVINE	—
PLAGIOCLASE	18
ILMENITE	16-17
ARMALCOLITE	
CHROMITE	
ULVOSPINEL	
METAL	—
TROILITE	1.0
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	18
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



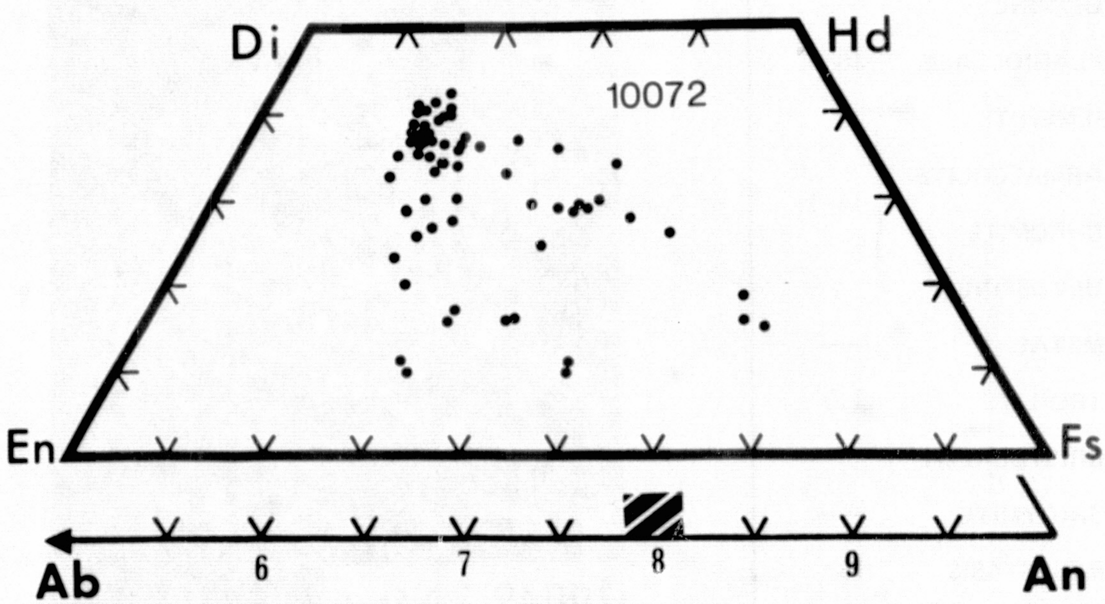
10072 Medium Grained, Intersertal Basalt

Sample 10072 is one of the unphotographed grab samples collected near the east rim of the large double crater.

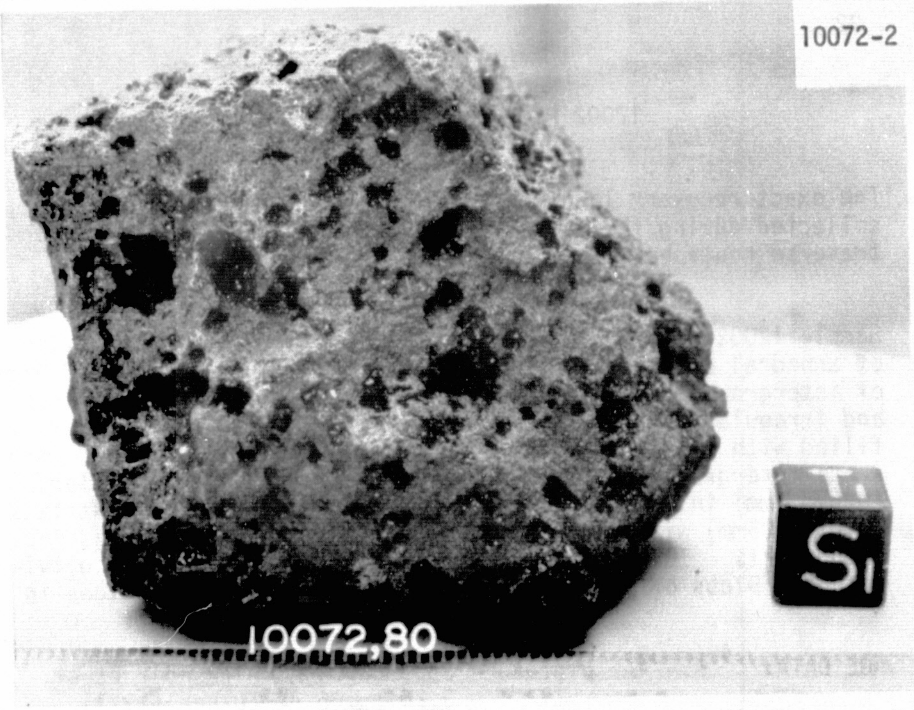
Sample 10072 is a medium grained intersertal basalt which consists of intergrown pyroxene, plagioclase and opaque minerals with interstitial occurrences of cristobalite and glass. Spherical vugs range in diameter from 0.5mm to 1.0mm. Pyroxene crystals (0.1-0.6mm) are subhedral to anhedral, commonly zoned, and contain rare inclusions of rod-shaped tranquillityite. Plagioclase displays a variety of shapes ranging from anhedral interstitial grains (0.1-0.6mm) to hollow euhedral tablets (0.1-1.0mm) intergrown with pyroxene. Ilmenite is the major opaque phase and typically occurs as blocky, irregularly shaped bodies (0.4-1.0mm) with arcuate boundaries and reentrants, and less commonly as needle-like laths (0.2-0.6mm). Blebs of troilite with Fe-Ni metal inclusions occur in association with ilmenite and in areas of glassy mesostasis.

AGE DATA: ^{40}Ar-^{39}Ar plateau - 3.52 ± .05 AE Turner (1970)
Rb-Sr isochron - 3.78 ± 10 AE Compston et al. (1970)

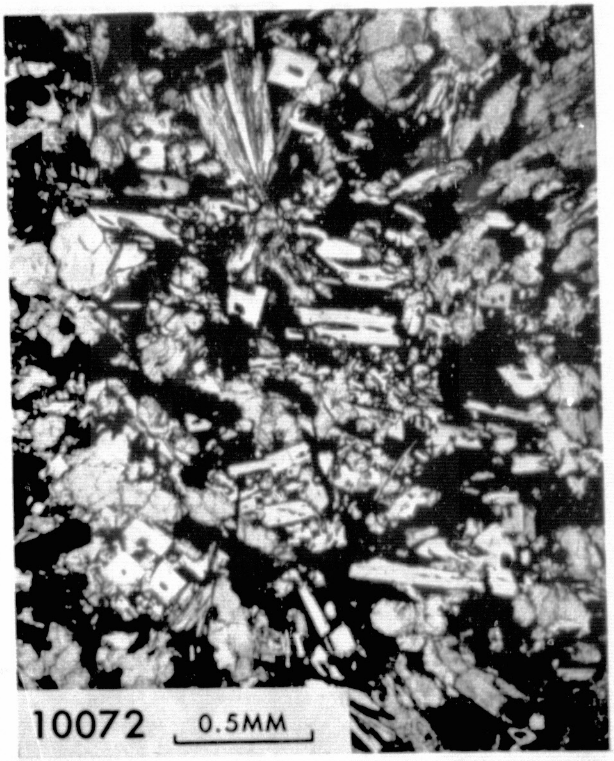
ADDITIONAL REFERENCES: Walker et al. (1975); Kushiro and Nakamura (1970); James and Jackson (1970); Simpson and Bowie (1970); Haggerty et al. (1970).



10072-2



10072 MODAL ANALYSIS (%)	
PYROXENE	49-59
OLIVINE	tr-1
PLAGIOCLASE	18-21
ILMENITE	13-22
ARMALCOLITE	
CHROMITE	
ULVOSPINEL	
METAL	0.3
TROILITE	0.2-0.7
CRISTOBALITE	0.2-2.0
TRIDYMITE	—
MESOSTASIS	7-9
PORE SPACE	1½ -7
PHOSPHATE	tr
OTHERS	—



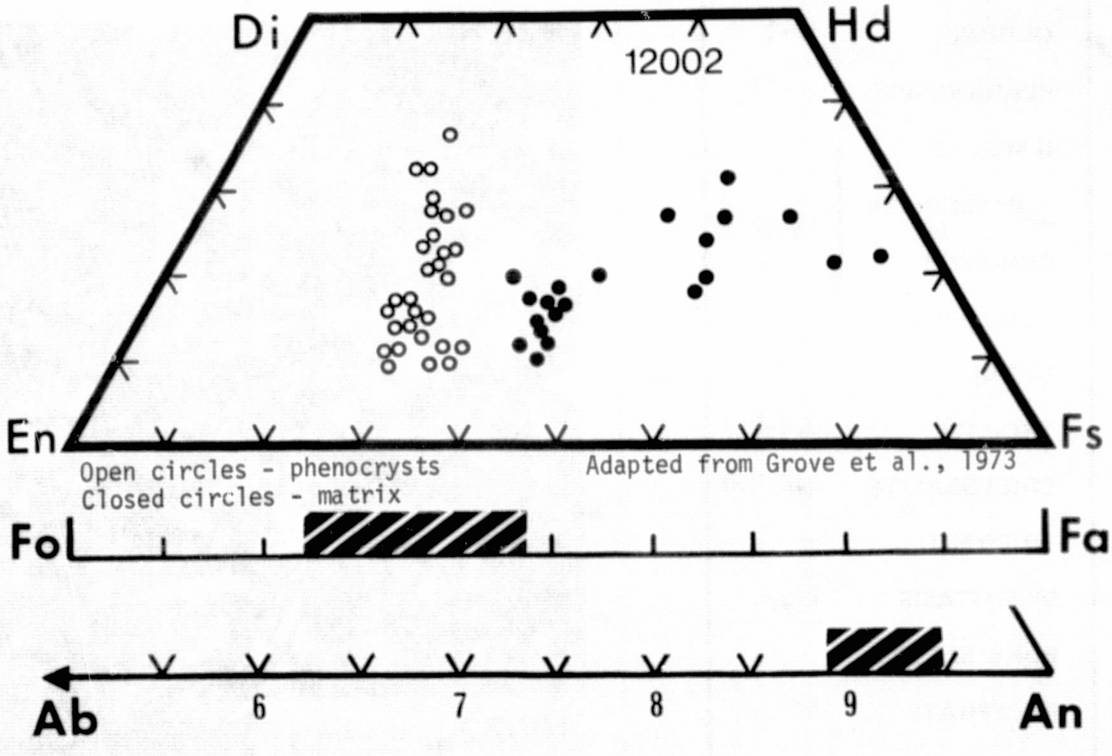
12002 Porphyritic Olivine, Pyroxene Basalt

The exact recovery location for sample 12002 is not documented; it was collected during the first extravehicular activity (EVA) period along a traverse route between the LM and Middle Crescent crater.

Sample 12002 is a medium grained porphyritic basalt consisting of phenocrysts of anhedral olivine (1.0-1.5mm) and tabular pyroxene (1.0-3.0mm) in a matrix of intergrown pyroxene anhedra (0.6-0.8mm), hollow plagioclase tablets (0.6-0.8mm) and irregular and lath-shaped ilmenite (0.2-0.4mm). Interstitial areas are filled with glassy mesostasis and rare, irregularly shaped pore space. In some areas intergrowths of plagioclase and pyroxene form acicular, radiating bundles (0.6-0.8mm) in the matrix. Chromite is present in the matrix as rounded octahedra (0.01-0.05mm) with distinct rims of ulvospinel and also as inclusions in pyroxene phenocrysts. In cases where chromite is in contact with olivine the rims are absent. Blebs of troilite and native iron fill interstices in the matrix.

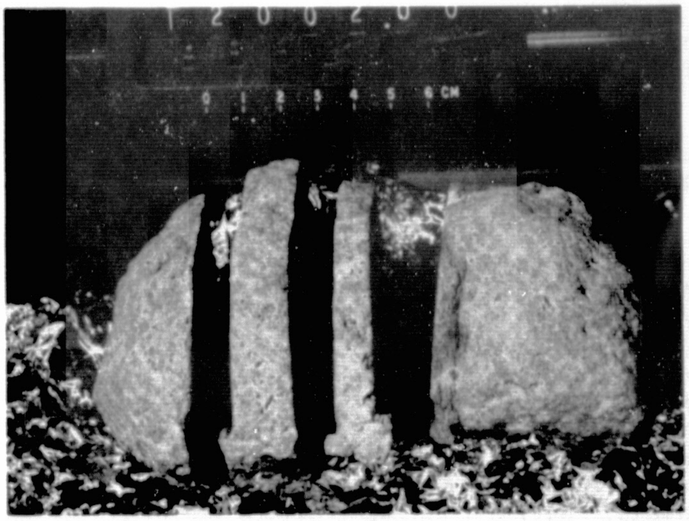
AGE DATA: $^{40}Ar-^{39}Ar$ plateau - 3.29 ± .04 AE Alexander et al. (1972)
3.26 ± .06 AE Turner (1971)
Rb-Sr isochron - 3.36 ± .10 AE } Papanastassiou and Wasserburg (1971b)
I_{Sr} - 0.69949 ±5

ADDITIONAL REFERENCES: Grove et al. (1973); Wang et al. (1971); Chung et al. (1971) Herzenberg et al. (1971); Papike et al. (1976).

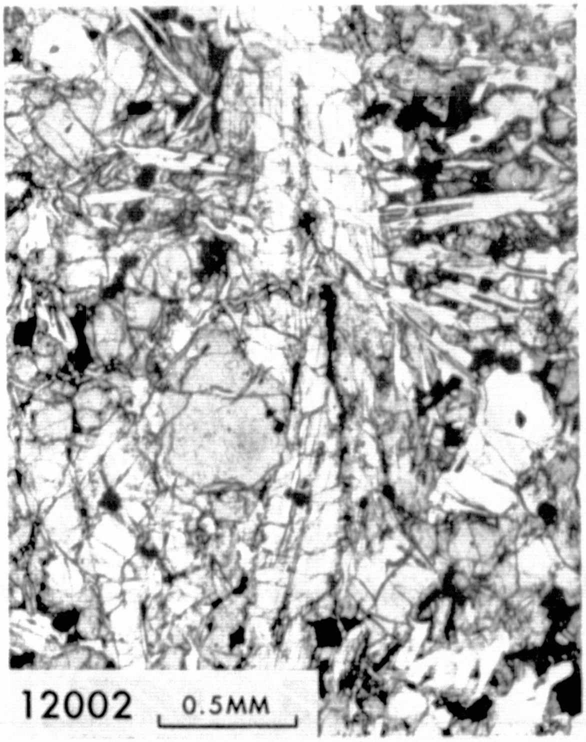


Open circles - phenocrysts
Closed circles - matrix

Adapted from Grove et al., 1973



12002 MODAL ANALYSIS (%)		
PYROXENE	49-59	
OLIVINE	11-19	
PLAGIOCLASE	16-29	
ILMENITE	3-8	8-11
ARMALCOLITE		
CHROMITE		
ULVOSPINEL		
METAL	0.3	
TROILITE	0.3	
CRISTOBALITE	tr-1.0	
TRIDYMITE	—	
MESOSTASIS	1-5	
PORE SPACE	—	
PHOSPHATE	—	
OTHERS	—	



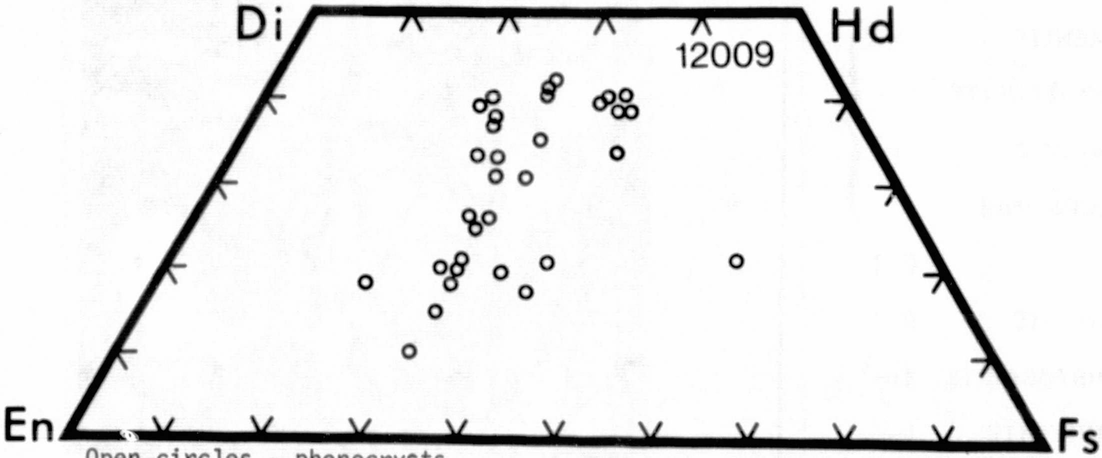
12009 Porphyritic Basalt Vitrophyre

The collection site for sample 12009 is not documented; it was collected during the first EVA along a traverse route between the LM and Middle Crescent crater.

Sample 12009 is a porphyritic basalt vitrophyre which consists of skeletal phenocrysts of olivine (0.3-1.0mm) and pyroxene (0.2-0.8mm) set in a matrix of microcrystalline devitrified glass and quench crystals of olivine, pyroxene and ilmenite. Olivine phenocrysts occur as skeletal euhedral crystals (Figure) with reentrants and irregularly shaped inclusions of matrix material, and as subhedral crystals without inclusions. Quench crystals of olivine (0.5-1.0mm) in the matrix have a ladder-shaped appearance (Figure). Pyroxene phenocrysts (0.6-1.0mm) are typically anhedral, occurring as bundles of elongate fibrous crystals (Figure) which display optical continuity, and as groups of irregularly shaped, rounded bodies when the bundles appear in cross section. Quench crystals of pyroxene (0.8-1.5mm) are present in the matrix and occur as delicate feathery crystals which resemble quill pens (Figure). Chromite is present as octahedra (0.01mm) in the matrix and rarely as inclusions in pyroxene and olivine phenocrysts. Native iron and troilite are dispersed as blebs throughout the matrix.

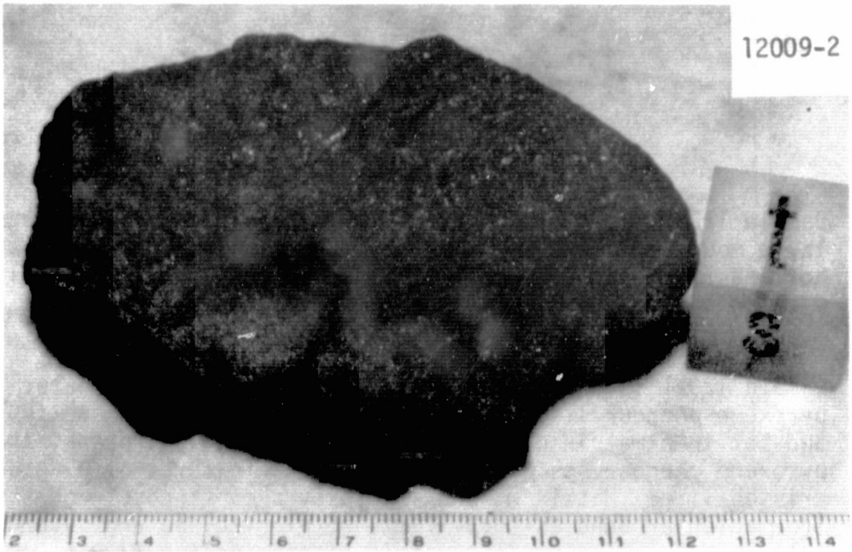
AGE DATA: ^{40}Ar-^{39}Ar plateau - 3.29 ± .07 AE, 3.17 ± .07 AE } Stettler et al. (1973)

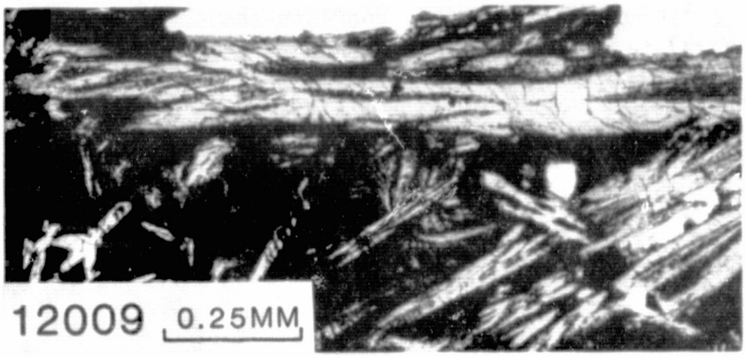
ADDITIONAL REFERENCES: Donaldson et al. (1975); Green et al. (1971); Brett et al. (1971); Papike et al. (1976).



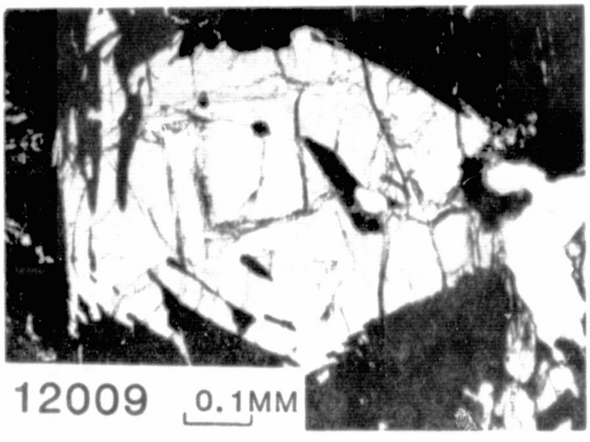
Open circles - phenocrysts
Closed circles - matrix

12009 MODAL ANALYSIS (%)	
PYROXENE	4-10
OLIVINE	22-24
PLAGIOCLASE	—
ILMENITE	0.3
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	—
METAL	tr
TROILITE	—
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	68-72
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



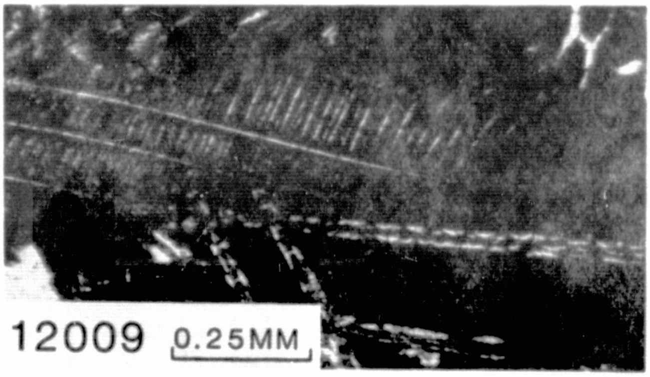


12009 0.25MM



12009 0.1MM

12009 0.5MM



12009 0.25MM

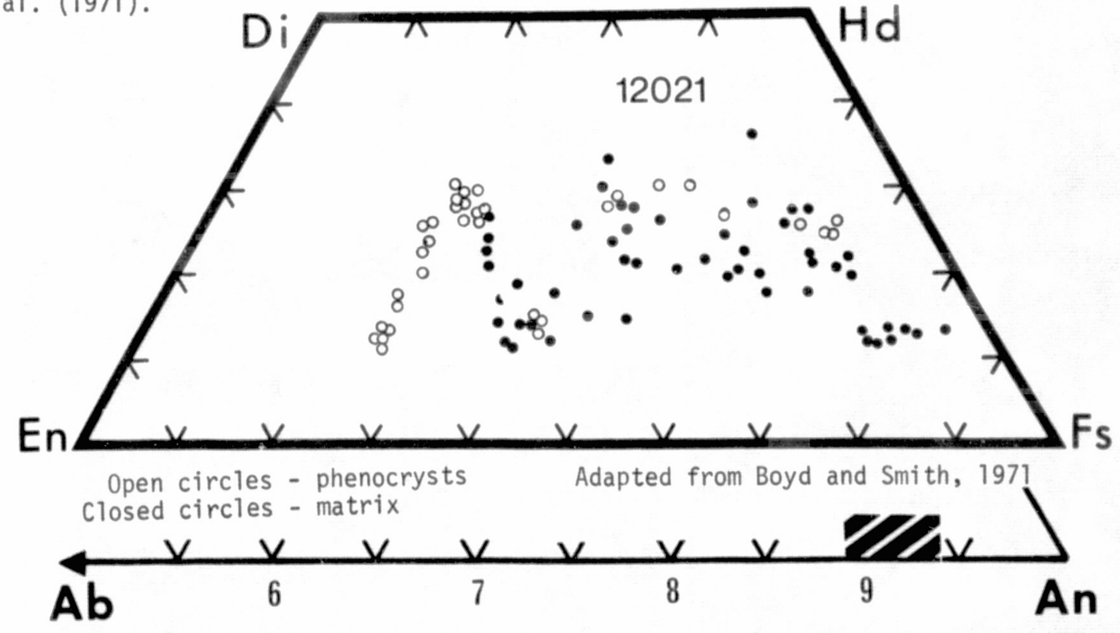
12021 Pyroxene Porphyritic Basalt

Sample 12021 was collected from an area near the eastern base of a large mound located approximately 120 meters northwest of the Lunar Module and northeast of Head Crater. The mound is believed to be a clump of regolith ejected by the impact of a nearby crater.

Sample 12021 is a coarse grained porphyritic basalt characterized by subhedral pyroxene phenocrysts (0.8x3.0mm to 0.5x5.0mm) which are typically sector zoned and set in a matrix of intergrown plagioclase, pyroxene, and ilmenite. Some pyroxene phenocrysts are hollow and contain cores of plagioclase, ilmenite, and cristobalite. Matrix minerals display a continuous range of sizes and shapes from acicular bundles (0.8-1.0mm) of plagioclase and pyroxene laths to sub-ophitic intergrowths of columnar crystals of plagioclase (2.0-5.0mm), anhedral pyroxene (0.8-1.0mm), and irregular and lath-shaped ilmenite (0.4-1.5mm). Plagioclase crystals are typically hollow with cores of pyroxene and ilmenite and contain rare inclusions of rod-shaped tranquillityite. Irregularly shaped pore spaces, anhedral cristobalite, acicular tridymite (.05-.08mm), and glassy mesostasis fill interstices in the matrix. Subrounded octahedra of chromite (0.1-0.3mm) with rims of ulvospinel are present in the matrix and in pyroxene phenocrysts. Fe-Ni metal is present as blebs in the glassy mesostasis.

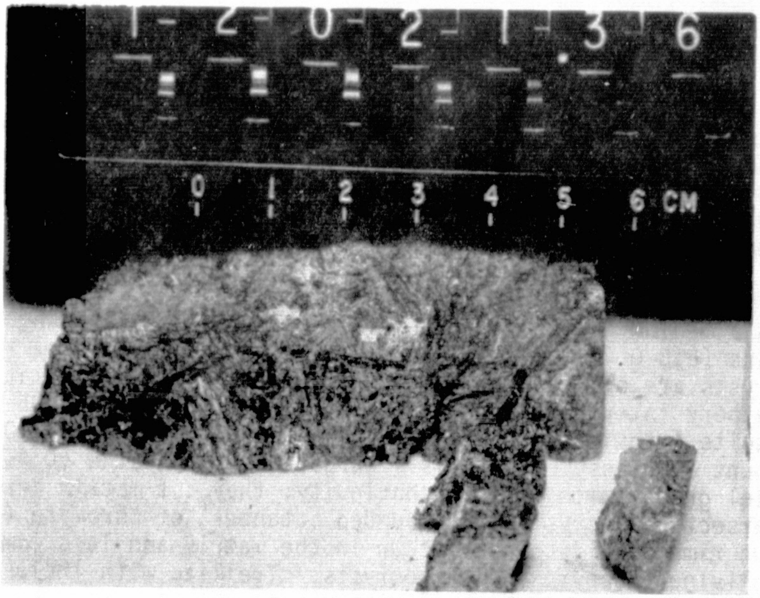
AGE DATA: Rb-Sr isochron - 3.33 ± .06 AE
I_{Sr} - 0.69949 ± 5
} Papanastassiou and Wasserburg (1971b)

ADDITIONAL REFERENCES: Green et al. (1971); Boyd and Smith (1971); Ross et al. (1971); Sippel (1971), Engel and Engel (1971); Papike et al. (1976); Klein et al. (1971).



Open circles - phenocrysts
Closed circles - matrix

Adapted from Boyd and Smith, 1971



12021
MODAL ANALYSIS (%)

PYROXENE	50-71
OLIVINE	—
PLAGIOCLASE	22-34
ILMENITE, ARMALCOLITE, CHROMITE, ULVOSPINEL	5-12
METAL	—
TROILITE	—
CRISTOBALITE	1
TRIDYMITE	4
MESOSTASIS	.8
PORE SPACE	—
PHOSPHATE	—
OTHERS	—


12021 0.5MM

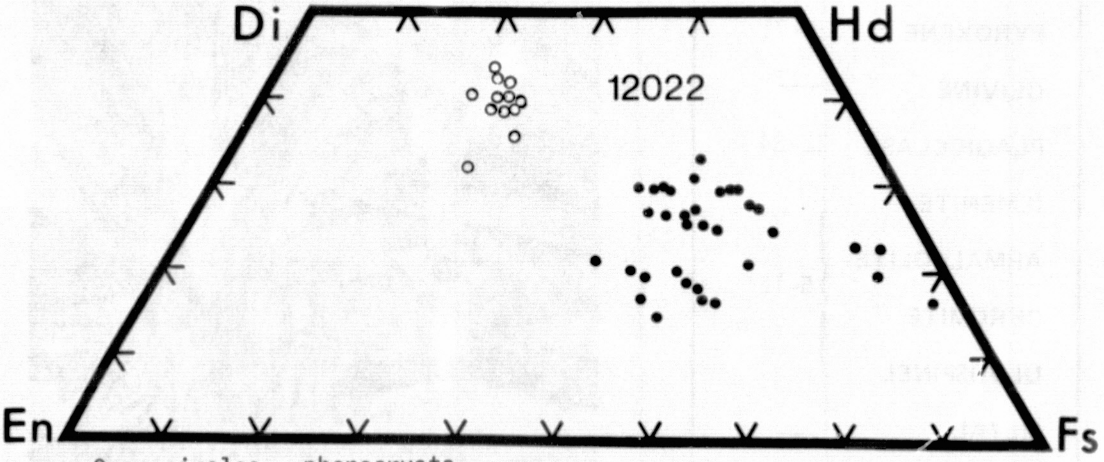
12022 Medium Grained Porphyritic Basalt

Sample 12022 was taken from a piece of imbedded crystalline rock located approximately 66.7 cm from the top of a large mound north of Head Crater. Bulk material of the mound appears to be composed predominantly of fine particle aggregates. The mound might possibly be a clump of regolith material ejected from a nearby crater.

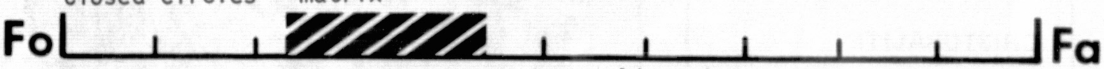
Sample 12022 is a medium grained porphyritic basalt characterized by subhedral olivine (0.3-0.4mm) and pyroxene (1.0-2.0mm) phenocrysts. Several olivine phenocrysts are epitaxially overgrown with pyroxene. The matrix consists of feathery intergrowths of parallel feldspar tablets (0.05-1.0mm), subrounded ilmenite laths (0.03-0.2mm), anhedral pyroxene crystals (0.6-0.8mm), and a minor amount of glassy mesostasis. Larger ilmenite laths (0.4-0.6mm) occur in parallel groups with optical continuity; they cut matrix intergrowths but do not intersect phenocrysts. Subrounded octahedra of chromite (0.05mm), with and without rims of ulvospinel, occur in the matrix and less commonly as inclusions in olivine and pyroxene phenocrysts. Troilite with inclusions of native iron is present as small blebs in the matrix.

AGE DATA: $^{40}Ar-^{39}Ar$ plateau - 3.18 ± .04 AE   Alexander et al. (1972)

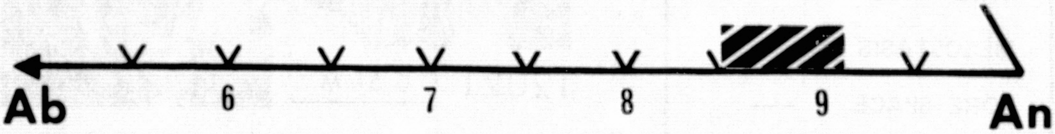
ADDITIONAL REFERENCES: Green et al. (1971); Boyd and Smith (1971); Papike et al. (1976); Chung et al. (1971); Brett et al. (1971) Engel and Engel (1971).



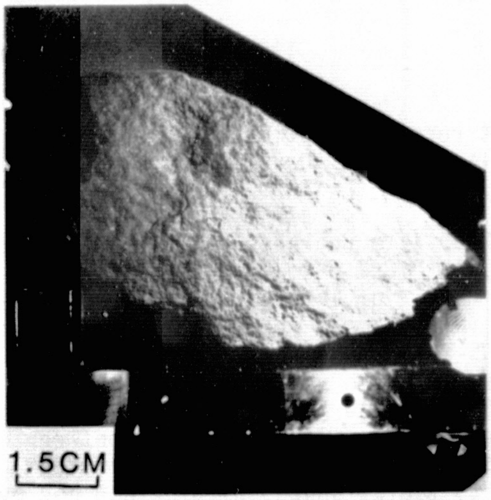
Open circles - phenocrysts
Closed circles - matrix



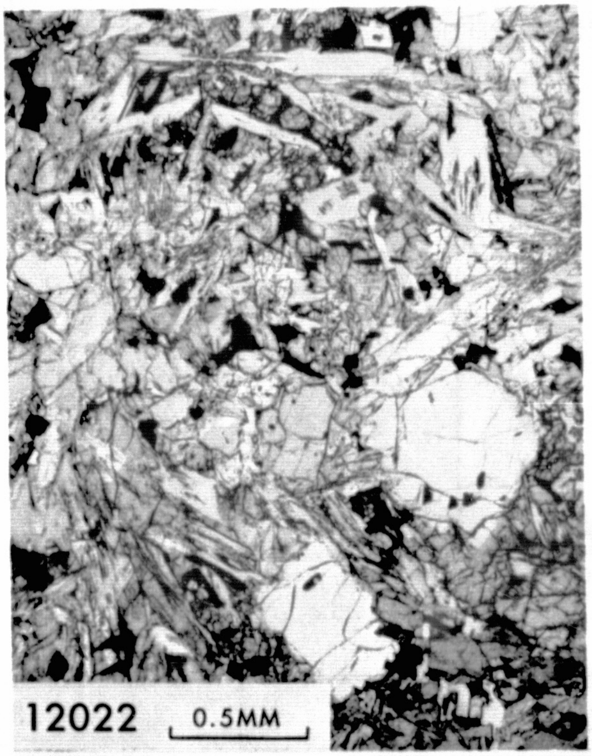
Adapted from Weill et al., 1971



Adapted from Weill et al., 1971



12022 MODAL ANALYSIS (%)	
PYROXENE	30-59
OLIVINE	16-33
PLAGIOCLASE	12-26
ILMENITE	9-23
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	—
METAL	tr
TROILITE	0.2
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	1½
PORE SPACE	—
PHOSPHATE	—
OTHERS	—

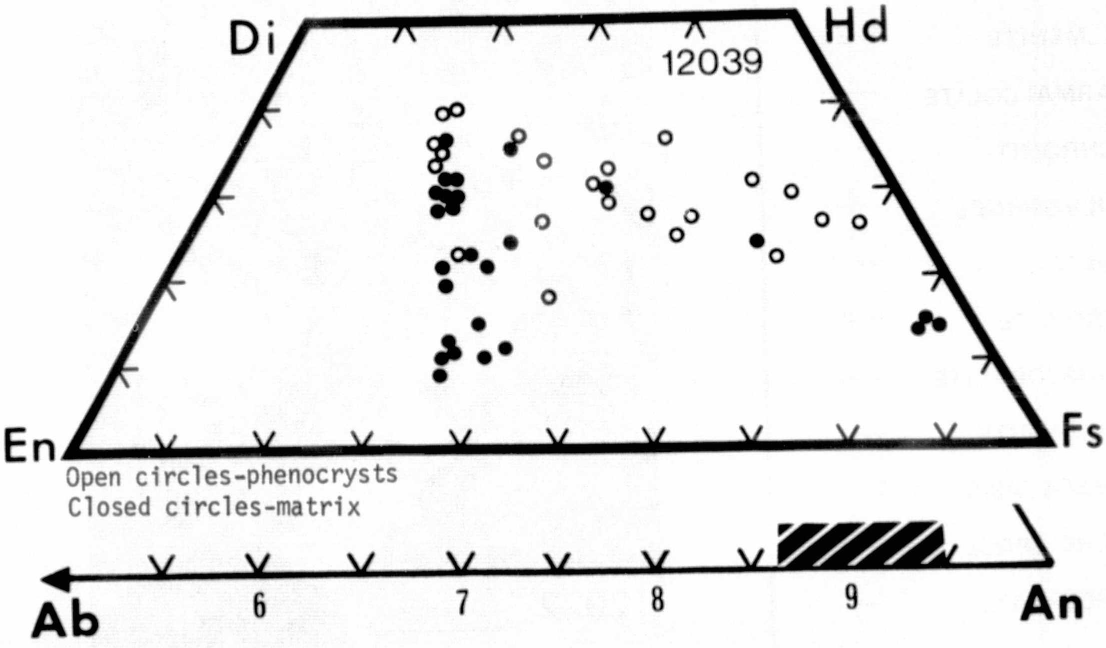


12039 Pyroxene Porphyritic Basalt

The exact recover location for 12039 is not documented; it is believed to have been collected from the west rim of Bench Crater.

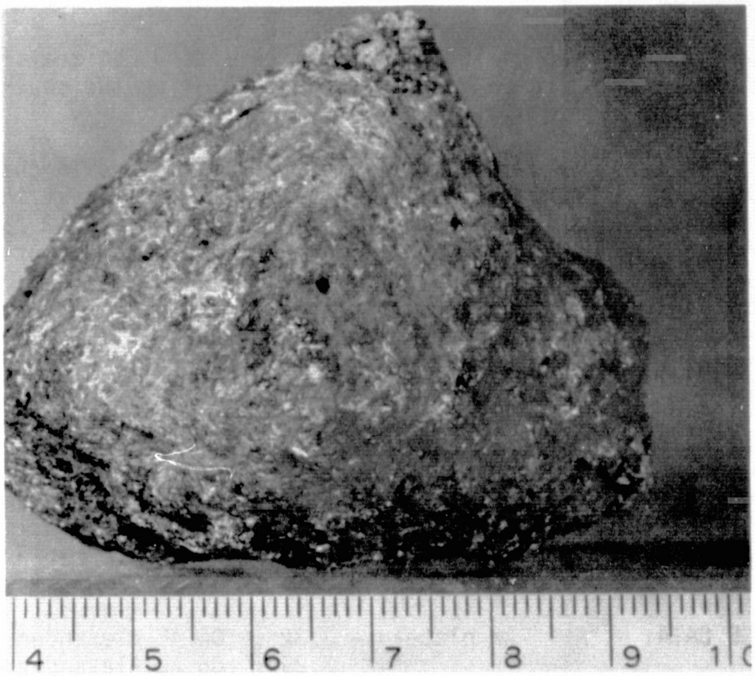
Sample 12039 is a coarse grained porphyritic basalt which consists of pyroxene phenocrysts (0.8x2.5 to 1.0x4.0mm), some of which are mantled by pyroxferroite, set in a matrix of intergrown plagioclase tablets (0.8-2.0mm), anhedral pyroxene crystals (0.8-2.0mm), rounded laths of ilmenite (0.8-2.0mm) and euhedral tridymite laths (.05-1.0mm). Rare crystals of pyroxferroite (0.1-0.3mm) are present, typically occurring adjacent to pyroxene phenocrysts which have mantles of pyroxferroite. Irregular pore space, subhedral to anhedral cristobalite (Figure), and glassy mesostasis fill interstices between matrix minerals. Several areas of the matrix consist of radiating bundled (0.8mm) formed by the intergrowth of acicular to tablet shaped plagioclase and pyroxene. Anhedral grains of tranquillityite are present in the mesostasis and occur rarely as inclusions in pyroxene and plagioclase. Ilmenite is the major opaque phase and is commonly intergrown with ulvospinel. Ulvospinel is present rarely as individual grains. Irregular blebs of troilite occur interstitial to matrix minerals and tend to have straight edges when in contact with euhedral crystals. Native iron is present as inclusions in troilite and randomly dispersed throughout the matrix.

ADDITIONAL REFERENCES: Bunch et al. (1972); Busche et al. (1972); Sippel (1971).

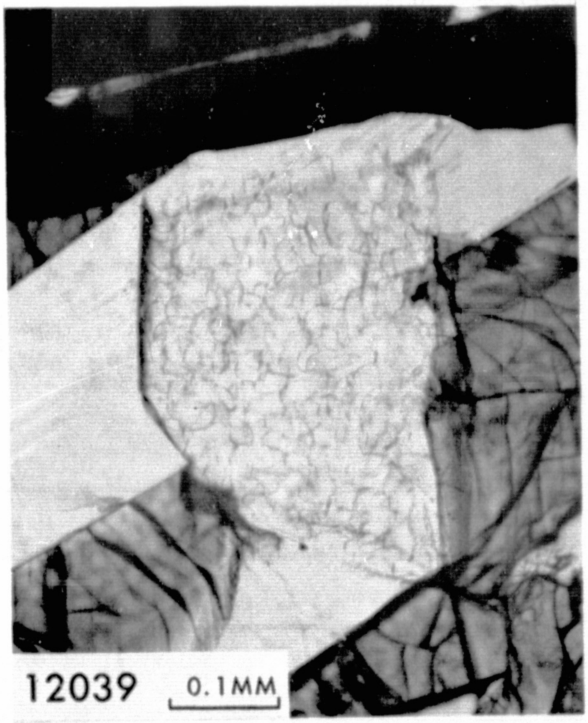


Open circles-phenocrysts
Closed circles-matrix

12039 MODAL ANALYSIS (%)	
PYROXENE	50-56
OLIVINE	—
PLAGIOCLASE	27-34
ILMENITE	8-10
ARMALCOLITE	—
CHROMITE } ULVOSPINEL	0.7
METAL	—
TROILITE	—
CRISTOBALITE	1.0 } -7.3
TRIDYMITE	4.0 }
MESOSTASIS	—
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



12039 0.5MM



12039 0.1MM

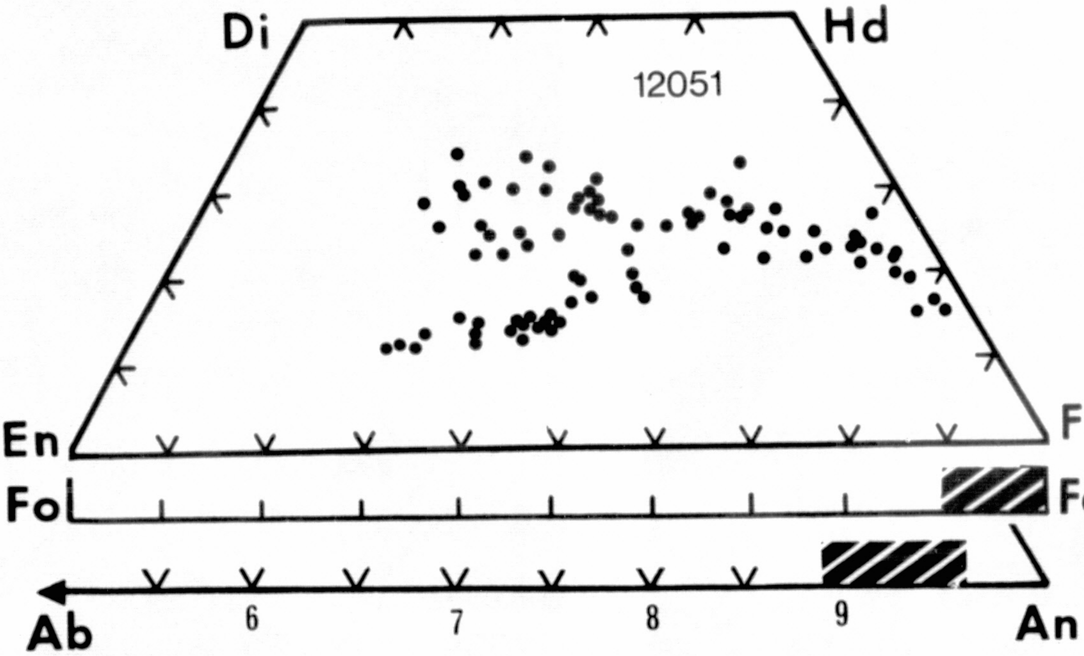
12051 Porphyritic Pyroxene Basalt

Sample 12051 was collected during the second EVA traverse. It is part of the blocky ejecta from a fresh, 4 meter crater on the south rim of Surveyor Crater.

Sample 12051 is a medium grained porphyritic basalt characterized by subhedral to anhedral phenocrysts of pyroxene (up to 10mm) set in a subophitic matrix. The matrix consists of plagioclase tablets (0.02x0.2 to 0.5x1.0mm) and rare plagioclase anhedra (0.2-0.3mm) intergrown with equant pyroxene crystals (0.2-1.0mm) and rounded laths of ilmenite (0.3-1.0mm). Ilmenite laths commonly cut silicate minerals. Rare plates of red-brown tranquillityite (10μ and less) occur as inclusions in pyroxene and in association with the mesostasis. A few vesicles with a diameter of 0.1mm are present. Cristobalite and glass fill interstices between silicate minerals. Rounded octahedra of Cr-spinel (0.05-0.08mm) with ilmenite lamellae and rims of ulvospinel are present as inclusions in pyroxene and commonly fill interstices between silicate minerals. Discrete ulvospinel grains are also present in interstitial areas. Troilite is present as tiny blebs in the mesostasis and is randomly dispersed throughout the matrix. Fe-Ni metal occurs as inclusions in troilite and more commonly as tiny blebs in the matrix.

AGE DATA:	$^{40}Ar-^{39}Ar$ plateau	- 3.32 ± .04 AE	Alexander et al. (1972)
		3.29 ± .06 AE	Alexander et al. (1972)
		3.27 ± .05 AE	Turner (1971)
	Rb-Sr isochron	- 3.26 ± .10 AE	Papanastassiou and Wasserburg (1971b)
	I_{Sr}	- 0.69932 ± 6	

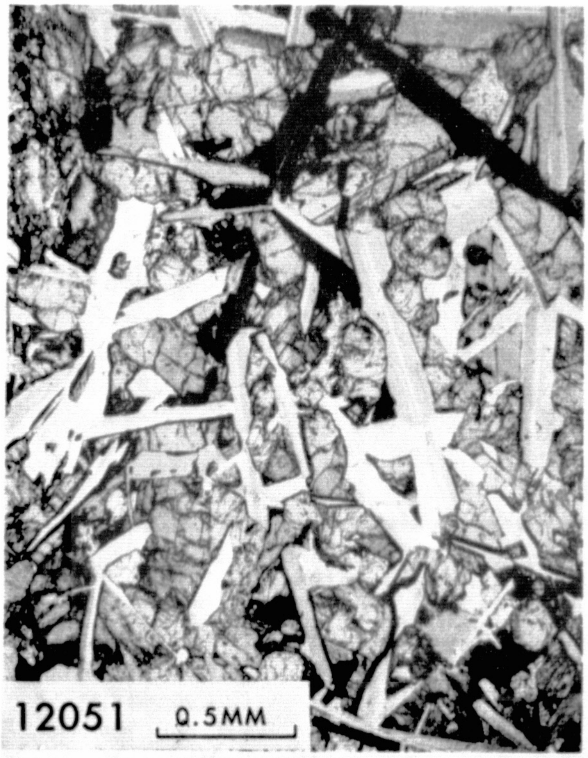
ADDITIONAL REFERENCES: Keil et al. (1971); Brown et al. (1971).



Adapted from Keil et al., 1971

12051-2

12051 MODAL ANALYSIS (%)	
PYROXENE	57-61
OLIVINE	—
PLAGIOCLASE	22-31
ILMENITE	
ARMALCOLITE	
CHROMITE	8-11
ULVOSPINEL	
METAL	—
TROILITE	—
CRISTOBALITE	2-3
TRIDYMITE	—
MESOSTASIS	1-3
PORE SPACE	2.0
PHOSPHATE	—
OTHERS	—



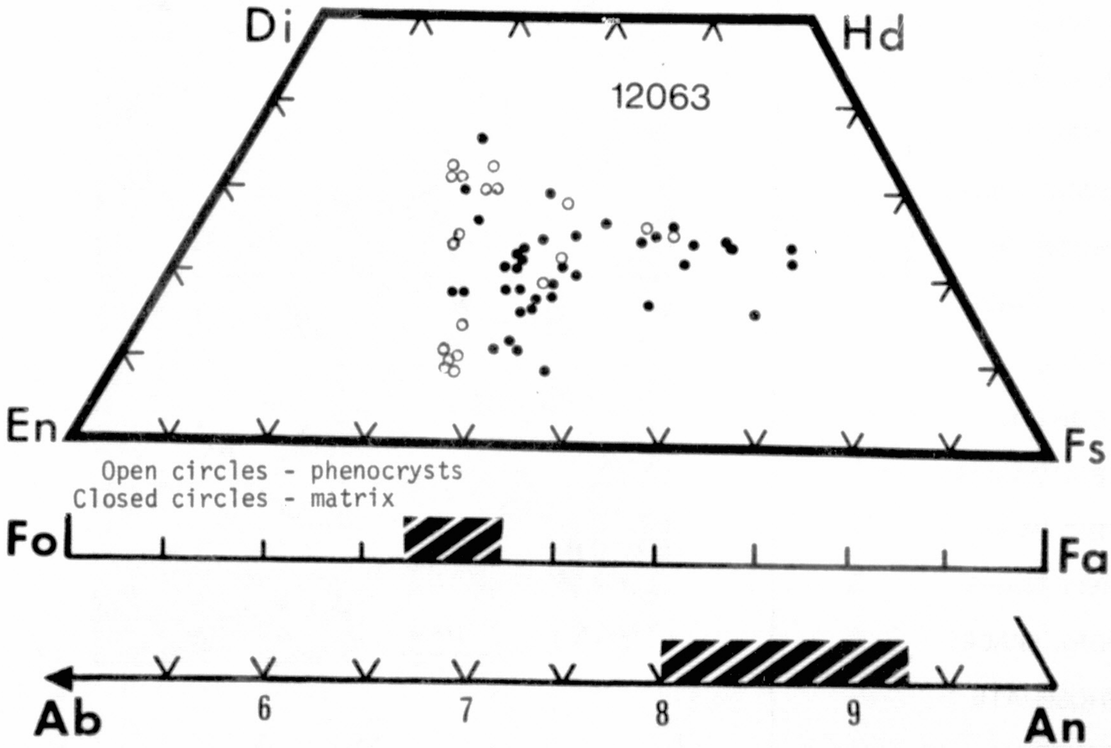
12063 Porphyritic Olivine, Pyroxene Basalt

Sample 12063 has not been identified in surface photographs but is believed to have been collected at Bench Crater together with sample 12039.

Sample 12063 is a medium-grained porphyritic olivine, pyroxene basalt. Phenocrysts of rounded olivine (0.6-0.8mm) and euhedral to subhedral pyroxene (0.3x1.0 to 0.5x1.5mm) are set in a matrix of intergrown plagioclase, pyroxene, and opaque minerals. Mesostasis fills interstices between matrix minerals and consists of vermicular, perhaps eutectic intergrowths, of single clinopyroxene crystals and glass (Figure). More normal glassy mesostasis occurs adjacent to these pyroxene-glass intergrowths. Plagioclase is present as hollow tablets (0.2-0.5mm), anhedral bodies (0.1-0.5mm), and as tablet-shaped bodies (0.8-2.5mm). Hollow tablets of plagioclase commonly contain cores of pyroxene, opaque minerals, and glass. In some areas of the matrix tablet-shaped plagioclase is intimately intergrown with pyroxene anhedra to form feathery bundles (0.8-1.2mm). Ilmenite is the major opaque phase, commonly occurring as rounded laths (0.5-1.0mm) and as blocky, irregularly shaped bodies (0.1-0.3mm). Rounded octahedra of chromite with rims of ulvospinel are present as inclusions in pyroxene phenocrysts. Troilite blebs are found in association with ilmenite and spinel and in the mesostasis. Fe-Ni metal inclusions are abundant in troilite and are dispersed throughout the matrix as independent blebs.

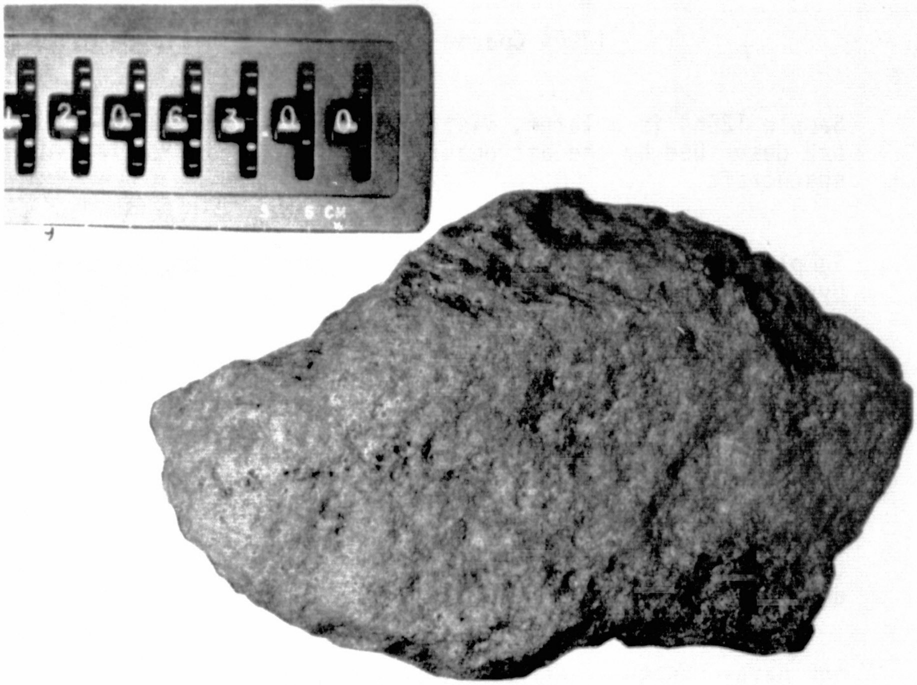
AGE DATA: Rb-Sr isochron - 3.30 ± .13 AE; I_{Sr} - 0.69918 ± 6 } Papanastassiou and Wasserburg (1971b)

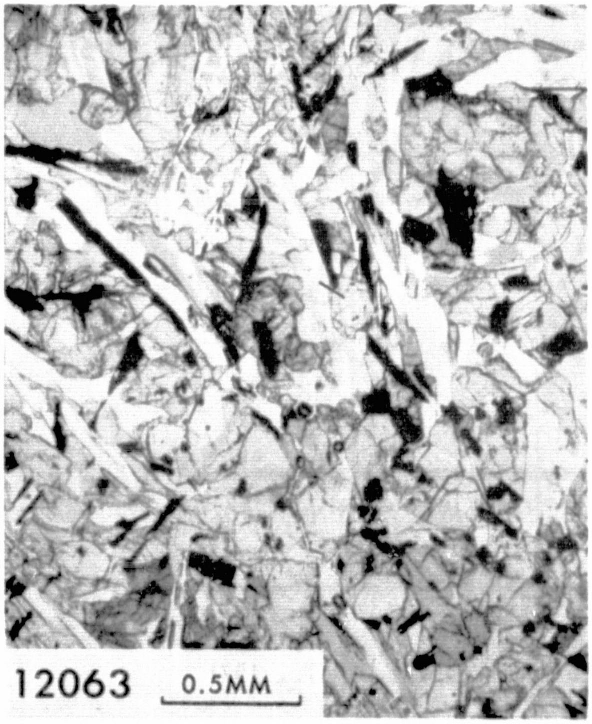
ADDITIONAL REFERENCES: Papike et al. (1976); Herzenberg et al. (1971).



Adapted from Trzcienski, 1971

12063 MODAL ANALYSIS (%)		
PYROXENE	56-64	
OLIVINE	3-9	
PLAGIOCLASE	22-28	
ILMENITE	6-	8-0
ARMALCOLITE		
CHROMITE		
ULVOSPINEL		
METAL	0.3	
TROILITE	0.3	
CRISTOBALITE	—	
TRIDYMITE	—	
MESOSTASIS	2-7	
PORE SPACE	—	
PHOSPHATE	—	
OTHERS	—	





12063 0.5MM

12063 0.05MM

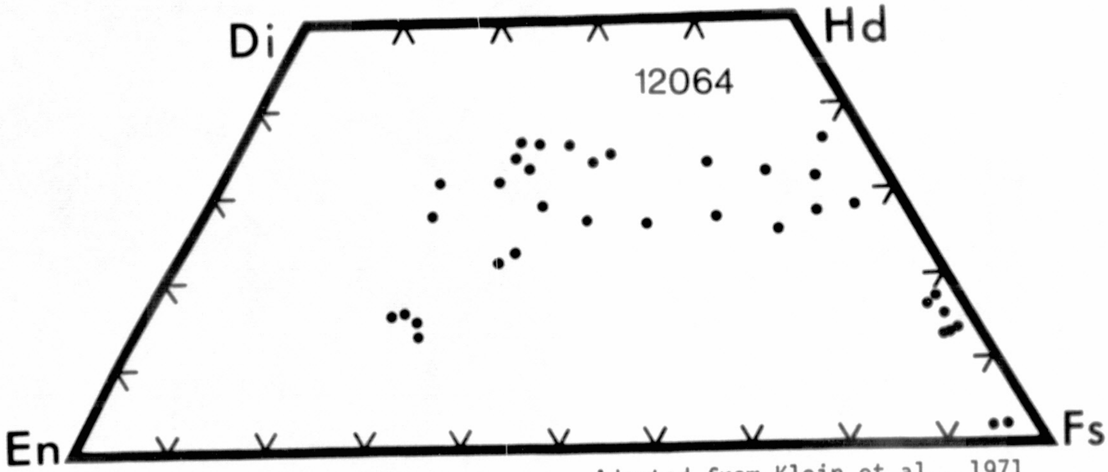
12064 Coarse Grained Sub-ophitic Basalt

Sample 12064 is a large, distinctly angular rock which is believed to be the one described by the astronauts as a square rock collected near the Surveyor spacecraft.

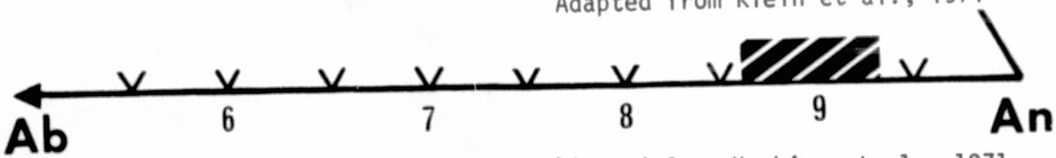
Sample 12064 is a coarse grained sub-ophitic basalt characterized by anhedral pyroxene crystals (0.4x0.4 to 0.6x2.0mm) subophitically intergrown with plagioclase anhedra (0.8-1.0mm) and rare subhedral plagioclase tablets (0.2x1.0mm). Some pyroxene crystals have mantles of pyroxferroite. Tridymite laths (1.0-1.5mm) are common and occur both interstitial to and intergrown with silicate minerals. Subhedral to anhedral cristobalite and irregularly shaped pore space fill interstices between silicate minerals. Mesostasis is typically characterized by intergrowths of fayalite, hedenbergite, and glass. Ilmenite is the major opaque phase and occurs as rounded laths (1.0-2.4mm) and irregularly shaped bodies (0.3-0.8mm), both of which have reentrants and are intergrown with plagioclase and pyroxene. Ulvospinel is present as anhedral bodies (0.1-0.2mm) and commonly contains lamellae of ilmenite. Troilite is found in association with ilmenite and ulvospinel and also in the mesostasis.

AGE DATA: Rb-Sr isochron - 3.18 ± .09 AE } Papanastassiou and Wasserburg (1971b)
I_{Sr} - 0.69943 ± 6

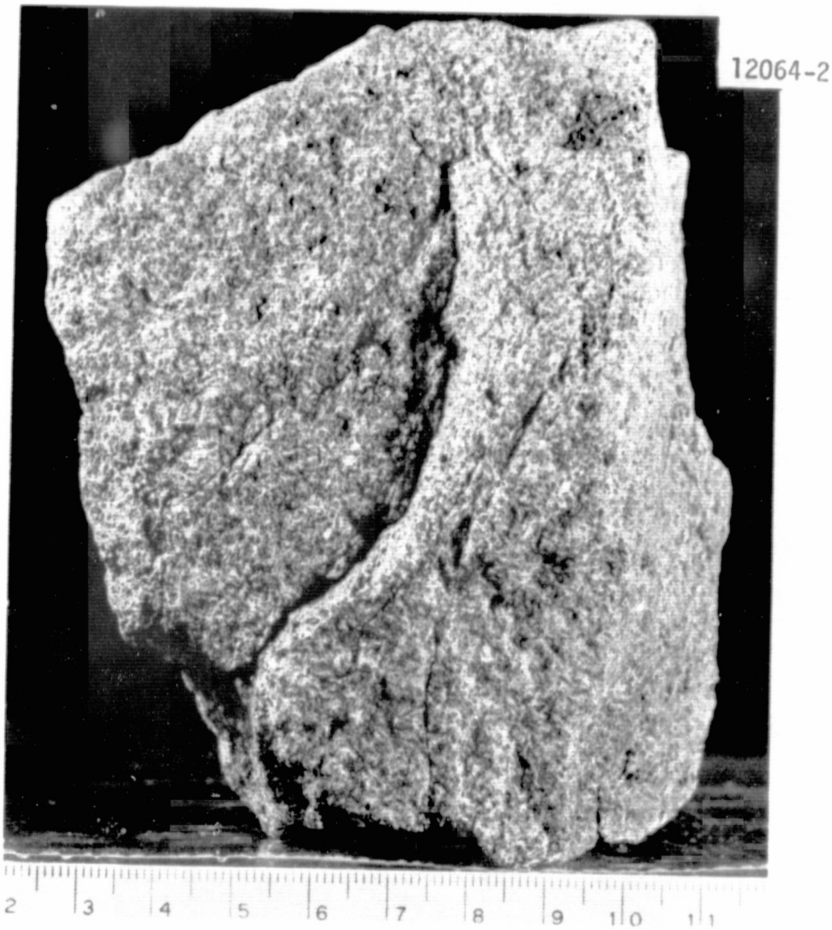
ADDITIONAL REFERENCES: Maun et al. (1971); Klein et al. (1972); Papike et al. (1976)



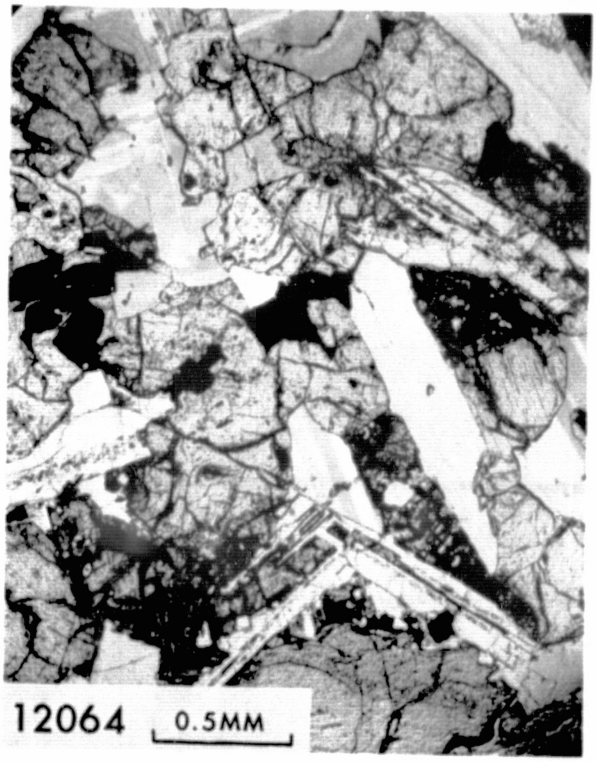
Adapted from Klein et al., 1971



Adapted from Kushiro et al., 1971



12064 MODAL ANALYSIS (%)	
PYROXENE	56-57
OLIVINE	1-2
PLAGIOCLASE	29-33
ILMENITE	7.0
ARMALCOLITE	
CHROMITE	
ULVOSPINEL	
METAL	—
TROILITE	—
CRISTOBALITE	2-5
TRIDYMITE	—
MESOSTASIS	1.0
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



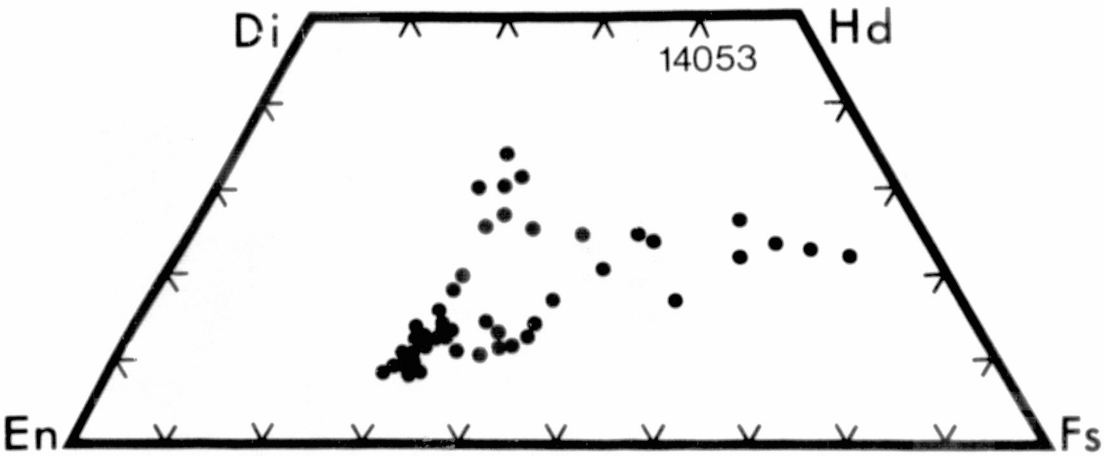
14053 Porphyritic Pyroxene Basalt

Sample 14053 was collected from the weathered surface of a boulder located 110 meters south of the rim of Cone Crater. The boulder is approximately 2 meters long and 1 meter high and contains a broad fillet which extends toward Cone Crater. Sample 14053 was taken from the eastern side of the rounded, friable boulder. The boulder is probably a breccia and 14053 a clast.

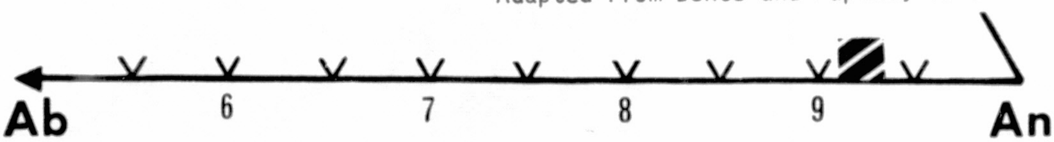
Sample 14053 is a medium grained porphyritic pyroxene basalt. It is characterized by subhedral to anhedral phenocrysts of pyroxene (1.0-1.6mm) set in an ophitic matrix of pyroxene anhedra (0.1-0.8mm) and euhedral to subhedral plagioclase tablets (0.2-0.8mm). Plagioclase tablets occur both ophitically intergrown with pyroxene anhedra and in masses interstitial to pyroxene phenocrysts. Opaque minerals and glass occupy interstitial areas between the larger silicate minerals. Ilmenite is the major opaque phase and is present as irregularly shaped bodies which contain rare lamellae of rutile. Troilite is present, typically in association with ilmenite or areas of mesostasis. Fe-Ni occurs as blebs randomly dispersed throughtout the matrix.

AGE DATA:	^{40}Ar-^{39}Ar plateau	- 3.95 ± .05 AE	Turner et al. (1971)
		3.95 ± .04 AE	Stettler et al. (1974)
		3.92 ± .08 AE	Husain et al. (1972)
	Rb-Sr isochron	- 3.96 ± .04 AE	Papanastassiou and Wasserburg (1971a)
	I_{Sr}	- 0.69948 ± 6	

ADDITIONAL REFERENCES: Kushiro et al. (1972); Gancarz et al. (1971).



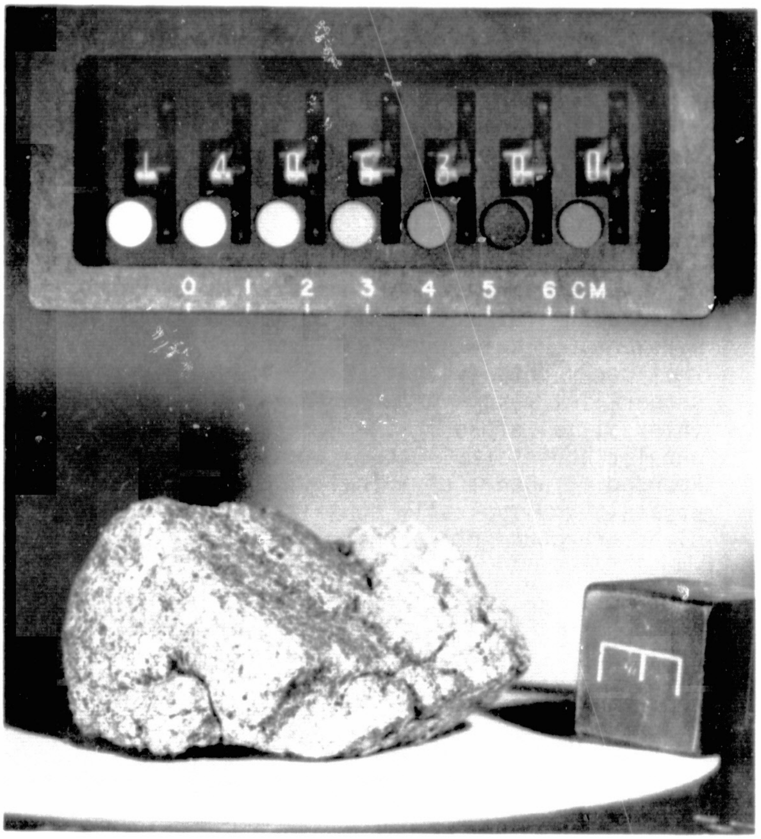
Adapted From Bence and Papike, 1972

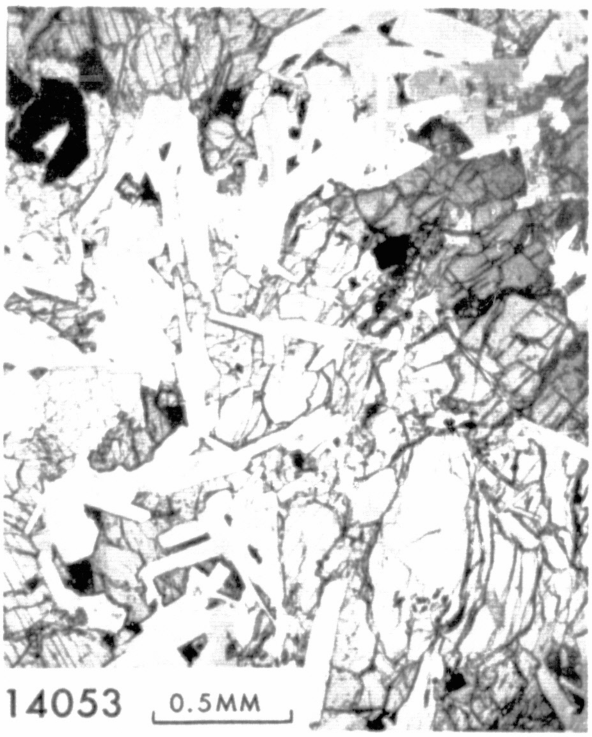


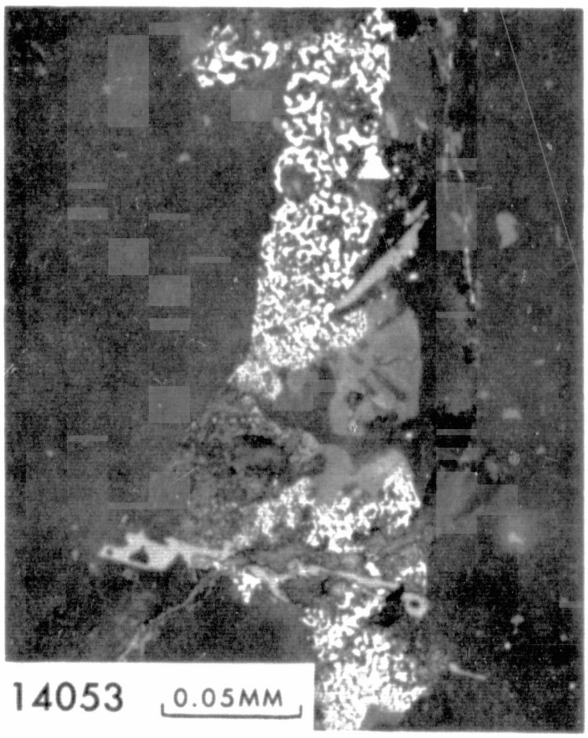
Adapted from Keil et al., 1971

14053
MODAL ANALYSIS (%)

PYROXENE	50
OLIVINE	—
PLAGIOCLASE	40
ILMENITE	3
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	—
METAL	—
TROILITE	tr
CRISTOBALITE	2
TRIDYMITE	—
MESOSTASIS	tr
PORE SPACE	—
PHOSPHATE	—
OTHERS	—




14053 0.5MM


14053 0.05MM

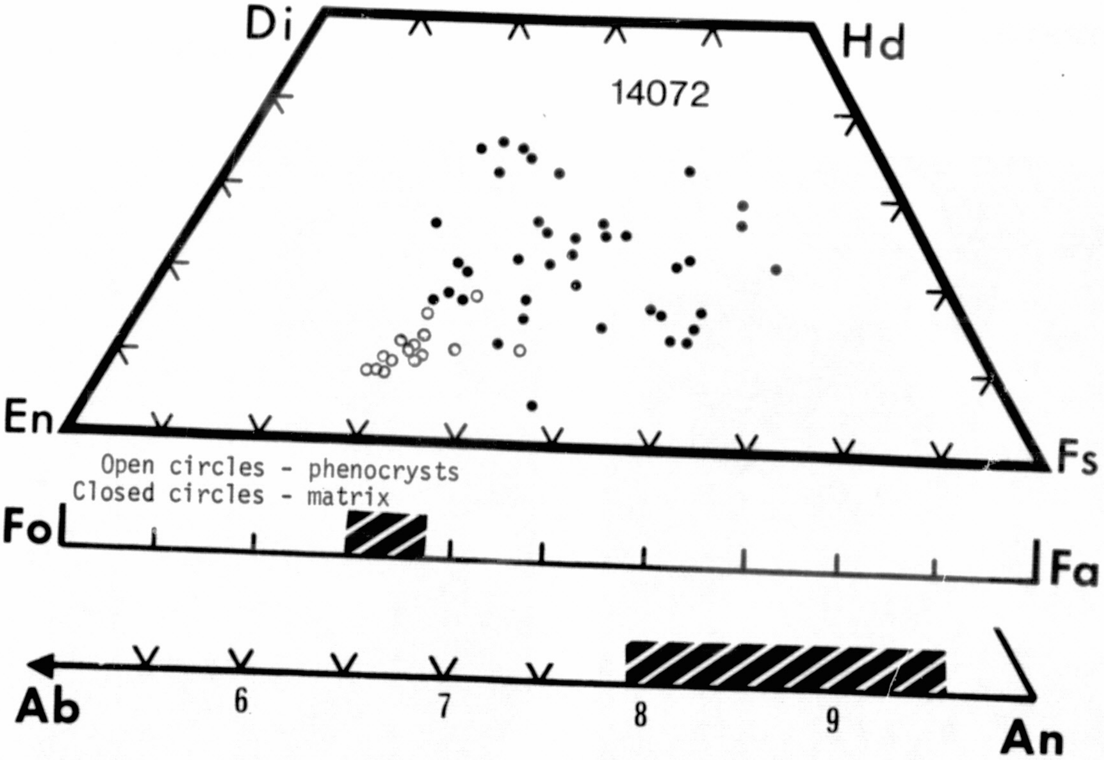
14072 Porphyritic Pyroxene Basalt

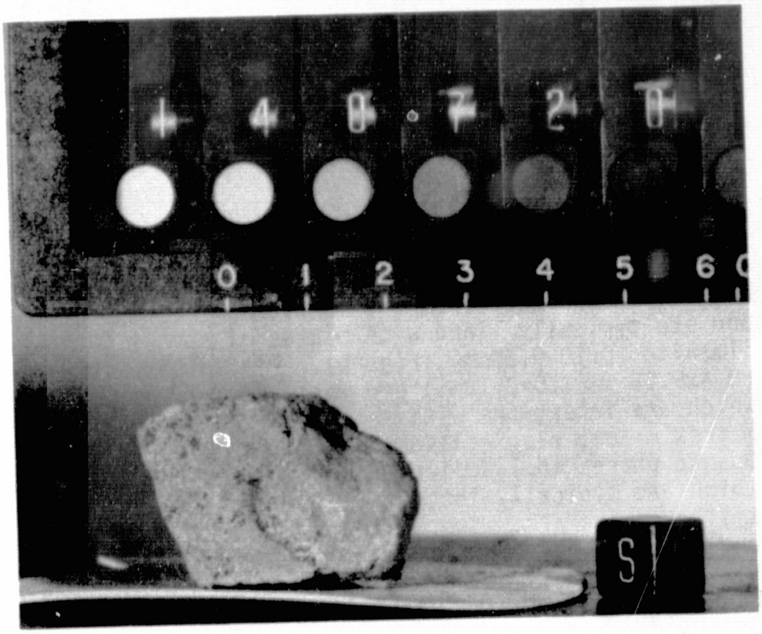
Sample 14072 was collected at Station C' from a large split boulder presumed to be ejected from Cone Crater. The boulder displays sharp fracture edges but is rounded similar to other boulders from the Cone Crater ejecta blanket.

Sample 14072 is a medium grained porphyritic basalt characterized by subhedral to anhedral pyroxene phenocrysts (0.2x0.4 to 1.0x2.0mm) and anhedral olivine phenocrysts (0.6mm) set in a subophitic matrix of subhedral plagioclase and pyroxene. Plagioclase is present as subhedral tablets (0.05x0.4 to 0.05x0.6mm) that occur both subophitically intergrown with pyroxene phenocrysts and in subparallel masses between the phenocrysts. Cristobalite and glass fill interstitial areas in the matrix. Ilmenite is present as irregularly shaped, angular bodies (0.1-0.4mm) and is commonly intergrown with silicate minerals. Rounded octahedra of spinel (0.01-0.05mm) are present as inclusions in pyroxene crystals and typically contain lamellae of ilmenite. Troilite and Fe-Ni metal blebs are abundant in the mesostasis.

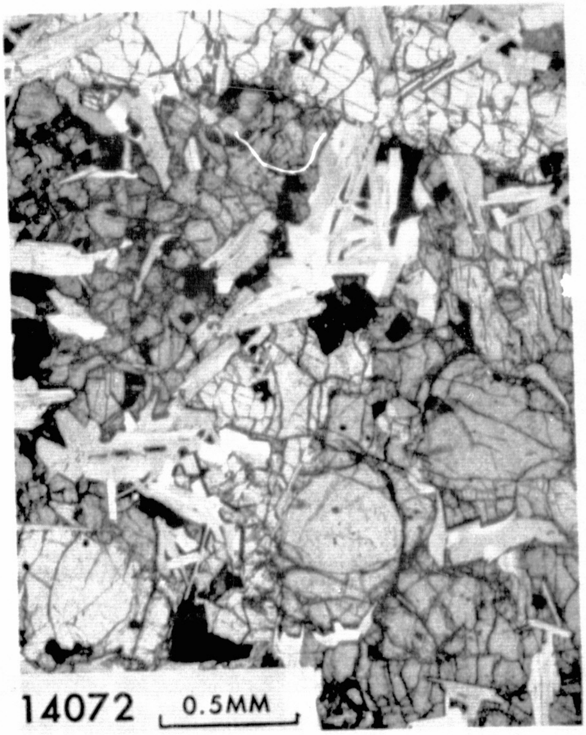
AGE DATA: $^{40}Ar-^{39}Ar$ plateau - 4.04 ± .05 AE York et al. (1972)

ADDITIONAL REFERENCES: Walker et al. (1972); Longhi et al. (1972)





14072 MODAL ANALYSIS (%)	
PYROXENE	50
OLIVINE	2-3
PLAGIOCLASE	38
ILMENITE	8
ARMALCOLITE	
CHROMITE	
ULVOSPINEL	
METAL	—
TROILITE	—
CRISTOBALITE	2
TRIDYMITE	—
MESOSTASIS	tr
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



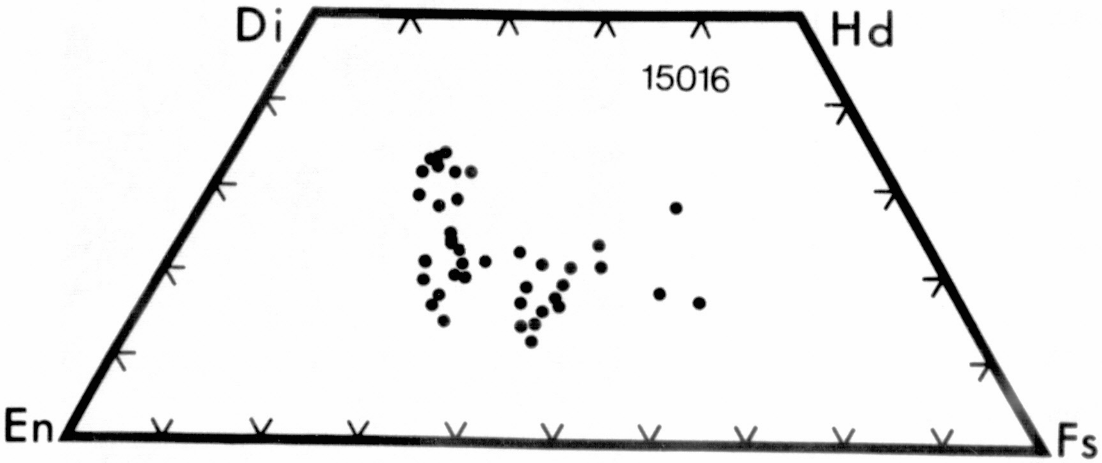
15016 Porphyritic, Vesicular Basalt

Sample 15016 was collected from the rim of a 50cm diameter crater located within a mare area at Station 3. The sample was plucked from the inner wall of the crater with the north end embedded in the regolith and the south end suspended above the crater wall.

Sample 15016 is a medium grained porphyritic, vesicular basalt characterized by subhedral to anhedral phenocrysts of pyroxene (1.0-2.0mm) and olivine (0.8-1.0mm) set in a matrix of subophitic intergrowths of plagioclase and pyroxene. Vesicles, ranging in diameter from 0.7 to 5.0mm, comprise approximately 50% of the sample and are typically lined with plates of spinel (0.05-0.10mm) and rounded laths of ilmenite (0.10-0.20mm) (Figure). Plagioclase is present as subhedral tablets (0.4x0.05 to 1.0x0.10mm) and more commonly as anhedra (0.40-1.0mm), both of which are intergrown with anhedral pyroxenes (0.1-0.8mm) to form the subophitic matrix. Some plagioclase tablets are hollow and contain cores of pyroxene. Opaque phases include irregularly shaped bodies of ilmenite (0.20-0.40mm) which are typically interstitial to silicate minerals but which rarely cut silicate minerals. Subrounded octahedra of spinel occur as inclusions in olivine and pyroxene phenocrysts and typically occur as clusters in the matrix. Troilite with Fe-Ni metal inclusions is associated with areas of mesostasis and also occurs as blebs in the matrix.

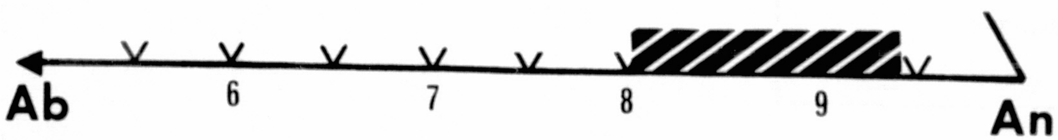
AGE DATA: Rb-Sr isochron - 3.29 ± .05 AE; I_{Sr} - 0.69914 ± 5 } Evensen et al. (1973)

ADDITIONAL REFERENCES: Rhodes and Hubbard (1973); Papike et al. (1976); Kesson (1975); Bence and Papike (1972).



Adapted from Bence and Papike, 1972

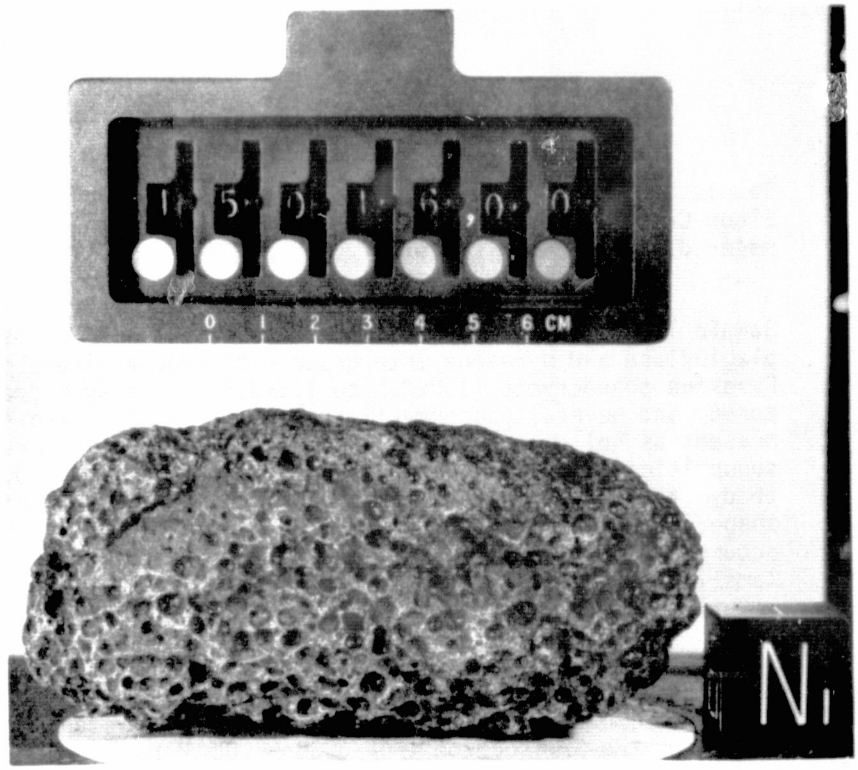
Adapted from Bence and Papike, 1972

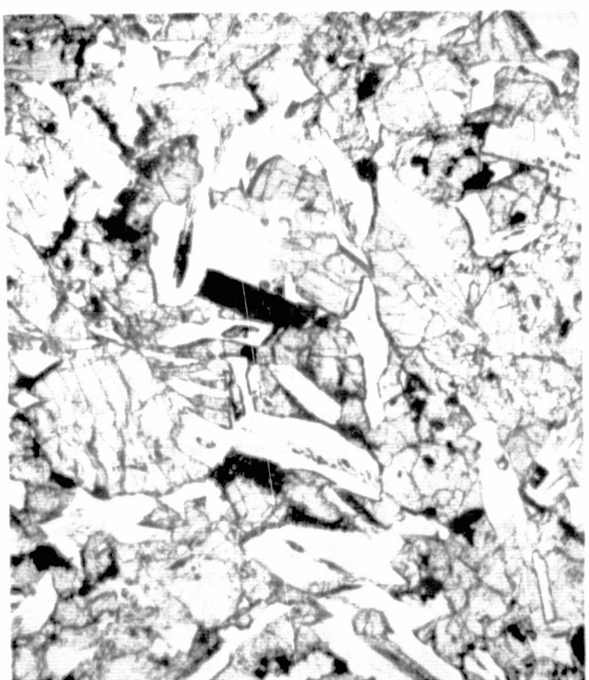


Adapted from Bence and Papike, 1972

15016
MODAL ANALYSIS (%)

PYROXENE	64-67
OLIVINE	7-8
PLAGIOCLASE	20-22
ILMENITE	6.0
ARMALCOLITE	—
CHROMITE	0.1
ULVOSPINEL	0.4
METAL	—
TROILITE	—
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	0.3
PORE SPACE	—
PHOSPHATE	—
OTHERS	—





15016 0.5MM

15016 0.1MM

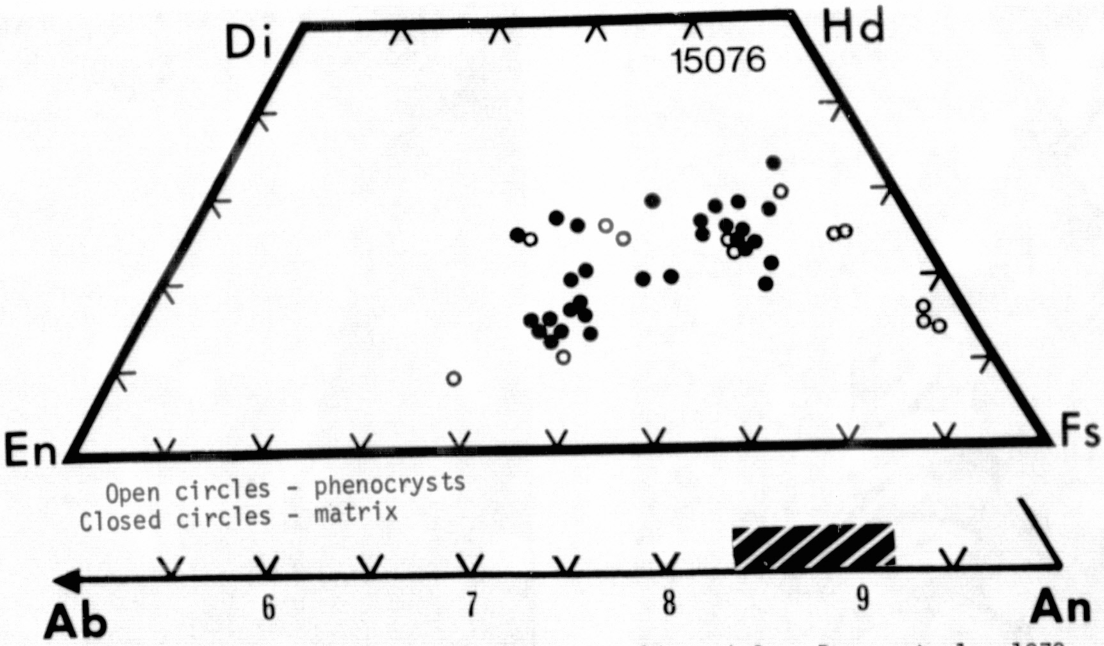
15076 Porphyritic Pyroxene Basalt

Sample 15076 was collected approximately 25 meters east of the rim crest of Elbow Crater. It is believed to be part of the ejecta blanket from the 400 meter diameter Elbow Crater.

Sample 15076 is a porphyritic pyroxene basalt with a subophitic matrix of plagioclase and pyroxene intergrown with opaque minerals. Glass fills interstices. Pyroxene phenocrysts (1.0x2.5 to 1.5x3.5mm) are subhedral to anhedral, typically zoned, and several phenocrysts are overgrown with pyroxferroite. Plagioclase is present as hollow tablets (0.2-2.0mm) which contain cores of pyroxene and are subophitically intergrown with anhedral pyroxene (0.2-0.8mm), and laths of tridymite (0.2-0.8mm). The major opaque phase is ilmenite, present as irregularly shaped, rounded bodies (0.2-0.5mm) and as rare rounded laths (0.4-0.6mm). Spinel occurs as subrounded octahedra (0.2mm) and as anhedral grains with ilmenite (?) lamellae. Troilite is present in the mesostasis and occurs in close association with ilmenite.

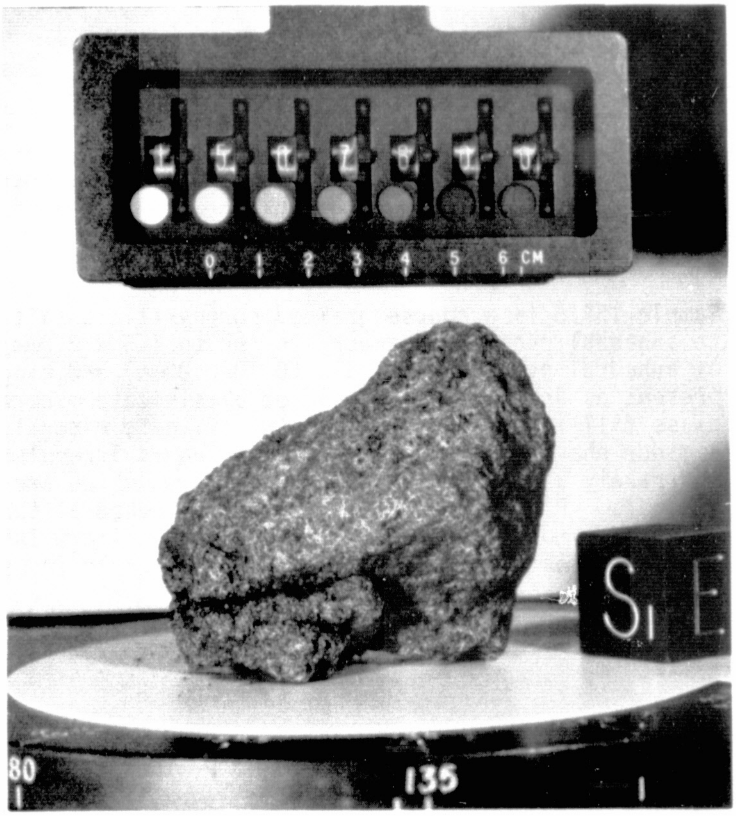
AGE DATA: ^{40}Ar-^{39}Ar plateau - 3.35 ± .04 AE Stettler et al. (1974)
3.35 ± .15 AE Kirsten et al. (1973)
Rb-Sr isochron - 3.33 ± .08 AE } Papanastassiou and Wasserburg (1973)
I_{Sr} - 0.69927 ±8

ADDITIONAL REFERENCES: Brown et al. (1972); Rhodes and Hubbard (1973); Lofgren et al. (1974).



Adapted from Brown et al., 1972

15076 MODAL ANALYSIS (%)	
PYROXENE	53-66
OLIVINE	—
PLAGIOCLASE	28-36
ILMENITE	0.5
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	1.4
METAL	—
TROILITE	0.5
CRISTOBALITE	2-6
TRIDYMITE	—
MESOSTASIS	0.6
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



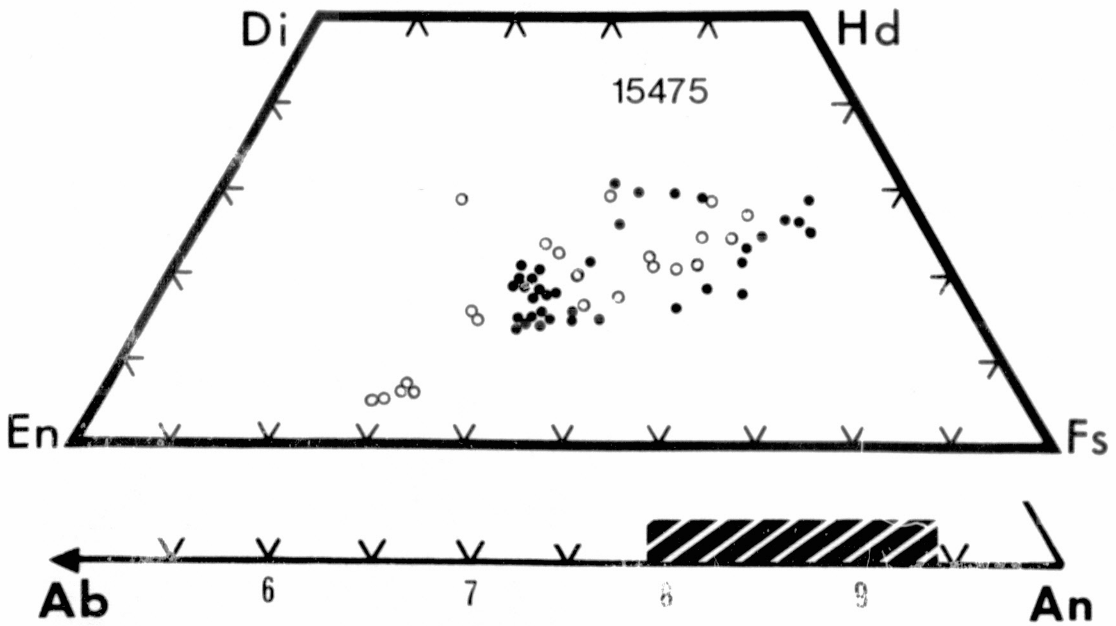
15076 , 0.5MM ,

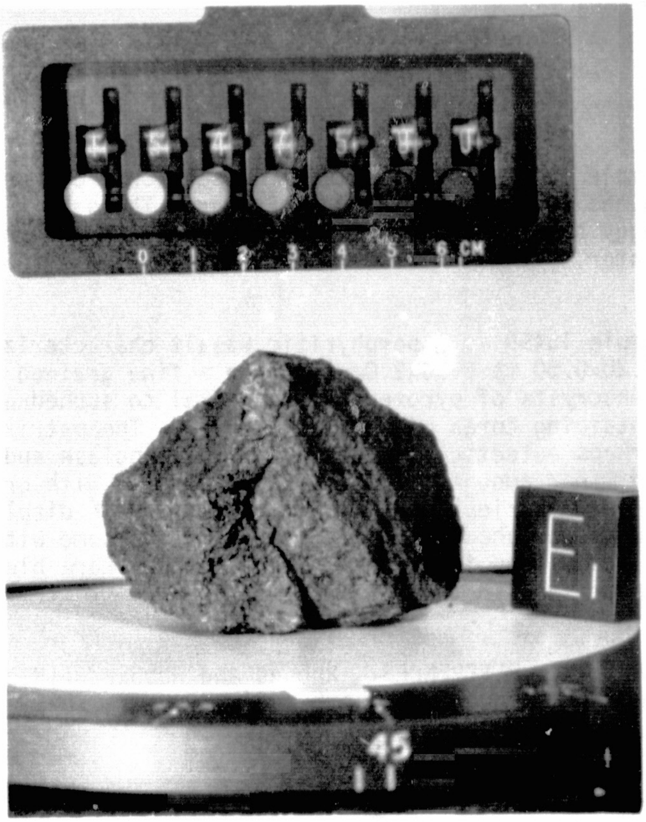
15475 Porphyritic Pyroxene Basalt

Sample 15475 was collected near Station 4, 28 meters south-southeast of the rim crest of Dune Crater. Small craters in the near vicinity are sparse and lineaments are not visible. There is a lack of filleting of fragments in the area and no rock fragments are buried.

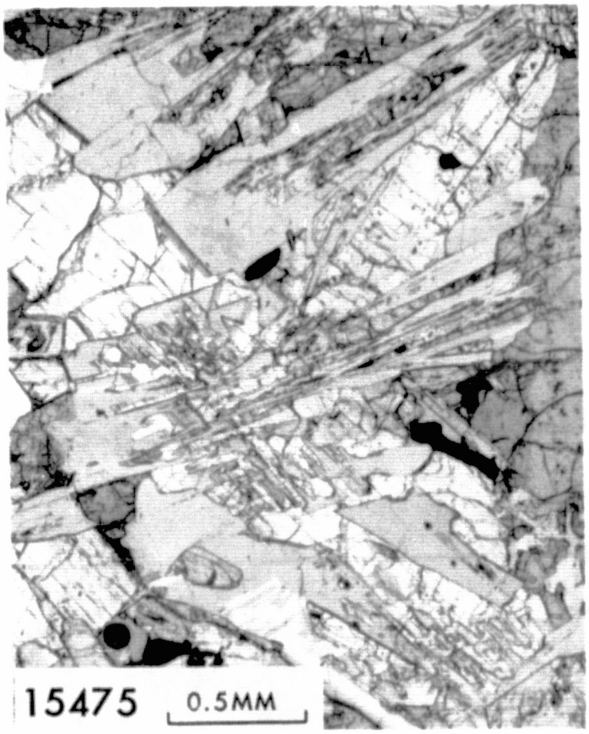
Sample 15475 is a coarse grained porphyritic basalt characterized by subhedral to anhedral pyroxene phenocrysts (up to 1.5 x 3.0mm) in a subophitic matrix of anhedral pyroxene crystals (0.10-0.80mm) and plagioclase. Pore space is present as angular voids enclosed by silicate minerals. Cristobalite and glass fill interstices between the silicate minerals. Ilmenite is present as a minor phase only, typically occurring as irregularly shaped bodies (0.50-1.0mm) and rarely as rounded laths (0.60-0.90mm) which are interstitial to the silicate minerals. Plagioclase occurs as hollow euhedral tablets (0.10-0.60mm) containing cores of pyroxene and more commonly as cruciform intergrowths up to 2.0mm. Rare blebs of troilite occur randomly in the sample in association with the mesostasis.

ADDITIONAL REFERENCES: Rhodes and Hubbard (1973); Takeda et al. (1975).





15475 MODAL ANALYSIS (%)	
PYROXENE	64
OLIVINE	—
PLAGIOCLASE	24
ILMENITE	1.0
ARMALCOLITE	—
CHROMITE	0.5
ULVOSPINEL	1.0
METAL	—
TROILITE	—
CRISTOBALITE	2.0
TRIDYMITE	0.6
MESOSTASIS	2.0
PORE SPACE	6.0
PHOSPHATE	—
OTHERS	—

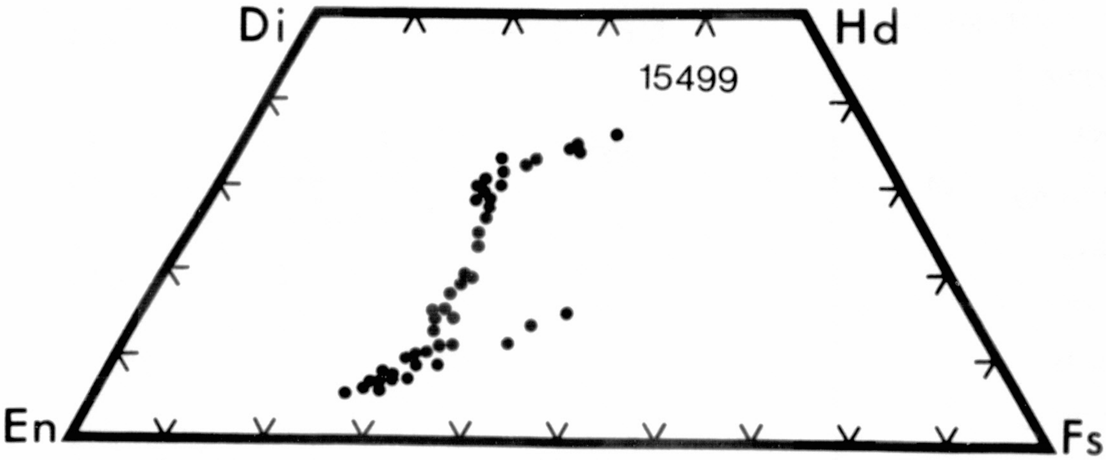


15499 Porphyritic Basalt Vitrophyre

Sample 15499 was collected from Station 4 of the Apollo 15 landing site located on the southern rim of Dune Crater. The sample was taken from a macro-vesicular, vuggy basalt boulder (2.0mx1.0mx0.5m) at the rim crest of the 460m diameter crater.

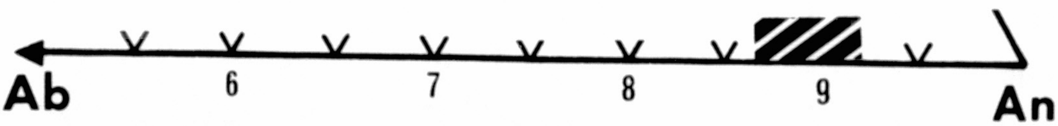
Sample 15499 is a porphyritic basalt characterized by phenocrysts of zoned pyroxene (0.20x0.50 to 0.50x2.0mm) set in a fine grained matrix of plagioclase and pyroxene. Phenocrysts of pyroxene are euhedral to subhedral and typically skeletal, containing cores of matrix material. The matrix consists of an interconnecting, perhaps eutectic, intergrowth of plagioclase and pyroxene with abundant glass and minor amounts of ilmenite (Figure). With crossed polars the intergrowths appear as oriented, feathery bundles which display optical continuity. Small rounded octahedra of chromite (0.05mm), some with rims of ulvospinel, are present as inclusions in pyroxene phenocrysts. Rare blebs of troilite and Fe-Ni metal are present in the matrix.

ADDITIONAL REFERENCES: Rhodes and Hubbard (1973); Humphries et al. (1972); Papanastassiou and Wasserburg (1973).



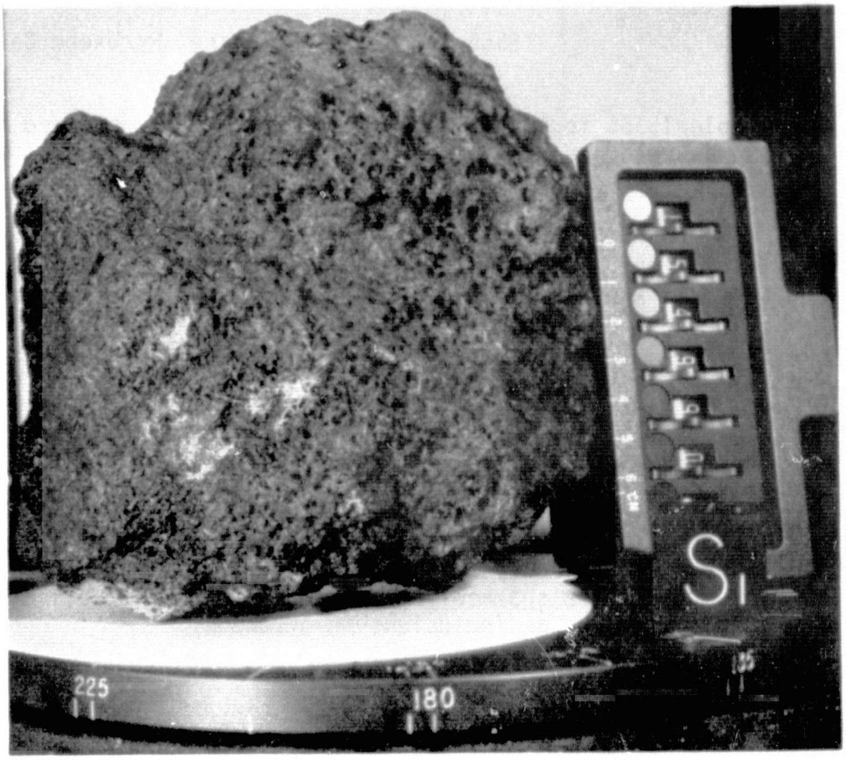
Adapted from Bence and Papike, 1972

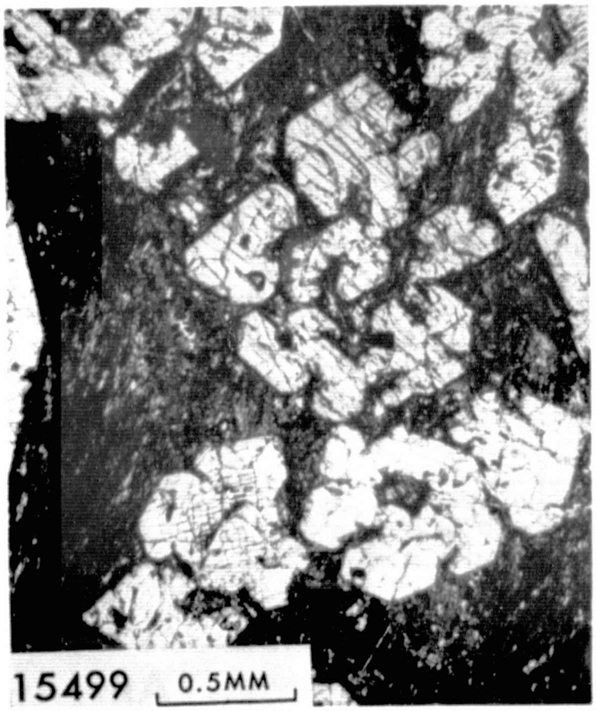
Adapted from Bence and Papike, 1972

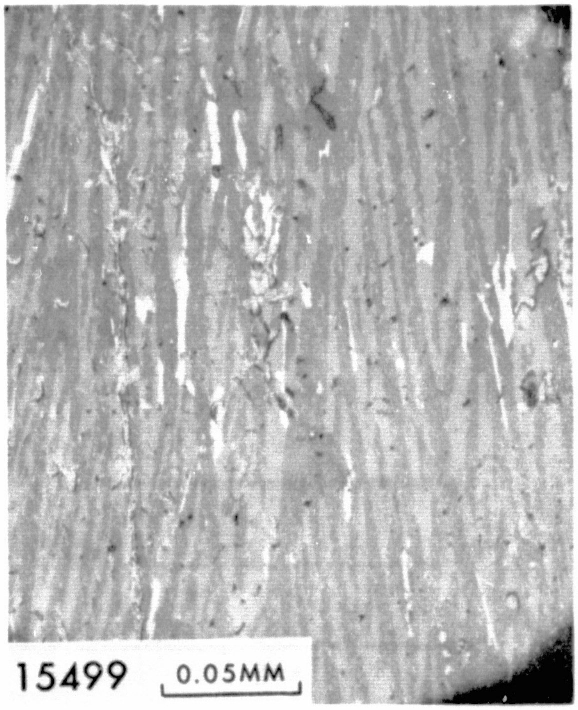


15499
MODAL ANALYSIS (%)

PYROXENE	42
OLIVINE	1.0
PLAGIOCLASE	—
ILMENITE	—
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	—
METAL	—
TROILITE	—
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	57
PORE SPACE	—
PHOSPHATE	—
OTHERS	—







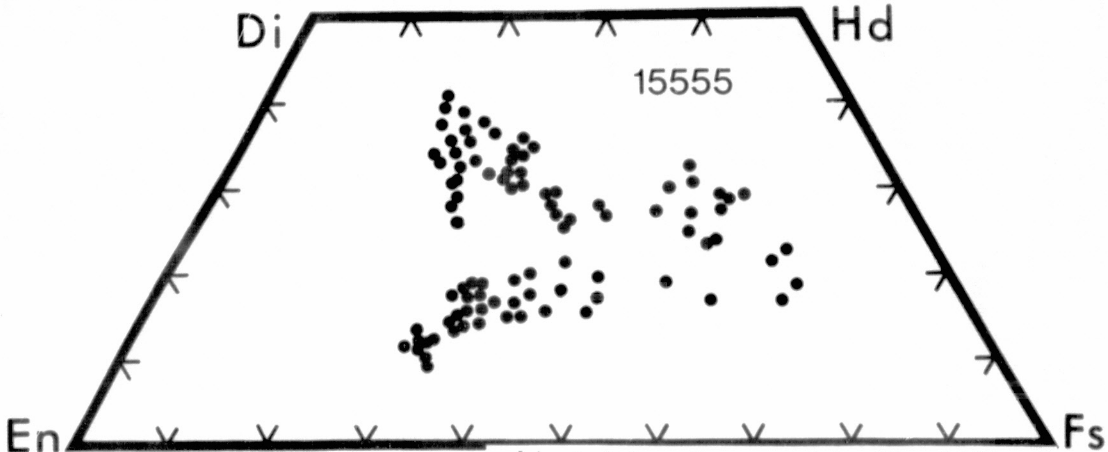
15555 Porphyritic Olivine, Pyroxene Basalt

Sample 15555 is the largest rock sample to be returned from the lunar surface. It was recovered from Station 9A, located 12 meters north of the rim of Hadley Rille.

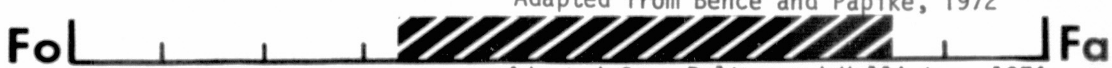
Sample 15555 is a coarse grained porphyritic olivine, pyroxene basalt. It is characterized by subrounded to rounded olivine phenocrysts (0.8-1.0mm) and subhedral phenocrysts of zoned pyroxene (0.5-2.0mm) in a matrix of poikilitic plagioclase megacrysts (0.9x1.5 to 1.0x3.0mm) which enclose euhedral grains of olivine and pyroxene (0.1-0.3mm). A small amount of irregular pore space is enclosed by the silicate minerals. Interstices between the plagioclase megacrysts are filled with opaque minerals, cristobalite, and glass. Irregularly shaped bodies of ilmenite (0.1-0.6mm) typically occupy interstitial areas but a few rare, rounded laths (0.4-0.8mm) cut silicate minerals. Subrounded octahedra of chromite (0.05-0.1mm), some with rims of ulvospinel, are present as inclusions in pyroxene phenocrysts. Rare inclusions of olivine (0.05mm) are also present in pyroxene phenocrysts. Blebs of troilite, commonly in association with the mesostasis, are sparesely dispersed throughout the section. Fe-Ni metal is rare and occurs as inclusions in pyroxene.

AGE DATA: ^{40}Ar-^{39}Ar plateau - 3.33 ± .05 AE Alexander et al. (1972)
Rb-Sr isochron - 3.32 ± .04 AE } Papanastassiou and Wasserburg (1973)
I_{Sr} - 0.69930 ± 3 }

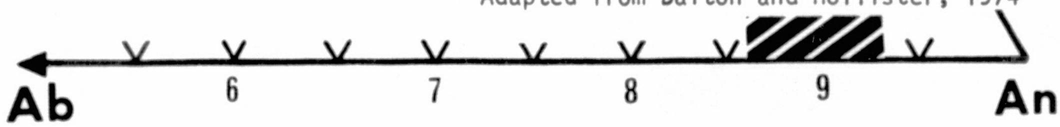
ADDITIONAL REFERENCES: Brown et al. (1972); Longhi et al. (1972) Rhodes and Hubbard (1973); Papike et al. (1976); Kesson (1975); Bence and Papike (1972).



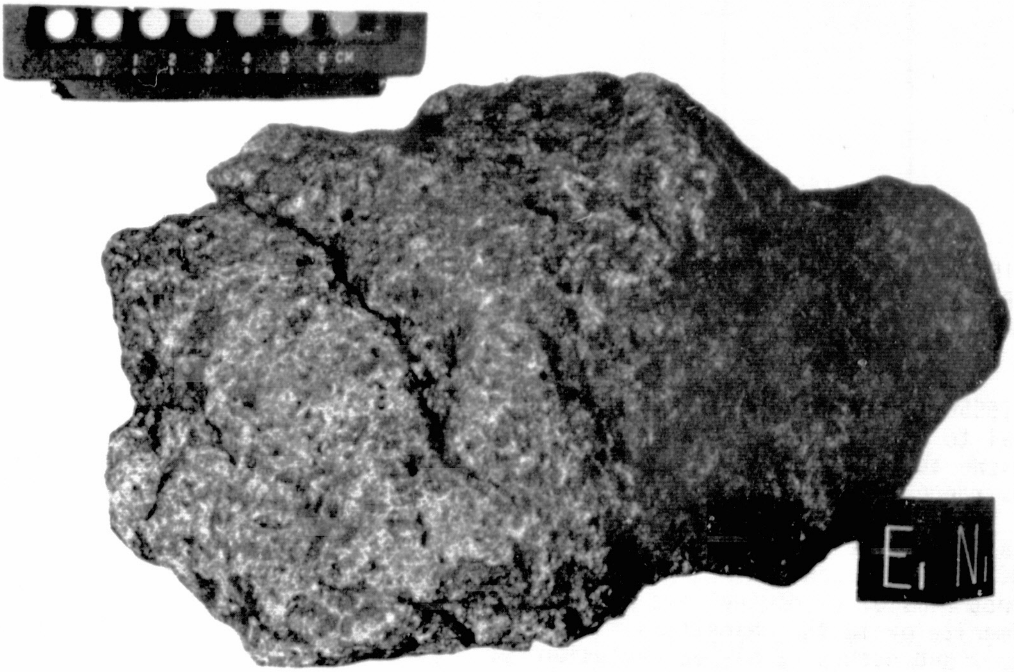
Adapted from Bence and Papike, 1972



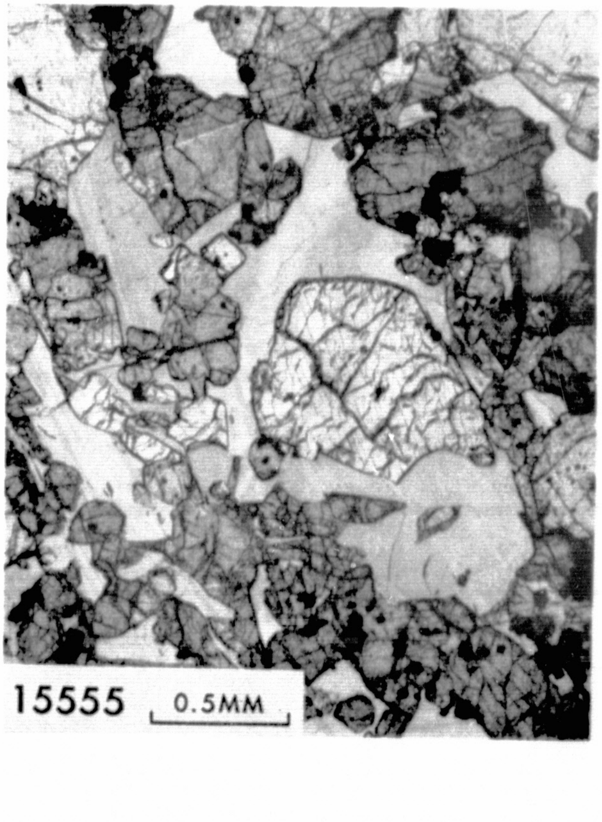
Adapted from Dalton and Hollister, 1974



Adapted from Dalton and Hollister, 1974



15555 MODAL ANALYSIS (%)		
PYROXENE	52-65	
OLIVINE	5-12	
PLAGIOCLASE	25-30	
ILMENITE	1	~5
ARMALCOLITE	—	
CHROMITE	0.5	
ULVOSPINEL	2	
METAL	—	
TROILITE	—	
CRISTOBALITE	0.3-2.0	
TRIDYMITE	—	
MESOSTASIS	0.2-0.4	
PORE SPACE	—	
PHOSPHATE	—	
OTHERS	—	

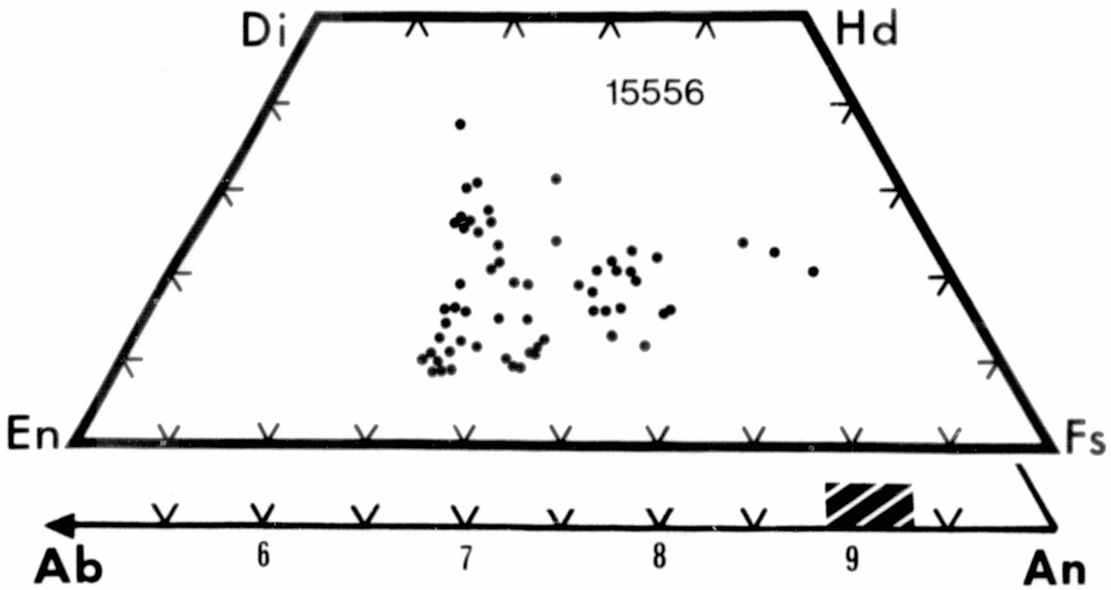


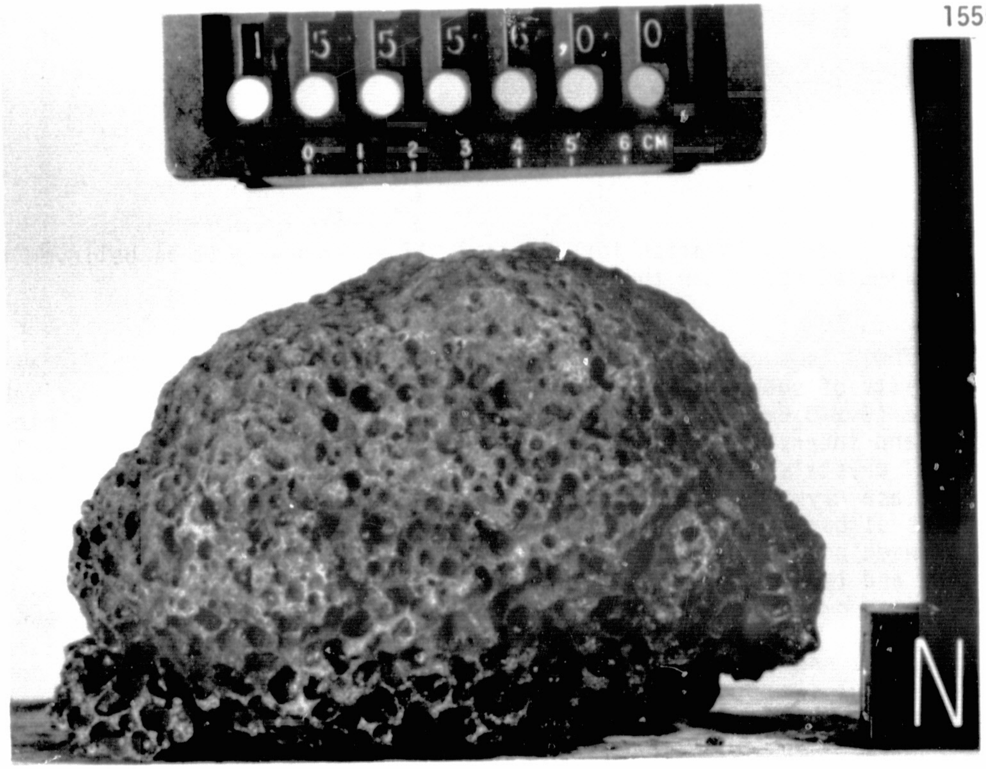
15556 Porphyritic, Vesicular Basalt

Sample 15556 was collected approximately 60 meters northeast of the rim of Hadley Rille at Station 9A. It was located 1 meter west of a 20 centimeter, fresh crater but is not believed to be related to that crater.

Sample 15556 is a fine grained porphyritic vesicular basalt characterized by subhedral to anhedral pyroxene phenocrysts (0.4-0.6mm) set in a subophitic matrix of pyroxene anhedra (0.1-0.4mm) and plagioclase tablets (0.1x0.4mm to 0.2x0.8mm). Vesicles range in diameter from 3.5 to 5.0mm and comprise approximately 50% of the sample. Opaque minerals and glass occupy interstitial areas between silicate minerals. Ilmenite is the major opaque phase and is present as rounded laths (0.05-0.1mm) with reentrants. Rounded octahedra of chromite (0.02-0.05mm) with indistinct rims of ulvospinel are also present. Troilite occurs in association with ilmenite or in the mesostasis. Native iron is randomly dispersed throughout the matrix and occurs rarely as inclusions in troilite.

ADDITIONAL REFERENCES: Rhodes and Hubbard (1973); Humphries et al. (1972).





15556
MODAL ANALYSIS (%)

PYROXENE	57
OLIVINE	0.1
PLAGIOCLASE	38
ILMENITE	2.0
ARMALCOLITE	—
CHROMITE	0.4
ULVOSPINEL	0.6
METAL	—
TROILITE	0.1
CRISTOBALITE	1.0
TRIDYMITE	—
MESOSTASIS	1.0
PORE SPACE	—
PHOSPHATE	—
OTHERS	—

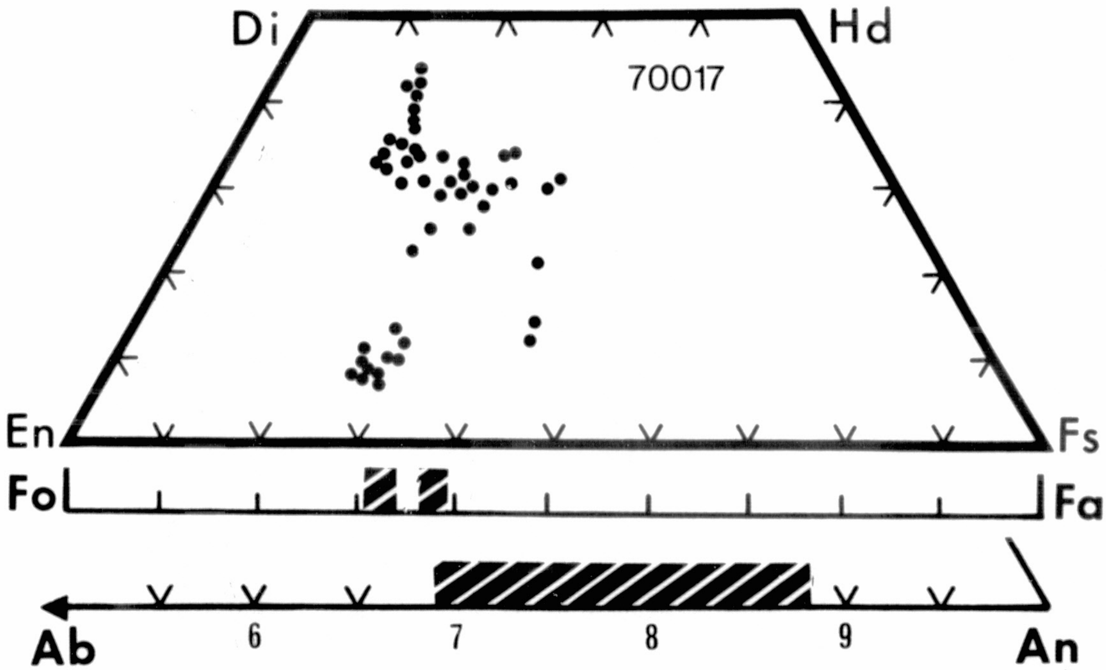
70017 Poikilitic Plagioclase Basalt

The exact recovery location for sample 70017 is unknown; it is believed to have been collected very near the front of the LM.

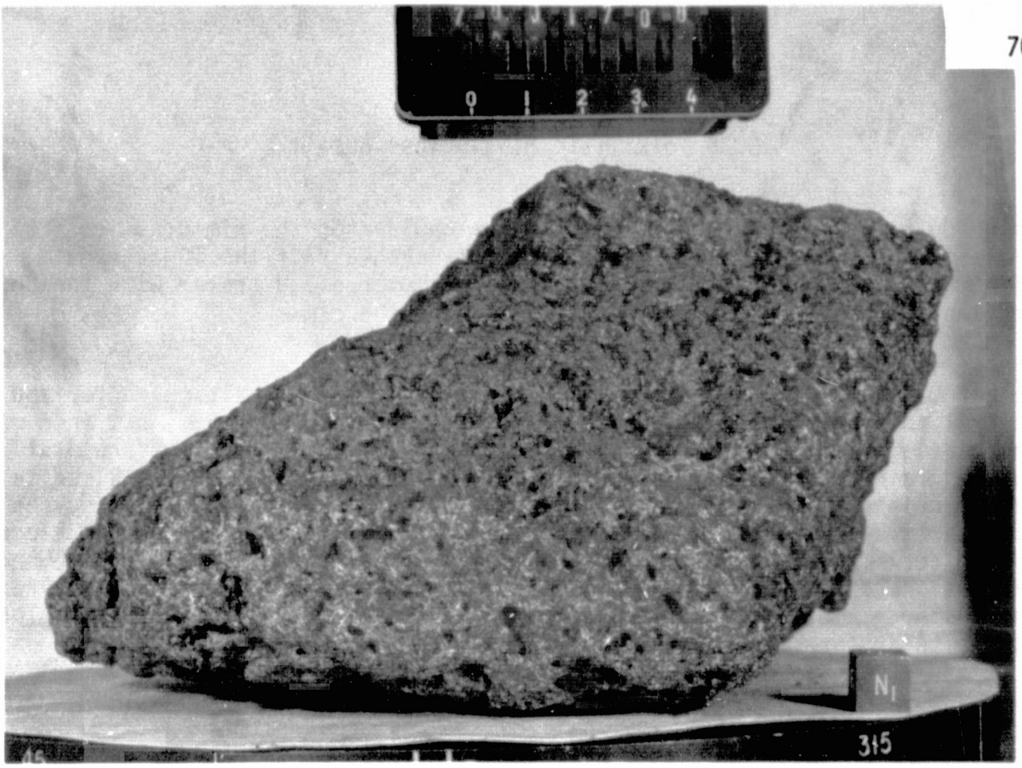
Sample 70017 is a coarse grained poikilitic plagioclase basalt characterized by phenocrysts of subhedral pyroxene (0.8-2.0mm) and smaller crystals of anhedral pyroxene (0.2-0.6mm) and ilmenite (up to 1.0mm), all of which occur both enclosed within and interstitial to large crystals (up to 5.0mm) of poikilitic plagioclase. Anhedral crystals of olivine (0.1-0.2mm) occur exclusively within poikilitic plagioclase crystals. Pyroxene phenocrysts commonly enclose anhedral ilmenite and crystals of barrel-shaped armalcolite (0.1-0.2mm). Ilmenite crystals (both within and between poikilitic plagioclase) occur as irregularly shaped bodies with sieve texture and typically contain lamellae of rutile and chromite. Patches of mesostasis commonly occur interstitial to large plagioclase crystals and pyroxene phenocrysts. They are composed of varying combinations of brown glass, cristobalite and tridymite; trace amounts of ilmenite and Fe-Ni metal commonly occur as inclusions in the glass. Troilite and Fe-Ni metal occur randomly dispersed throughout the sample.

AGE DATA: Rb-Sr isochron - 3.68 ± .18 AE } Nyquist et al. (1975)
I_{Sr} - 0.69920 ± 4

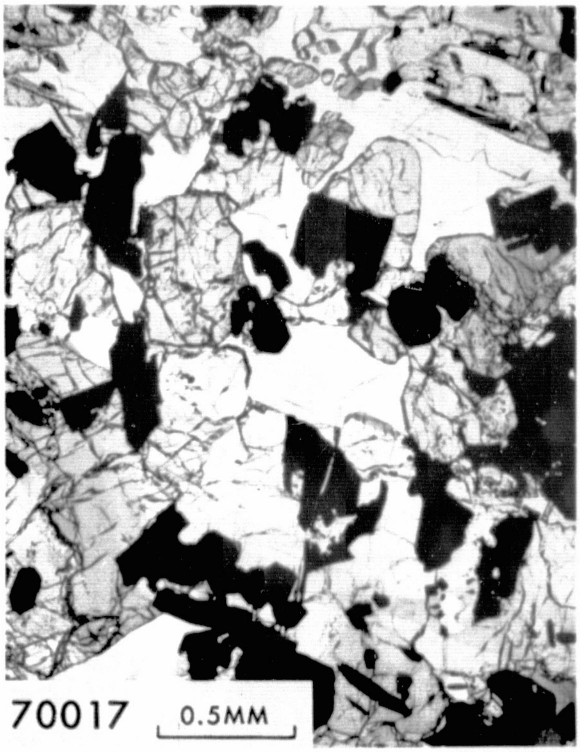
ADDITIONAL REFERENCES: McCallum et al. (1974); Rutherford et al. (1974); Longhi et al. (1974).



Adapted from Longhi et al., 1974



70017 MODAL ANALYSIS (%)	
PYROXENE	49-58
OLIVINE	0.4-1.0
PLAGIOCLASE	20-25
ILMENITE	19-23
ARMALCOLITE	
CHROMITE	
ULVOSPINEL	
METAL	0.4
TROILITE	—
CRISTOBALITE	1-2
TRIDYMITE	—
MESOSTASIS	0.3-1.0
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



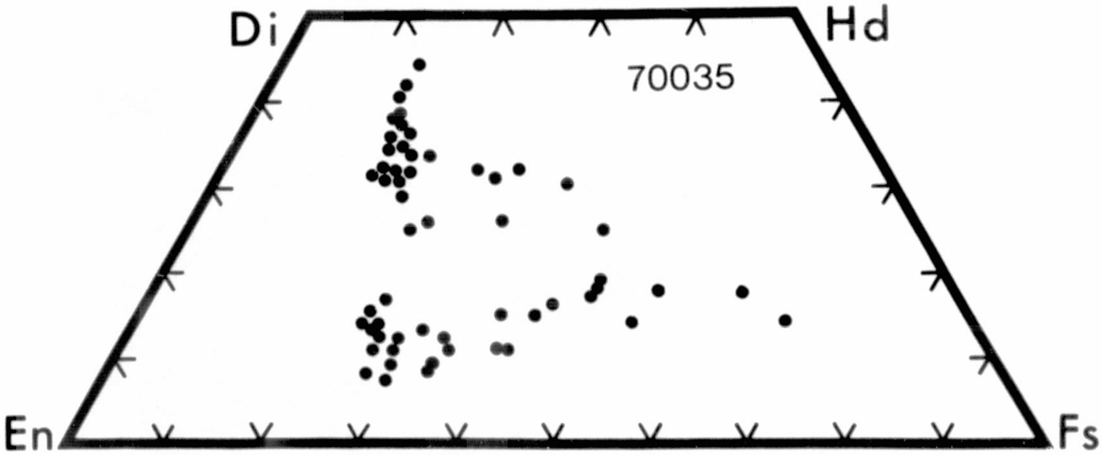
70035 Poikilitic Plagioclase Basalt

Sample 70035 was collected from a 1.5 meter boulder on the rim crest of a 25 m diameter crater approximately 45 meters east-northeast of the lunar module. The fragment population is extremely low for a 25 meter sized crater with the boulder being the only rock in the intermediate area of the rim.

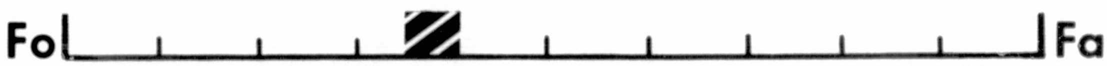
Sample 70035 is a coarse grained poikilitic plagioclase basalt characterized by subhedral to anhedral pyroxene phenocrysts (0.8x2.0 to 1.0x2.5mm) set in a matrix of plagioclase megacrysts (1.0x4.0mm) which poikilitically enclose anhedral pyroxene grains (0.1-0.6mm), rounded olivine grains (0.1-0.3mm) and ilmenite. Anhedral cristobalite, glassy mesostasis, and irregularly shaped pore spaces fill interstices between the silicate minerals. Ilmenite is present as blocky crystals (0.3-1.0mm) which typically display a sieve texture and occur commonly as inclusions in plagioclase oikocrysts. Several ilmenite crystals cut pyroxene phenocrysts. Lamellae of rutile are abundant in the ilmenite crystals. Blebs of troilite are present in the mesostasis or in close association with ilmenite.

AGE DATA:	^{40}Ar-^{39}Ar plateau	- 3.74 ± .07 AE	Nyquist et al. (1973)
	Rb-Sr isochron	- 3.81 ± .20 AE	Nyquist et al. (1973)
		3.83 ± .10 AE	Chappel et al. (1973)
		3.82 ± .06 AE	Murthy et al. (1973)
		3.82 ± .07 AE	Evensen et al. (1973)
	I_{Sr}	- 0.69923 ± 3	Evensen et al. (1973)

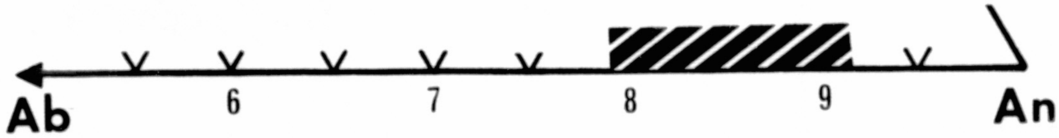
ADDITIONAL REFERENCES: Cassidy and Hapke (1973); Brown et al. (1975); Roedder and Weiblen (1975); Green et al. (1975);Papike et al. (1974).

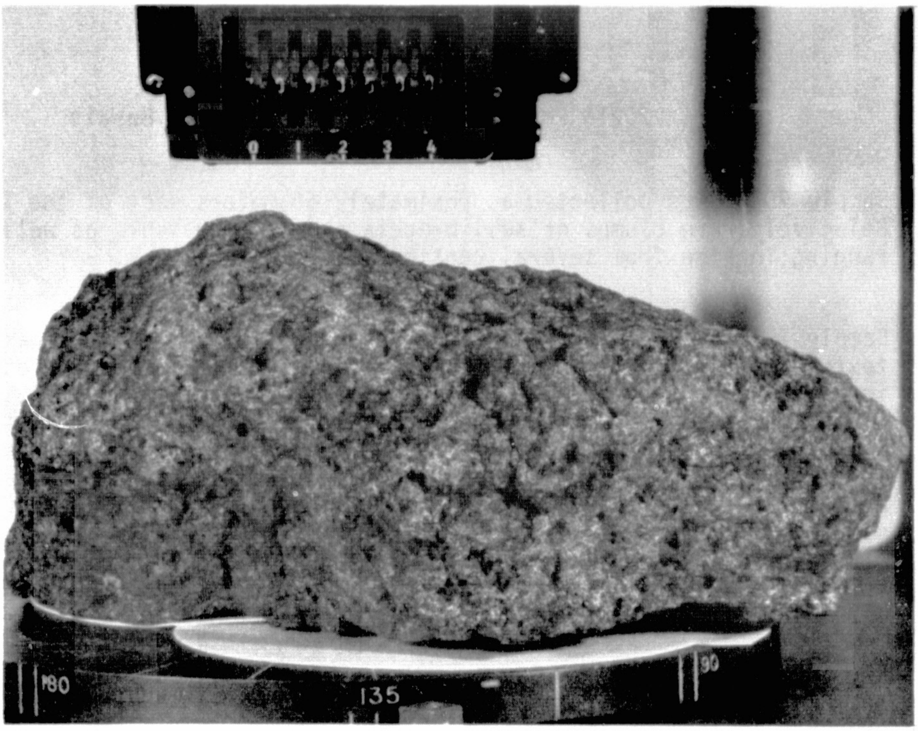


Adapted from Papike et al., 1974



Adapted from Papike et al., 1974





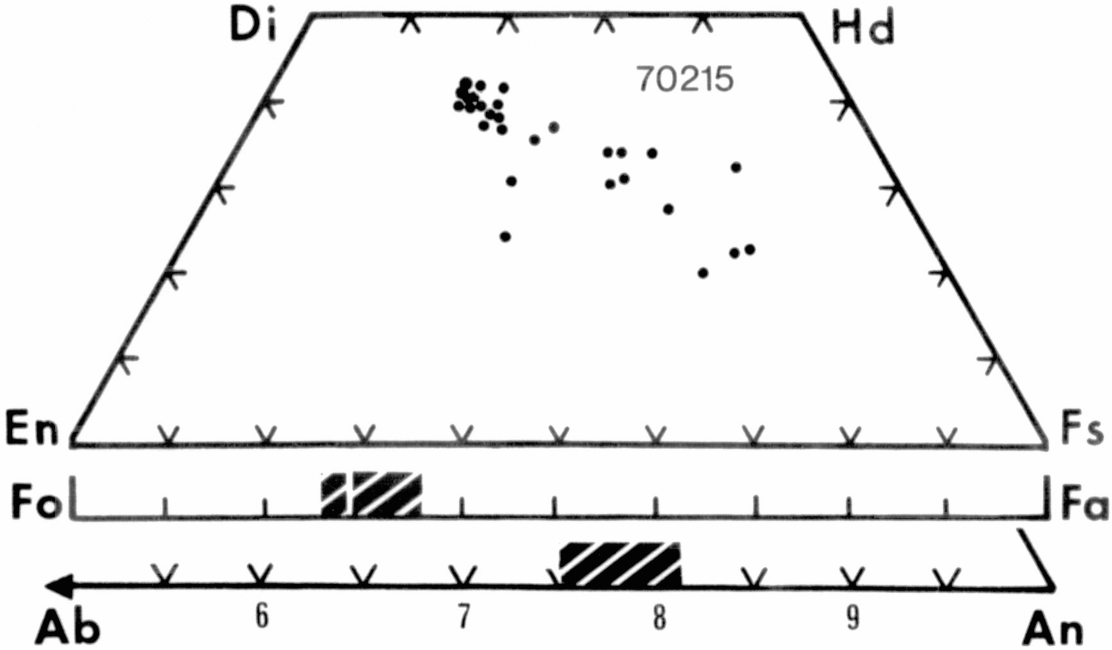
70035 MODAL ANALYSIS (%)	
PYROXENE	46-57
OLIVINE	1-3
PLAGIOCLASE	22-26
ILMENITE	15-24
ARMALCOLITE	
CHROMITE	
ULVOSPINEL	
METAL	0.4
TROILITE	—
CRISTOBALITE	2.0
TRIDYMITE	—
MESOSTASIS	0.4-4.0
PORE SPACE	2.0
PHOSPHATE	—
OTHERS	—

70215 Porphyritic Olivine, Pyroxene Basalt

Sample 70215 was collected approximately 65 meters east of the lunar module. Relatively rare clumps of soil breccia are also present, as well as blocks ranging in size from several centimeters up to 4 meters.

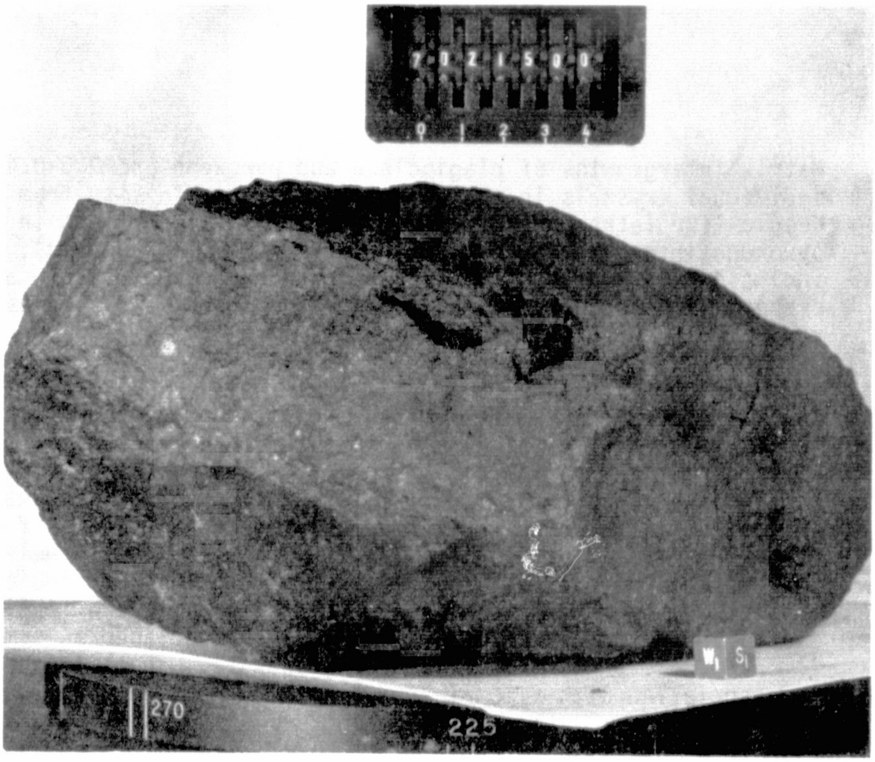
Sample 70215 is a fine grained porphyritic olivine, pyroxene basalt with two texturally distinct regions. Both regions are not commonly present together in a single thin section but both are present in sections 70215,145 and 70215,147 from which these descriptions were made. One region is finer-grained and consists of phenocrysts of olivine and ilmenite in a groundmass of fan-shaped intergrowths of plagioclase and pyroxene. The other region is coarser grained and contains essentially equal size olivine and pyroxene phenocrysts (0.3-0.8mm) set in a matrix consisting of feathery to acicular intergrowths of subparallel plagioclase and pyroxene crystals. Both regions contain a small amount of irregular pore space and rare vesicles 0.05 to 0.1mm in diameter. The two regions are intimately intergrown; contacts are gradational.

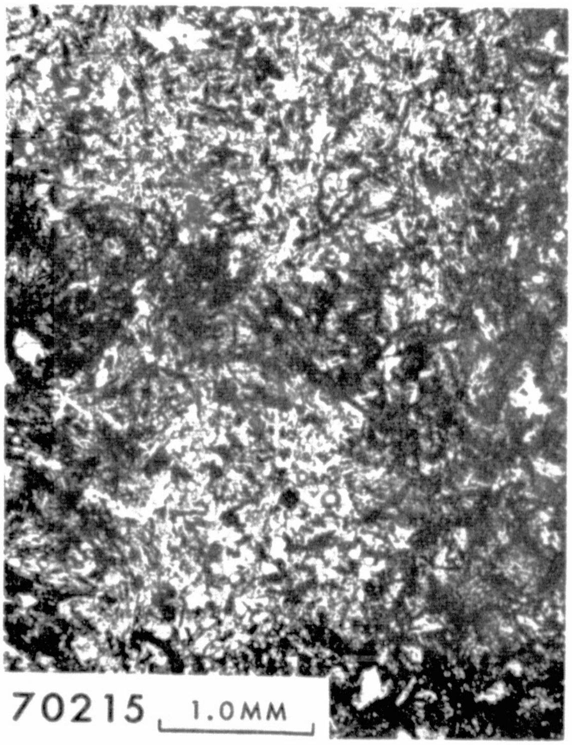
In the fine grained region olivine displays a variety of shapes including elongate, hollow prisms (0.1x0.4 to 0.2x0.8mm), equant and subequant grains (0.1-0.3mm) and skeletal, euhedral phenocrysts (0.1-0.3mm). Ilmenite phenocrysts occur as equant grains (0.4mm) and as laths (0.6-2.0mm) with irregular jagged edges which commonly contain cores of armalcolite and lamellae of rutile.

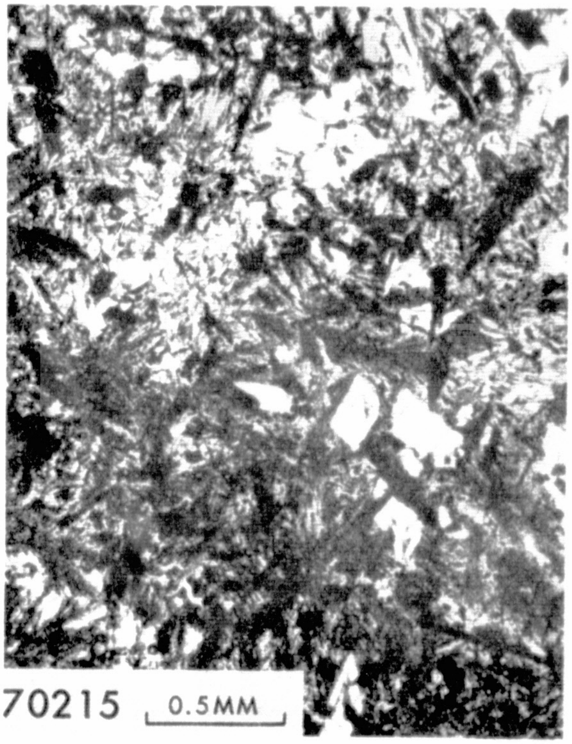


Adapted from Dymek et al., 1975

70215 MODAL ANALYSIS (%)	
PYROXENE	41-58
OLIVINE	6-9
PLAGIOCLASE	13-29
ILMENITE	13-37
ARMALCOLITE	0.2
CHROMITE	——
ULVOSPINEL	tr
METAL	——
TROILITE	tr
CRISTOBALITE	4.0
TRIDYMITE	——
MESOSTASIS	——
PORE SPACE	——
PHOSPHATE	——
OTHERS	tr*




70215 1.0MM


70215 0.5MM

Matrix intergrowths of plagioclase and pyroxene are 0.3-0.4mm in length and individual crystals in the intergrowths range in size from 0.05-0.10mm. Needle-like laths of ilmenite (0.05mm) are also present in the plagioclase, pyroxene intergrowths. Octahedra of spinel (0.03-0.05mm), commonly with ilmenite inclusions, are present in olivine phenocrysts. Troilite and native iron are present in association with ilmenite and spinel and also as blebs scattered randomly in the matrix.

In the coarser grained region, phenocrysts of pyroxene (0.2-0.6mm) and olivine (0.1-0.6mm) are typically anhedral but rare subhedral phenocrysts of each may be present. Several olivine phenocrysts are epitaxially overgrown with pyroxene. Rare grains of anhedral plagioclase (0.1mm) are present but it occurs more commonly in the matrix intergrown with pyroxene. Skeletal laths of ilmenite (0.01-0.08 to 0.20x1.0mm) are commonly arranged in parallel sets (0.1-0.8mm) which display optical continuity. This characteristic (optical continuity of ilmenite laths) is best represented in section 70215,147. Lamellae of rutile are common in laths and in subequant grains of ilmenite. Spinel octahedra, some with inclusions of ilmenite, are present in olivine phenocrysts. Troilite and native iron occur in association with ilmenite and also occur randomly in the matrix.

AGE DATA: $^{40}Ar-^{39}Ar$ plateau - 3.84 ± .04 AE Kirsten and Horn (1974)

ADDITIONAL REFERENCES: Brown et al. (1975); Dymek et al. (1975); Longhi et al. (1974); Green et al. (1975).

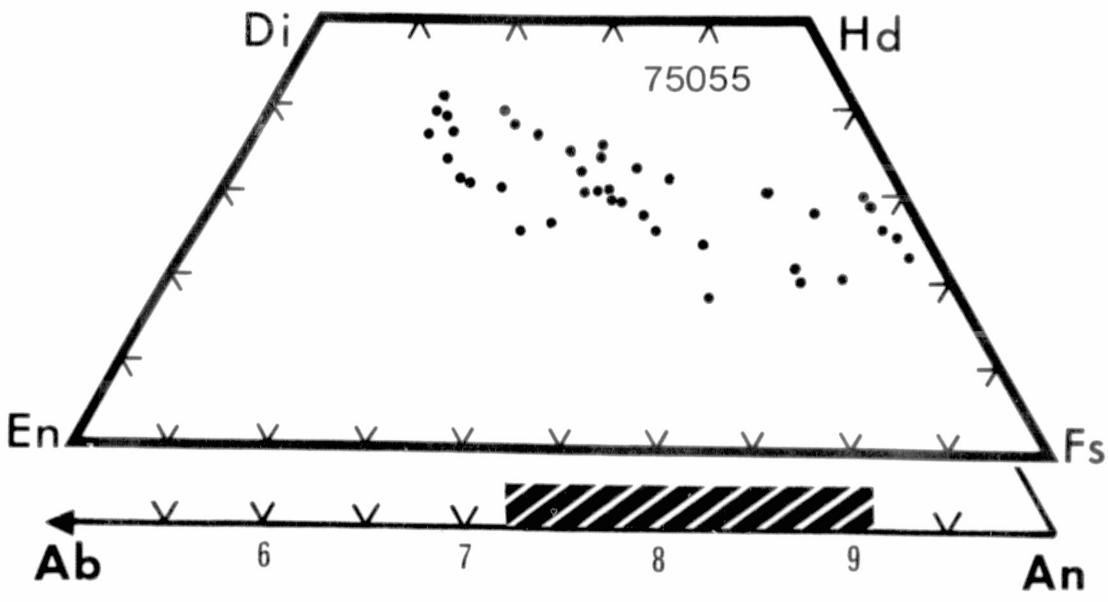
75055 Subophitic Basalt

Sample 75055 was collected at Station 5, a block field on the southwest rim of the 650 m diameter crater Camelot. Blocks are subrounded to angular, moderately to deeply buried, and are located along the rounded rim crest of the crater and extending down the crater walls.

Sample 75055 is a coarse grained subophitic basalt characterized by plagioclase tablets (0.05-0.10 x 0.30mm to 0.10 x 2.0mm) and anhedra (0.10-0.40mm) intergrown with subhedral to anhedral pyroxene crystals (0.05-0.80mm) and irregular (0.10-0.80mm) and lath-shaped (0.4-1.4mm) ilmenite. Irregularly shaped bodies of ilmenite commonly display a sieve texture and ilmenite laths typically contain many re-entrants. Pore space is present in the form of connecting veinlets up to 0.20mm in width and as irregularly shaped vugs. Troilite with Fe-Ni metal blebs is present as a minor opaque phase, typically in the mesostasis or in close association with ilmenite.

AGE DATA: ^{40}Ar-^{39}Ar plateau - 3.82 ± .05 AE Huneke et al. (1973)
3.78 ± .02 AE Huneke et al. (1973)
3.76 ± .05 AE Turner et al. (1973)

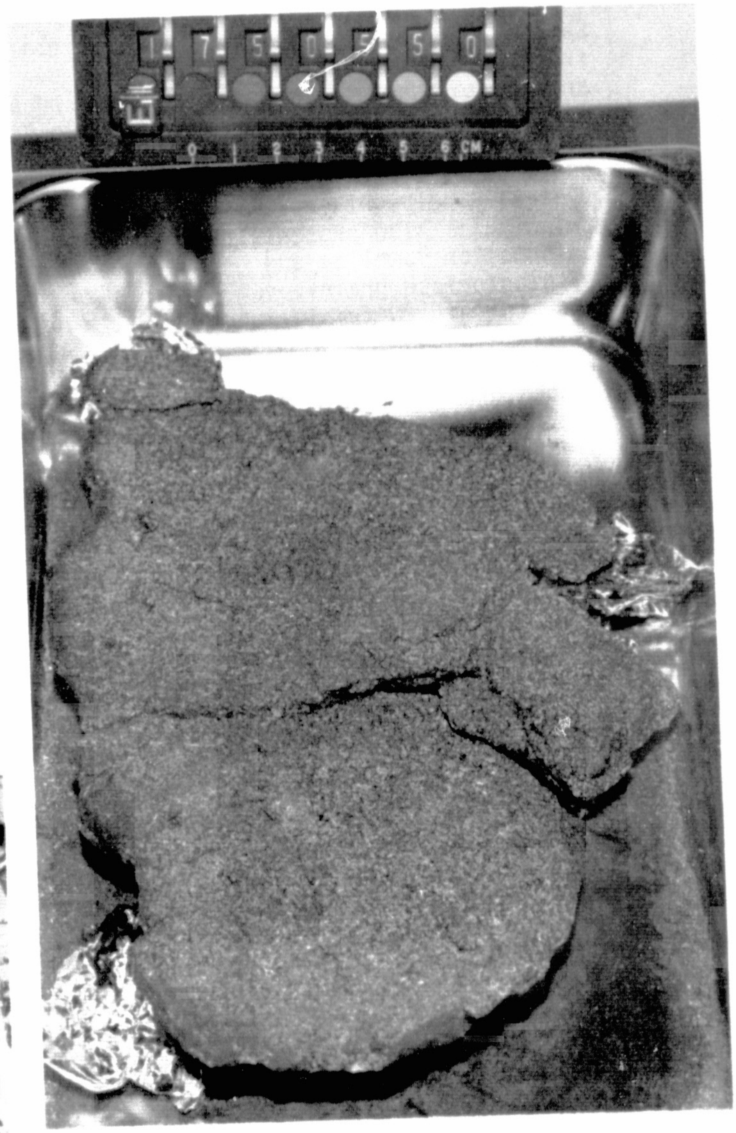
ADDITIONAL REFERENCES: Brown et al. (1975); Dymek et al. (1975a); Kridelbaugh and Weill (1973); Tatsumoto et al. (1973); Green et al. (1975).



Adapted from Dymek et al., 1975

75055 MODAL ANALYSIS (%)	
PYROXENE	45-51
OLIVINE	—
PLAGIOCLASE	29-35
ILMENITE	12-20
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	tr
METAL	tr
TROILITE	—
CRISTOBALITE	3-5
TRIDYMITE	—
MESOSTASIS	1-2
PORE SPACE	—
PHOSPHATE	tr
OTHERS	—

75055 0.5MM



15415 Coarse-grained Anorthosite

Sample 15415 was plucked from a much lower albedo, poorly consolidated breccia located on the subdued rim crest of Spur Crater.

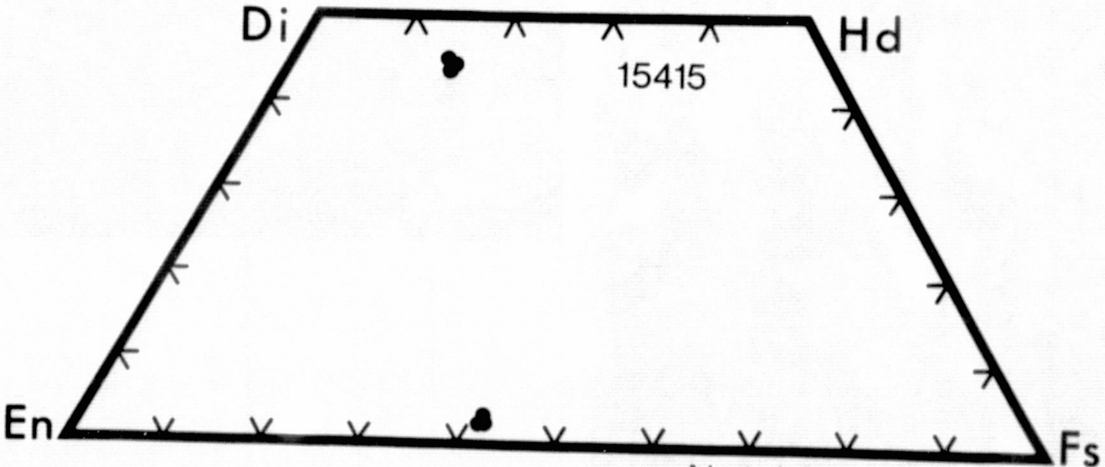
Sample 15415 is a coarse grained anorthosite of cumulate origin which consists of fractured, blocky plagioclase fragments. The multiple generations of plagioclase are due to repeated episodes of crushing and annealing. Plagioclase fragments may be divided into three separate size groups, each with its own distinctive morphology. The largest plagioclase fragments are present as anhedral megacrysts as large as 3.0 cm (seldom seen in their entirety in thin section) which are typically polysynthetically twinned with the twins offset by fractures. Shock twinning is also present in several of the megacrysts and with higher magnification deformation lamellae can be observed normal to the twin planes. A second group of plagioclase grains, ranging in size from 1.0 - 1.5mm, are subrounded to rounded and meet at 120 triple junctions with adjacent grains. These grains are interstitial to the larger megacrysts and also display mechanical and shock twinning. The final group of plagioclase grains occurs as chains of ovoid and polygonal shaped grains which occur along fracture zones in larger plagioclase grains. They are typically 0.05-0.10mm across and are interpreted as result of recrystallization along a shear zone.

Pyroxene is present as a minor phase in 15415, occurring as anhedral or ovoid shaped grains (0.05-0.10mm) which occur as inclusions in large and intermediate sized plagioclase grains and at the central point of plagioclase triple junctions.

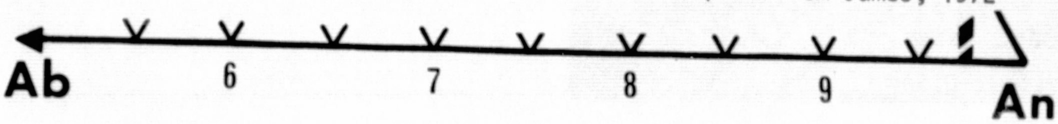
Trace amounts of troilite and Fe-Ni metal are present and occur as blebs both included within and interstitial to plagioclase grains.

AGE DATA: ^{40}Ar-^{39}Ar plateau - 4.05 ± .15 AE Turner (1972)

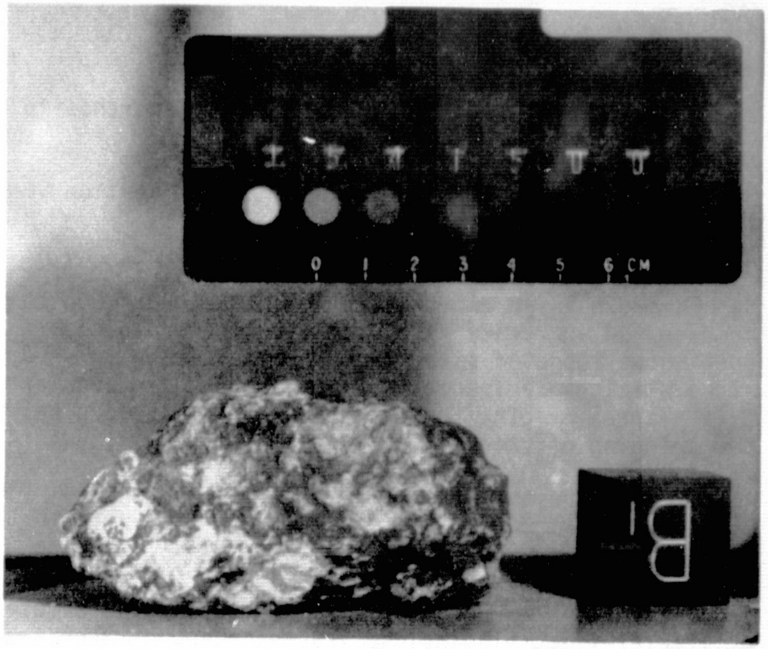
ADDITIONAL REFERENCES: Steele and Smith (1971); James (1972); Hargraves and Hollister (1972).



Adapted from James, 1972



Adapted from James, 1972



15415 MODAL ANALYSIS (%)	
PYROXENE	3
OLIVINE	—
PLAGIOCLASE	97
ILMENITE	—
ARMALCOLITE	—
CHROMITE	—
ULVOSPINEL	—
METAL	—
TROILITE	—
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	—
PORE SPACE	—
PHOSPHATE	—
OTHERS	—

60025 Cataclastic Anorthosite

Sample 60025 was collected at the LM/ALSEP station very near the lunar module itself.

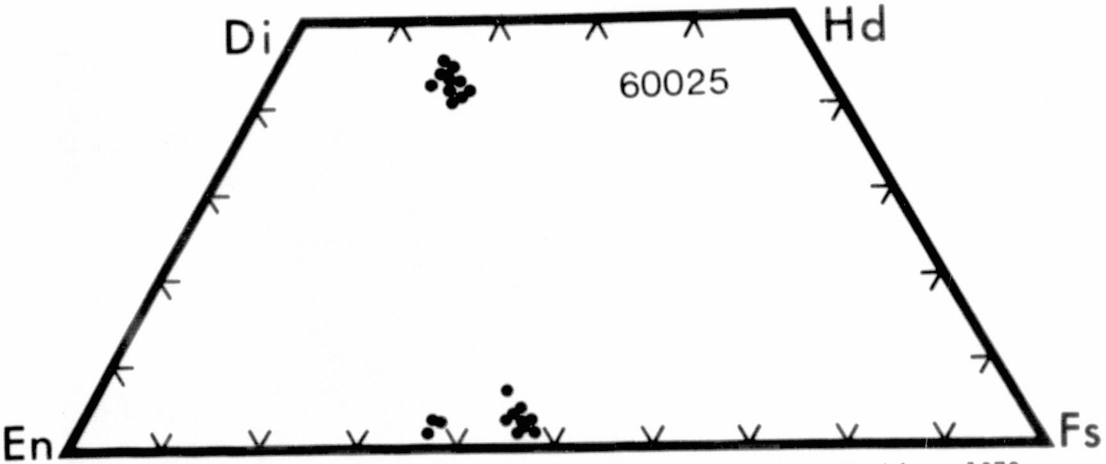
Sample 60025 is an anorthosite which has undergone cataclasis. This event produced an aggregate of plagioclase fragmental debris which displays a continuous range of sizes from one micrometer to several millimeters. Millimeter-sized plagioclase fragments are subrounded to angular and represent pieces of still larger original grains. Many fragments are polysynthetically twinned with the twinning offset by fractures and several fragments display shock twinning.

Pyroxene is present as subhedral to anhedral grains (100-200μm) included within plagioclase fragments and as anhedral grains between the smaller plagioclase fragments.

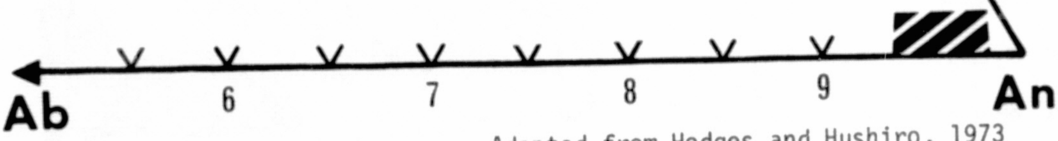
Trace amounts of troilite and Fe-Ni metal exist as blebs (1-10μ) within millimeter-sized plagioclase fragments and between smaller plagioclase fragments.

AGE DATA: ^{40}Ar-^{39}Ar plateau - 4.18 ± .06 AE Schaeffer and Husain (1973)

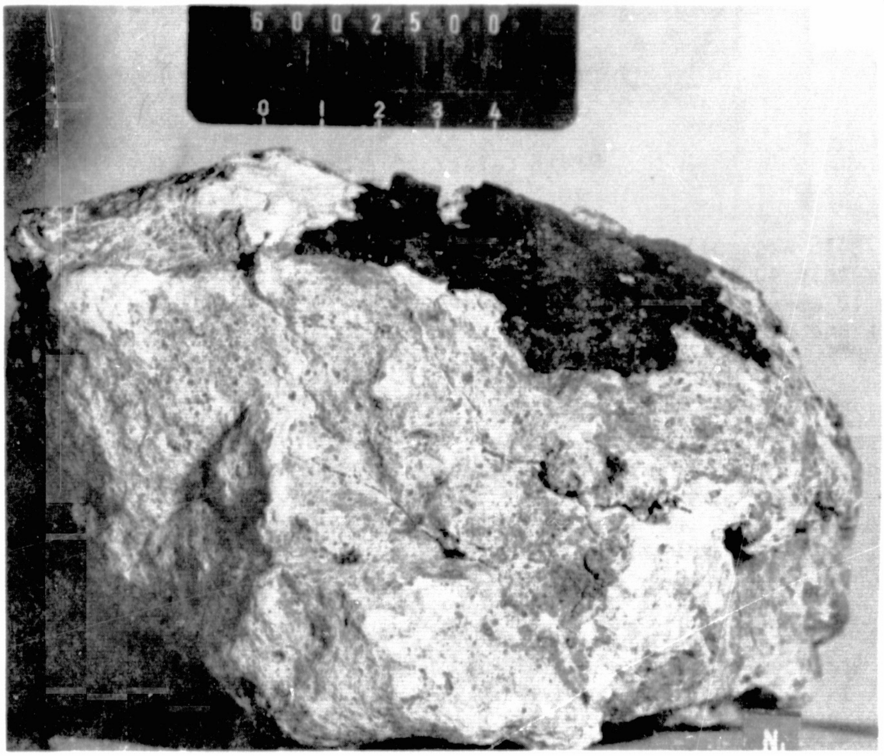
ADDITIONAL REFERENCES: Wasserburg and Papanastassiou (1975); Walker et al. (1973); Hodges and Kushiro (1973).



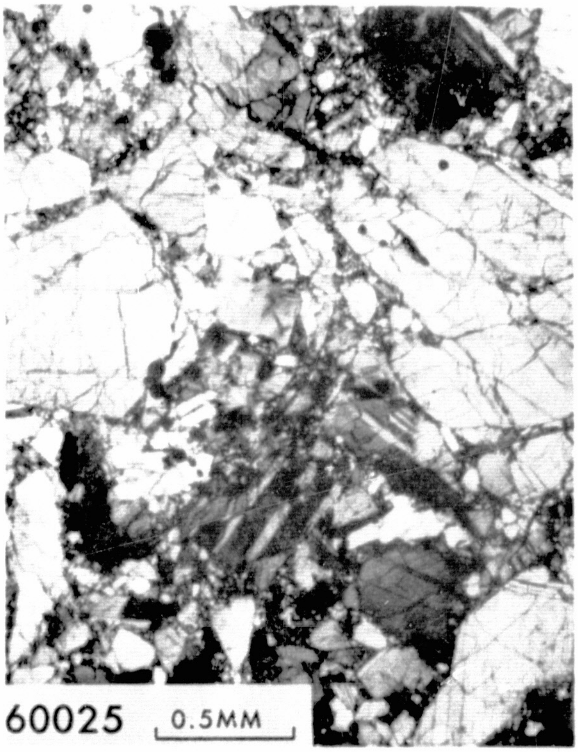
Adapted from Hodges and Kushiro, 1973



Adapted from Hodges and Hushiro, 1973



60025 MODAL ANALYSIS (%)	
PYROXENE	1
OLIVINE	—
PLAGIOCLASE	98-99
ILMENITE	tr
ARMALCOLITE	tr
CHROMITE	tr
ULVOSPINEL	tr
METAL	tr
TROILITE	tr
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	—
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



72415 Cataclastic Dunite

Sample 72415 was collected at Station 2 from an equant, subangular breccia boulder approximately 40 centimeters across. The boulder contained several 2-4 cm clasts and one 10 cm light gray clast in a gray matrix. The boulder was one of several found at and near the break in slope at the foot of the South Massif.

Sample 72415 is a coarse grained dunite probably formed by cumulate processes. Its present highly fractured state is the result of a later cataclastic event which produced a texture characterized by angular to subrounded fragments of olivine (up to 3.0mm) set in a matrix of finer grained (0.05mm and less) fragmental debris. Olivine comprises the major portion of matrix fragments with plagioclase, pyroxene, and opaque minerals totaling less than 5% of the matrix mineralogy.

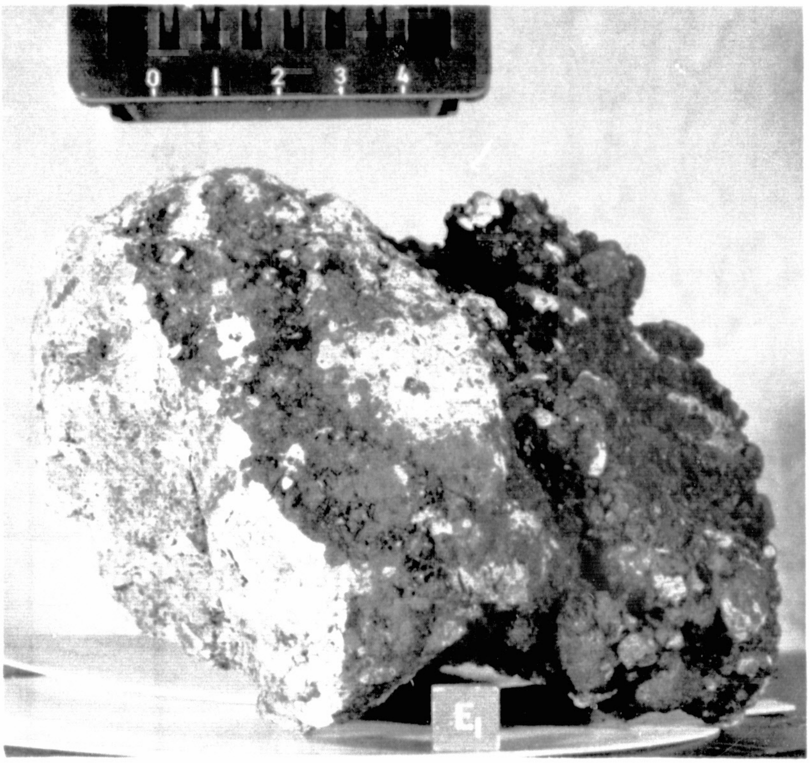
Olivine fragments display a variety of petrographic features, the most conspicuous of which is the occurrence of small (0.01-0.03mm) symplectic intergrowths of Cr-spinel and two pyroxenes. Only rarely are these symplectites associated with a plagioclase-olivine boundary, a fact which raises questions concerning the interpretation of their origin as a plagioclase-olivine reaction. An alternative interpretation is that these symplectites are the result of crystallization of trapped residual liquids. Another common feature is the occurrence of veinlets of plagioclase which crosscut olivine fragments and are inferred to be the result of shock melting of interstitial plagioclase grains. Linear zones containing aggregates of polygonal olivine grains, tablet-shaped plagioclase, and minor amounts of opaque minerals also crosscut olivine fragments and have been interpreted by Dymek et al. (1975) to be intercumulus phases along relic olivine grain boundaries. Most olivine fragments are characterized by the presence of abundant sub-μm sized plagioclase and opaque mineral inclusions which give the grains a clouded appearance. In addition, several fragments contain parallel strain bands which display undulatory extinction.

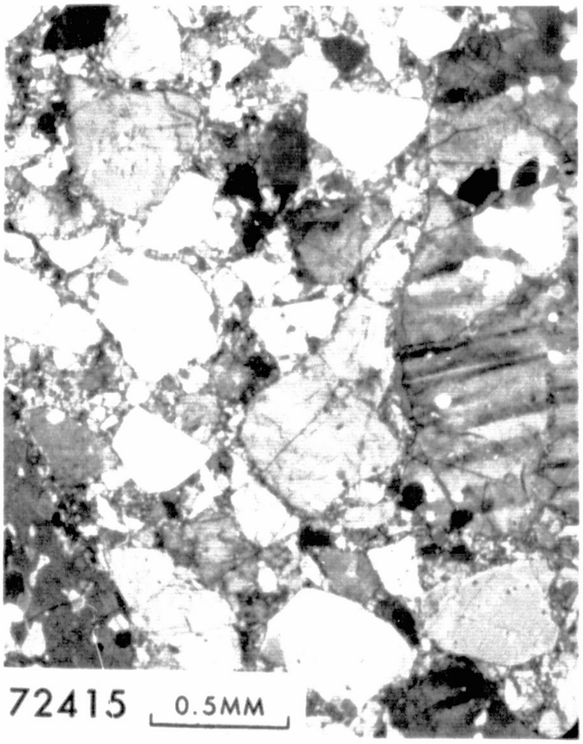
Although olivine is the most abundant mineral fragment type, several others are present. Unusual symplectite-like aggregates of Cr-spinel, pyroxene, plagioclase and troilite were observed with textures ranging from granular to vermicular. These aggregates are interpreted to be recrystallized mesostasis. Aggregates of polygonal olivine grains, together with plagioclase represent another fragment type.

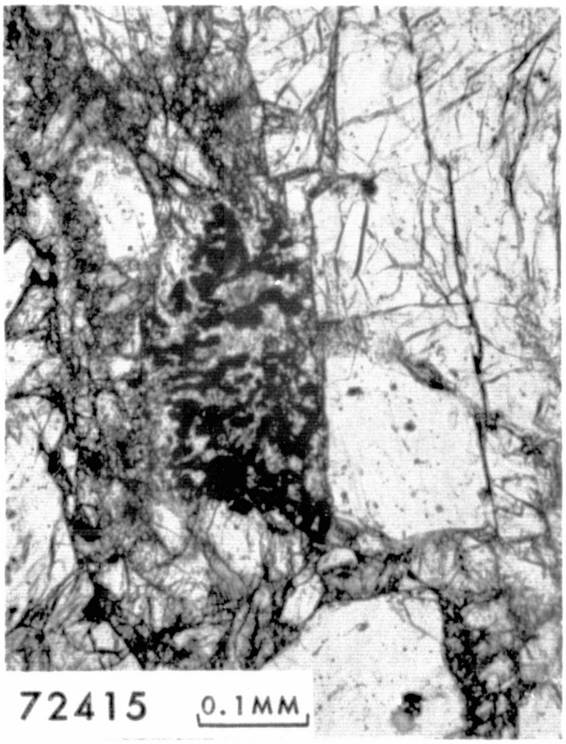
AGE DATA: Rb-Sr isochron - 4.55 ± .10 AE } Papanastassiou and Wasserburg (1975)
I_{Sr} - 0.69900 ± 7

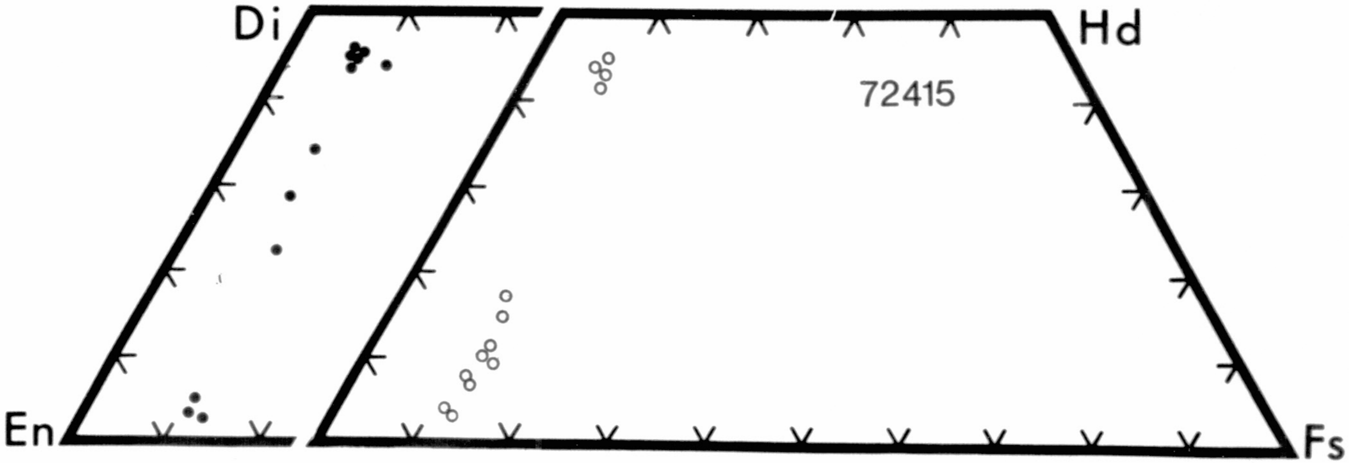
ADDITIONAL REFERENCES: Dymek et al. (1975b).

72415 MODAL ANALYSIS (%)	
PYROXENE	3
OLIVINE	93
PLAGIOCLASE	4
ILMENITE	—
ARMALCOLITE	—
CHROMITE	tr
ULVOSPINEL	—
METAL	tr
TROILITE	—
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	—
PORE SPACE	—
PHOSPHATE	—
OTHERS	—



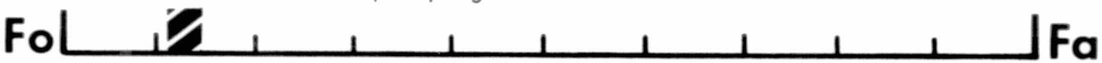




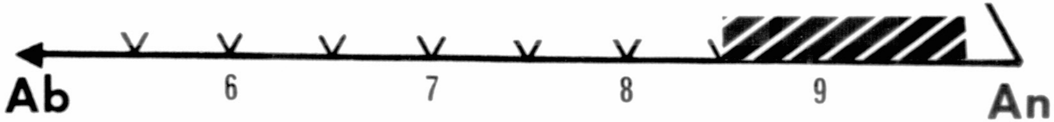


Open circles - In symplectites
Closed circles - With lath shaped plagioclase

Adapted from Dymek et al., 1975



Adapted from Dymek et al., 1975



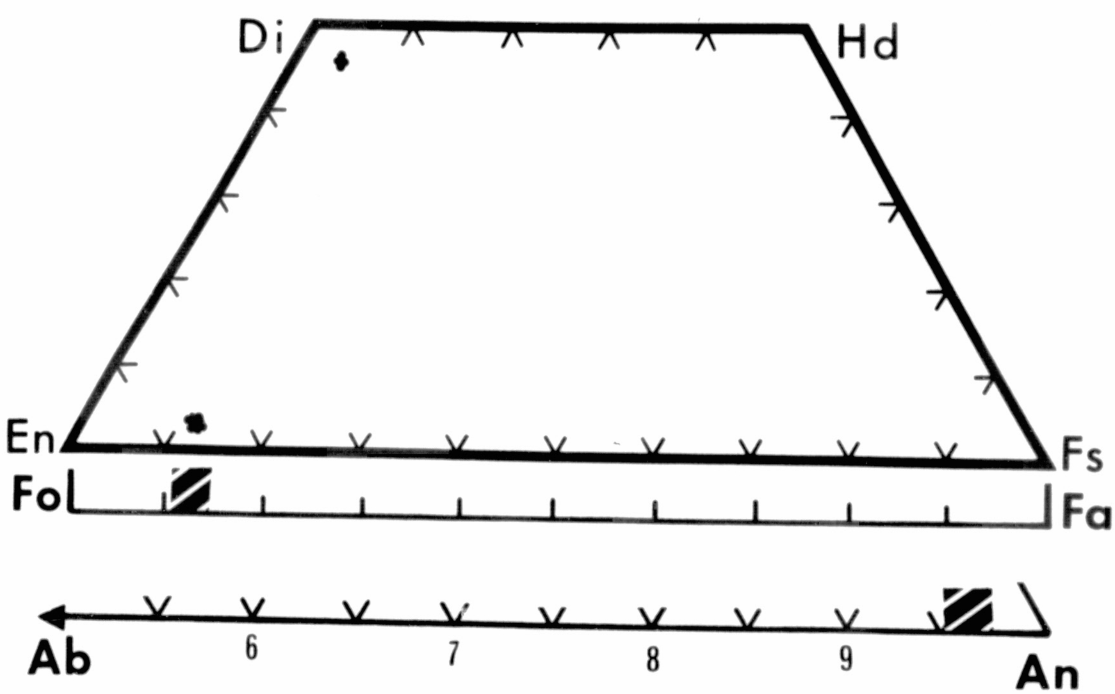
Adapted from Dymek et al., 1975

76535 Coarse Grained Troctolite

Sample 76535 was collected at Station 6, located on the ejecta blanket of a 10m unnamed crater at the foot of the North Massif.

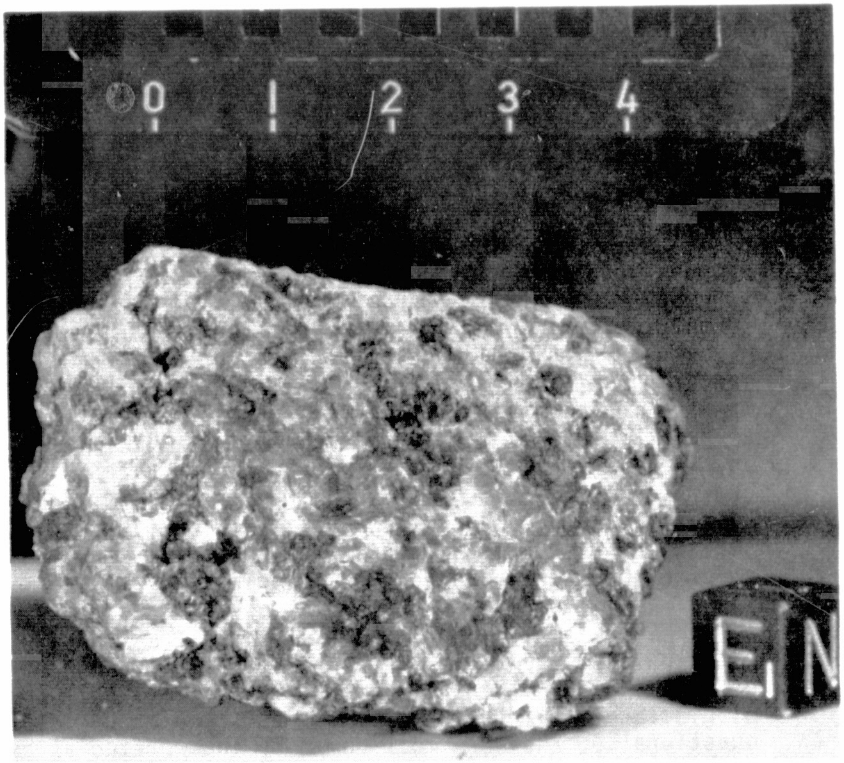
Sample 76535 is a coarse grained troctolite with petrographic characteristics suggestive of an olivine-plagioclase cumulate origin. It consists of polysynthetically twinned prisms of plagioclase and randomly occurring olivine and pyroxene grains. Plagioclase prisms (up to 4.0mm) typically form 120° triple junctions with adjacent grains and contain abundant, rod-shaped, μm-sized opaque mineral inclusions which give the grains a clouded appearance. Olivine is present as subhedral to anhedral grains, equal in size to the largest plagioclase prisms and forms straight to slightly curved boundaries with plagioclase grains. Several grains of pyroxene (up to 3.0mm) were also observed and display the same smooth boundary relationships which exist between plagioclase and olivine grains. One small anhedral pyroxene grain was located at the central point of a triple junction between three large plagioclase prisms.

A common characteristic of 76535 is the occurrence of vermicular intergrowths of Cr-spinel and two pyroxenes (symplectites) up to 0.4mm which are present along plagioclase-olivine grain boundaries. The exact origin of these symplectites is questionalbe; they are most commonly interpreted as being the result of a solid-state reaction between plagioclase and olivine at high pressures.

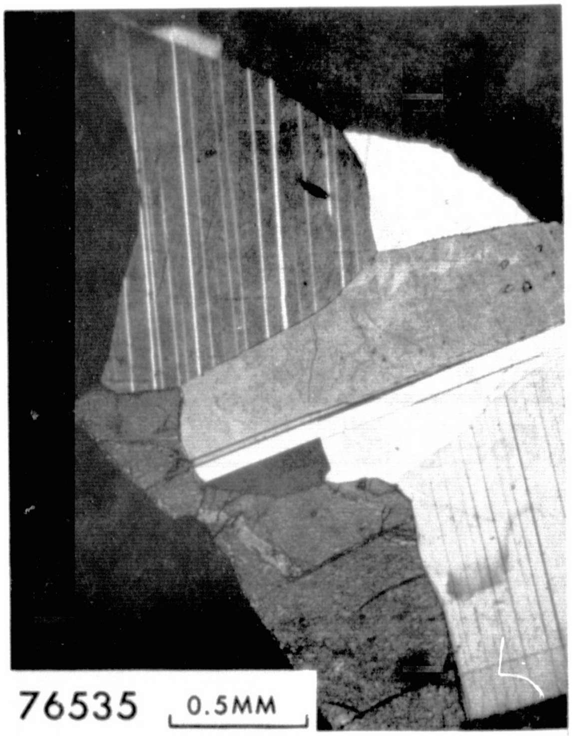


Adapted from Gooley et al., 1974

76535	
MODAL ANALYSIS (%)	
PYROXENE	4-5
OLIVINE	37-60
PLAGIOCLASE	35-58
ILMENITE	—
ARMALCOLITE	—
CHROMITE	1
ULVOSPINEL	—
METAL	tr
TROILITE	tr
CRISTOBALITE	—
TRIDYMITE	—
MESOSTASIS	—
PORE SPACE	—
PHOSPHATE	tr
OTHERS	tr



76535 0.5MM



76535 0.5MM

76535 also contains aggregates which consist of variable combinations of a number of phases including low-Ca pyroxene, high-Ca pyroxene, apatite, whitlockite, Cr-spinel, metal, baddeleyite, K-Ba feldspar, and "pyrochlore." These aggregates (called "mosaic assemblages" by Gooley et al. 1973) are present as inclusions withint olivine grains or along plagioclase-plagioclase grain boundaries, and are interpreted to be the result of the crystallization of trapped residual liquids.

AGE DATA:			
	Rb-Sr isochron	- 4.61 ± .07 AE	Papanastassiou and Wasserburg (1976)
	I_{Sr}	- 0.69900 ± 3	

ADDITIONAL REFERENCES: Gooley et al. (1975); Dymek et al. (1975b).

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17 34

15426 Green Glass: A Pyroclastic

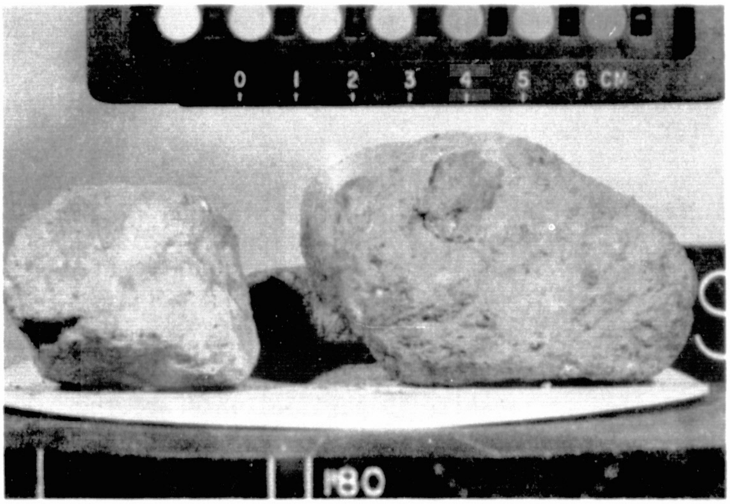
Sample 15426 was collected on the crest of the north rim of Spur Crater.

Sample 15426 is a compacted soil composed of pale green to colorless glass spheres and fragments of spheres, mineral and lithic fragments and minor amounts of brown, orange and yellow glass fragments (Figure). The texture is seriate; fragments range in size from the limit of resolution up to 0.8mm. Green glass spheres occur most commonly in the 0.2-0.3mm size range and angular brown glass fragments rarely exceed 0.1mm. Green glass is almost entirely undevitrified although rare dendritic growths of pyroxene may be present in some spheres, giving them a pale brown color. Orange and brown glass fragments commonly contain prisms and dendrites; possibly pyroxene. Angular fragments of plagioclase (up to 0.3mm) and pyroxene (up to 0.2mm) are typical and comprise 30-35% of the sample. Lithic fragments are relatively rare (5%); anorthositic mosaics (0.2-0.4mm) are the most common type but several fine grained breccia fragments were observed.

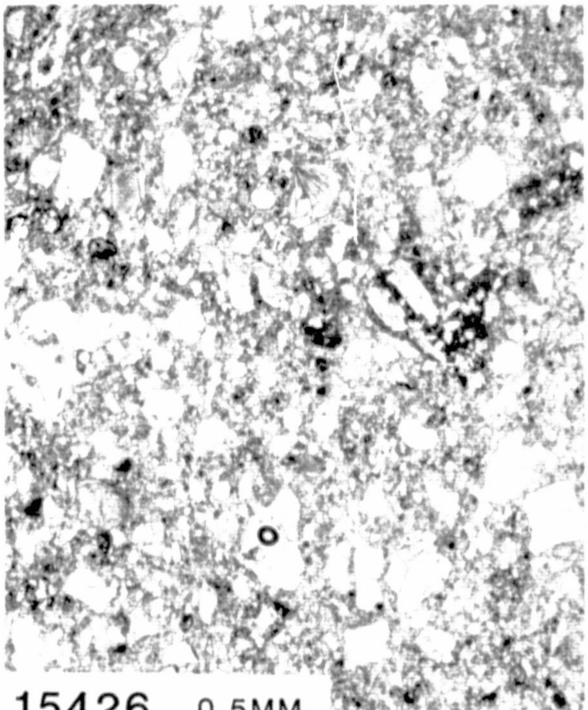
Green glass spheres are believed to be the result of lava fountaining. The homogeneity and chemical uniformity of the glasses are strong evidence against an impact origin, although many lunar glasses are formed by the splash produced by an impacting body. The shock features and rock fragments normally produced by such an event are lacking in this pyroclastic deposit.

AGE DATA: ^{40}Ar-^{39}Ar plateau - 3.79 ± .08 AE Husain (1972)

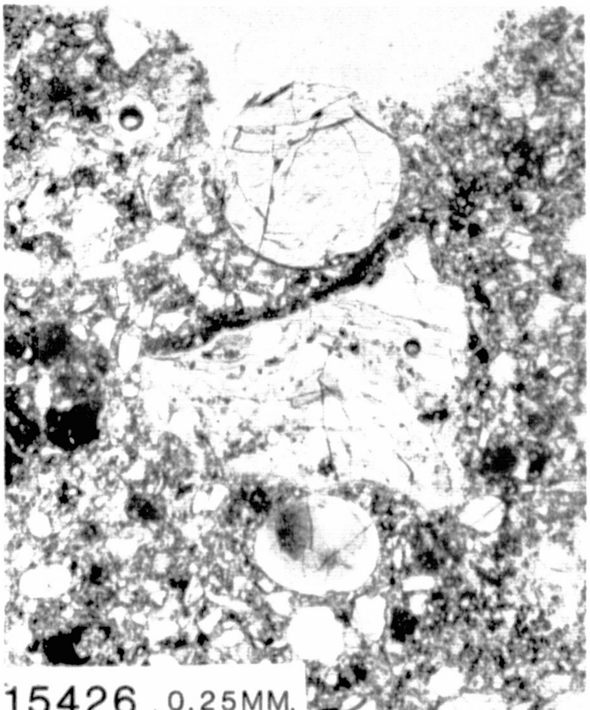
ADDITIONAL REFERENCES: McKay et al. (1973); Reid et al. (1973); Ridley et al. (1973).



0 1 2 3 4 5 6 CM



15426 0.5MM



15426 0.25MM

74220 Orange Glass: A Pyroclastic

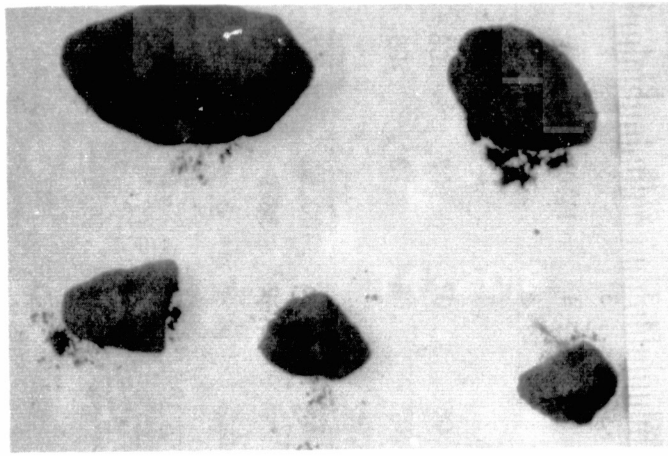
Sample 74220 was collected at Station 4 from a 6 to 8 cm deep trench on the rim of 120m Shorty Crater.

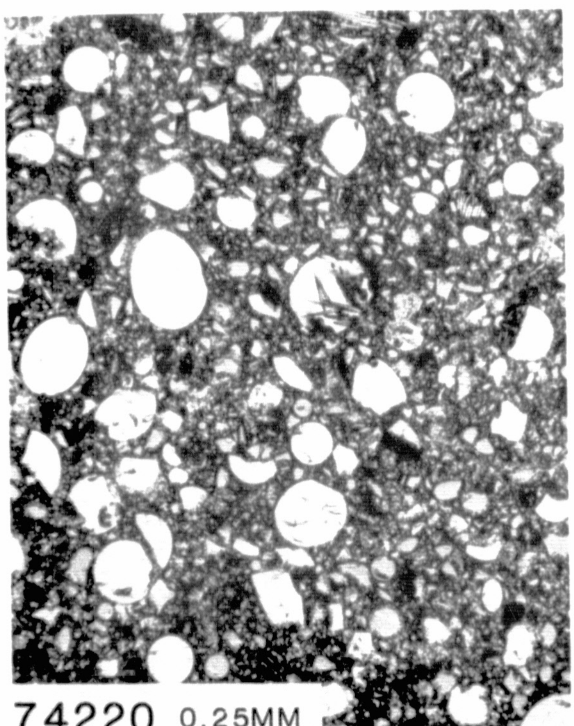
Sample 74220 is a cohesive orange soil composed primarily of orange glass spheres, fragments of spheres, and the devitrified equivalents of both which appear opaque in thin section. Mineral fragments are present in minor abundances and rarely exceed 0.1mm in size. Glass fragments display a seriate texture, ranging in size from the limit of resolution up to 0.5mm. Glass spheres occur most frequently in the 0.1-0.3mm size range although smaller spheres (0.05mm) are observable. Crystallization features in devitrified spheres and fragments range from dendritic and axiolitic crystallites of ilmenite to parallel intergrowths of acicular crystals of olivine and ilmenite (Figure). One relatively large (0.15mm) subhedral olivine crystal was observed within an orange glass sphere.

The uniformity of composition and extreme homogeneity of the glasses, together with the lack of shock effects and rock fragment inclusions argue for an endogenetic source for the glasses. The present data supports the general belief that the glass spheres are volcanic in origin and have formed from lava fountaining.

AGE DATA: ^{40}Ar-^{39}Ar plateau - 3.71 ± .06 AE Schaeffer and Husain (1973)

ADDITIONAL REFERENCES: Uhlmann et al. (1973); Reid et al. (1973); McKay and Heiken (1973).




74220
0.25MM


74220
0.05MM

Table · Geochemistry

	10003	10017	10044	10045	10049	10072	12002	12009	12021	12022	12039
SiO_2	39.8	40.6	42.2	39.3	41.0	40.4	43.6	45.0	46.7	42.8	47.
TiO_2	11.3	11.8	9.0	11.2	11.3	12.0	2.6	2.9	3.5	4.9	3.
Al_2O_3	10.7	8.0	10.9	9.5	9.5	8.0	7.9	8.6	10.8	9.1	11.
Cr_2O_3	.3	.4	.2	.4	.3	.4	1.0	.6	.4	.6	.2
FeO	19.8	19.7	18.4	19.4	18.7	19.6	21.7	21.0	19.3	21.8	21.
MnO	.3	.2	.3	.3	.3	.2	.3	.3	.3	.3	.2
MgO	6.9	7.7	6.1	7.9	7.0	7.7	14.9	11.6	7.4	11.0	5.
CaO	11.1	10.7	12.2	11.2	11.0	10.4	8.3	9.4	11.4	9.5	12.
Na_2O	.6	.5	.5	.4	.7	.5	.2	.2	.3	.4	.4
K_2O	.06	.3	.1	.05	.4	.3	.05	.06	.07	.07	.08
P_2O_5	.1	.2	.06	.07	<.2	.2	.11	.07	.09	.13	.09
S	.18	.22	.18	.15	—	.23	.06	.06	—	—	—
Total	101.14	100.32	100.14	99.87	100.4	99.93	100.72	99.79	100.26	100.60	99.97
Reference	116	90,153	2,31	2,22	116	153	2	23	25,32	32	16
Li ppm	—	—	—	—	—	—	—	—	8.37	9.3	—
Rb ppm	.49	5.63	—	.8	6.24	5.61	1.04	—	1.14	.738	—
Sr ppm	159	175	—	144	161	168	101	—	128	143	—
Ba ppm	108	309	—	95	338	300	67.2	—	71.1	59.5	—
La ppm	15.5	26.6	—	6.7	29.2	22.7	6.02	6.1	—	—	—
Ce ppm	47.2	77.3	—	22.5	84.2	69	17.0	16.8	19.8	17.4	—
Nd ppm	40.0	59.5	—	21	64.3	51	12.3	16	14.4	14.4	—
Sm ppm	14.4	20.9	—	7.94	22.5	17.9	4.24	4.53	4.84	5.38	—
Eu ppm	1.81	2.14	—	1.52	2.31	2.07	.85	.94	1.12	1.26	—

Gd ppm	19.5	27.4	—	12.3	29.6	26	5.65	5.2	6.59	7.71	—
Dy ppm	21.9	31.7	—	14.4	34.0	31.2	6.34	7.13	7.86	9.37	—
Er ppm	13.6	20.0	—	8.7	21.2	16	3.89	3.6	4.53	5.42	—
Yb ppm	11.7	17.1	—	8.6	20.2	16.6	3.36	3.74	4.12	5.06	—
Lu ppm	1	2.66	—	1.17	—	2.24	—	.55	.64	—	—
Zr ppm	—	476	—	194	—	497	—	—	—	—	—
Hf ppm	—	—	—	7.7	—	—	—	—	—	—	—
Th ppm	—	3.7	—	.4	—	3.5	—	—	—	—	—
U ppm	—	—	—	—	—	—	—	—	—	—	—
Reference	37	22,37	—	22,47	22	22,47	56	48	122	56	—
Ir ppb	—	.02	—	—	—	.022	—	.08	—	.09	—
Re ppb	—	—	—	—	—	—	—	—	—	—	—
Au ppb	—	.72	—	—	—	.12	.024	—	—	—	—
Ni ppm	—	—	—	—	—	—	—	—	—	—	—
Sb ppb	—	—	—	—	—	—	—	—	—	—	—
Ge ppb	—	—	—	—	—	60	<57	<41	—	<30	—
Se ppb	—	215	—	—	—	188	141	—	—	—	—
Te ppb	—	—	—	—	—	—	10	—	—	—	—
Ag ppb	—	16	—	—	—	17.3	.81	—	—	—	—
Bi ppb	—	1.15	—	—	—	.73	1.4	—	—	—	—
Zn ppm	—	18	—	—	—	1.77	.70	1.8	—	2.0	—
Cd ppb	—	68	—	—	—	10	1.4	2.2	—	6.4	—
Tl ppb	—	6.16	—	—	—	.92	.25	—	—	—	—
Reference	—	4	—	—	—	4,34,151	4,5	5	—	5	—

	12051	12063	12064	14053	14072	15016	15076	15475	15499	15555	15556
SiO_2	45.3	43.5	46.3	46.2	45.2	44.1	48.4	48.2	47.8	44.6	45.8
TiO_2	4.7	5.0	4.0	2.9	2.6	2.3	1.9	1.8	1.8	2.1	2.7
Al_2O_3	10.0	9.3	10.7	13.0	11.1	8.4	9.0	9.4	9.2	8.7	9.6
Cr_2O_3	.3	.4	.4	.4	.5	.9	.3	.6	.5	.6	.7
FeO	20.2	21.3	19.9	17.0	17.8	22.7	20.3	20.0	20.4	22.5	21.9
MnO	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3
MgO	7.0	9.6	6.5	8.7	12.2	11.3	8.6	8.9	9.0	11.4	8.0
CaO	11.4	10.5	11.8	11.2	9.8	9.3	10.5	10.6	10.4	9.4	10.7
Na_2O	.3	.3	.3	.4	.3	.3	.3	.3	.3	.3	.3
K_2O	.06	.06	.07	.1	.08	.04	.07	.06	.06	.04	.06
P_2O_5	.08	.14	.04	.1	.08	.07	.07	.06	.08	.06	.08
S	.09	.09	.07	.12	.12	.10	.08	.05	.07	.06	.08
Total	99.73	100.49	100.38	100.42	100.08	99.81	99.82	100.27	99.91	100.06	100.22
Reference	23	153	124	82	24	20,26,111	26,111	20,111	20,111	26,29,111	111,132
Li ppm	—	6	—	—	—	—	—	6.3	—	6.36	—
Rb ppm	.909	1.1	—	2.19	—	—	.917	.696	—	.445	—
Sr ppm	148	130	—	98	—	—	112	111	—	84.4	—
Ba ppm	73.6	140	—	146	—	—	62.7	45.2	—	32.2	—
La ppm	6.53	6.24	6.76	13.0	6.76	5.77	7.38	4.01	—	8.06	—
Ce ppm	19.2	17.8	17.5	34.5	17.9	15.6	15.1	13.1	—	6.26	—
Nd ppm	15.4	16	16	21.9	13	11.4	10.6	8.87	—	2.09	—
Sm ppm	5.68	6.48	5.51	6.56	3.93	4.05	3.52	2.93	—	.688	—
Eu ppm	1.23	1.36	1.16	1.21	.88	.97	.978	.481	—	2.9	—

Gd ppm	7.89	9.4	7.2	8.59	4.2	5.4	4.95	—	—	2.9	—
Dy ppm	9.05	11.3	9.03	10.5	6.0	5.74	5.60	4.59	—	3.27	—
Er ppm	5.57	5.3	6	6.51	3.5	3.1	3.40	2.70	—	1.7	—
Yb ppm	4.86	5.4	4.59	6.0	4.05	2.62	2.77	2.35	—	1.45	—
Lu ppm	—	.79	.67	—	.61	.321	.33	.35	—	—	—
Zr ppm	—	—	—	—	—	—	—	84	—	57.3	—
Hf ppm	—	6.3	3.9	9.8	6.9	2.6	—	2.7	—	—	—
Th ppm	—	.82	—	—	—	—	—	—	—	—	—
U ppm	—	.24	—	.60	—	—	.15	.11	—	—	—
Reference	56	48,148	48,148	51,58	58	51a	59	59	—	123	—
Ir ppb	.09	<.04	—	.017	—	.12	—	.0146	—	.006	—
Re ppb	—	—	—	.0066	—	—	—	.0026	—	.0013	—
Au ppb	.007	—	—	.11	—	.27	—	.0094	—	.139	—
Ni ppm	—	—	—	—	—	85	—	35	—	—	—
Sb ppb	—	—	—	.64	—	—	—	.34	—	0.67	—
Ge ppb	—	<20	—	—	—	28	—	5.2	—	8.5	—
Se ppb	202	—	—	141	—	—	—	92	—	156	—
Te ppb	13	—	—	15	—	—	—	2.5	—	3.4	—
Ag ppg	.81	—	—	.60	—	—	—	.72	—	1.0	—
Bi ppb	.53	—	—	.29	—	—	—	.08	—	.089	—
Zn ppm	.53	2.3	—	2.1	—	1.8	—	1.1	—	.78	—
Cd ppb	1.1	1.1	—	20	—	2.0	—	2.0	—	2.1	—
Tl ppb	.36	—	—	1.4	—	—	—	.38	—	.20	—
Reference	4	5	—	92	—	6	—	42	—	91	—

	70017	70035	70215	75055	15415	60025	72415	76535	15426	74220
SiO_2	38.5	37.8	37.8	40.6	44.1	44.3	39.9	42.9	45.2	38.8
TiO_2	13.0	13.0	13.0	10.8	.02	.02	.03	.05	1.1	8.8
Al_2O_3	8.7	8.9	8.9	9.7	35.5	35.2	1.5	20.7	15.1	6.4
Cr_2O_3	.5	.6	.4	.3	.003	.03	.3	.1	.4	.7
FeO	18.3	18.5	19.7	18.0	.2	.5	11.3	5.0	13.7	22.2
MnO	.3	.3	.3	.3	0	.02	.1	.07	.2	.3
MgO	10.0	9.9	8.4	7.1	.1	.2	43.6	19.1	12.14	17.4
CaO	10.3	10.1	10.7	12.4	19.7	19.2	1.1	11.4	11.11	7.7
Na_2O	.4	.3	.4	.4	.3	.5	<.02	.2	.4	.4
K_2O	.05	.06	.05	.08	<.01	.03	0	.03	.1	.08
P_2O_5	.05	.05	.09	.07	.01	.003	.04	.03	.09	.04
S	.16	.15	.18	.17	0	—	.01	0	.06	.07
Total	100.26	99.66	99.92	99.92	99.94	100.00	97.90	99.58	99.60	102.89
Reference	97	85	113,117	85	83	84	85	39,113	83	28,85,97
Li ppm	8.1	8.1	—	8.6	1.0	—	4.9	3.0	—	10.7
Rb ppm	.30	.63	.356	.482	.17	<.1	.066	.24	—	1.11
Sr ppm	153	161	121	180	178	—	2.24	114	—	2.09
Ba ppm	45.8	79.5	56.9	66.0	6.2	—	3.27	32.7	—	76.4
La ppm	3.99	7.04	5.22	5.39	—	.28	.05	1.51	—	6.25
Ce ppm	11.3	23.4	16.5	18.5	.32	.65	.07	3.81	—	19.0
Nd ppm	13.2	25.9	16.7	20.7	.20	.42	.07	2.30	—	17.8
Sm ppm	5.67	10.5	6.69	8.80	.49	.092	.022	.61	—	6.53
Eu ppm	1.49	1.88	1.37	1.91	.807	1.04	.016	.73	—	1.80

Gd ppm	9.05	13.5	10.4	13.9	.062		.030	.73	—	8.52
Dy ppm	10.7	18.8	12.2	16.1	.063	.19	.035	.80	—	9.40
Er ppm	6.46	11.0	7.4	9.54		.05	.04	.53	—	5.10
Yb ppm	5.98	10.0	7.04	8.68	.045	.048	.045	.56	—	4.43
Lu ppm	.93		1.03	1.63		.006	.008	.079	—	.611
Zr ppm	177	217	—	—	—	—	3.0	24	—	—
Hf ppm	—	—	—	—	—	.02	.015	.52	—	—
Th ppm	198	—	—	.44	.027	—	—	.16	—	—
U ppm	.06	.091	.13	.13	.0098	—	<.005	.056	—	—
Reference	*	*	*,125	*,125	57	49	*	50	—	113
Ir ppb	—	—	.003	.019	<.01	.0057	.0052	—	.22	.214
Re ppb	—	—	.0015	—	.00084	.0016	.0048	—	.020	.0553
Au ppb	—	—	.026	.029	.117	.0074	.255	—	.188	1.07
Ni ppm	—	—	1	1.5	—	.3	149	—	—	70
Sb ppb	—	—	.18	—	.067	.035	.47	—	.12	25.3
Ge ppb	—	—	1.66	3.5	1.2	2.30	29.8	—	37	191
Se ppb	—	—	176	—	.23	21.7	4.9	—	69	460
Te ppb	—	—	2.1	—	2.1	65	<.36	—	3.3	49
Ag ppb	—	—	1.1	—	1.73	.22	.25	—	8.9	75
Bi ppb	—	—	.099	—	.097	3.58	.41	—	.38	1.53
Zn ppm	—	—	2.1	1.7	.26	.17	2.1	—	19	200
Cd ppb	—	—	1.8	1.9	.57	7.25	.37	—	46	260
Tl	—	—	.16	—	.09	26	.049	—	1.13	9.9
Reference	—	—	93	10	91	74	53	—	35	93,149

*Hubbard, unpublished data.

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