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CATALOG OF APOLLO 16 ROCKS

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INTRODUCTION

This catalog characterizes each of 543 individually numbered rock samples in the Apollo 16 collection, showing what each sample is and what is known about it. Regolith samples are not included. The catalog is intended to be used by both researchers requiring sample allocations and a broad audience interested in Apollo 16 rocks. The sample descriptions are arranged in numerical order, closely corresponding to the sample collection stations.

Information on sample collection, petrography, chemistry, stable and radiogenic isotopes, surface characteristics, physical properties, and curatorial processing is summarized and referenced as far as it is known. In many cases we found it necessary to reinspect samples in the laboratory and have new thin sections of several rocks cut. Our intention has been to be comprehensive--we have attempted to include all published studies of any kind which provide information on a sample, as well as some unpublished information. Exceptions are made where the same research group published the same data and conclusions in two journals, in which case one reference (usually the earlier) is chosen; if one is the Proceedings of the Lunar Science Conference, this reference is selected. We have rarely included references which are primarily bulk interpretations of existing data (such as mixing models) or mere lists of samples. The references are complete to early 1980. Foreign language journals were not scrutinized, but as far as we can tell little data has been published only in such journals.

Much valuable information exists in the original Apollo 16 Sample Information Catalog (1972). However, that catalog was compiled and published only three months after the mission itself, from rapid descriptions of usually dust-covered rocks, usually without anything other than macroscopic observations, less often thin sections, and rarely some chemical data. Since that time, the rocks have been extensively studied, analyzed, and split, with numerous published papers. These make the original catalog inadequate, outmoded, and in some cases erroneous, providing the motivation for this revision. However, The Apollo 16 Sample Information Catalog (1972) contains more information on macroscopic observations for most samples than does the present volume. Early catalogs were produced specifically for those rocks collected by raking the regolith: LM area and Station 5 (Keil, Dowty, Prinz); Stations 1, 4, and 13 (Phinney and Lofgren); and Stations 11 and 8 (Smith and Steele). These samples are included in the present catalog.

ACKNOWLEDGMENTS

Many of the Northrop Services, Inc., personnel employed in the Lunar Curatorial Laboratory worked on the compilation of this catalog. Gabriel Garcia, Catherine King, Andrea Mosie, and Frank Rodriguez processed the samples we reinspected in the laboratory. Jimmy Holder, Dan Jezek, and Janet Nieber cut new thin sections for this study. Lee Smith and Polly McCamey provided support for data pack research and the thin section library. Sherry Feicht drafted many of the diagrams and amended the photographs.

Outside of the Lunar Curatorial Laboratory, several persons directly or indirectly provided assistance. Sources of unpublished data are quoted directly in the text. K. Keil and G.J. Taylor (University of New Mexico) provided many photomicrographs, and I.M. Steele, E.C. Hansen, and J.V. Smith (University of Chicago) assisted in many ways in the inspection and photographing of the Stations 8 and 11 rake sample thin sections.

The catalog was produced with the encouragement and support of P. Butler, Jr. (NASA: Lunar Sample Curator); C.H. Simonds (NSI: Lunar Curatorial Laboratory Manager); and the Lunar and Planetary Sample Team during its chairmanship by J.J. Papike.

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ABBREVIATIONS

The following abbreviations have been used in this catalog:

ppl. : plane polarized light (i.e. transmitted light)
xpl. : crossed polarizers
rfl. : reflected light

JSC : Johnson Spacecraft Center
TSL : Thin Section Laboratory
TS : Thin Section
PM : Probe Mount
P.I. : Principal Investigator

ANT : Anorthosite-norite-troctolite suite of rocks; a catch-all acronym for rocks usually with granoblastic, poikiloblastic, or cumulate textures, but sometimes brecciated, and with low abundances of incompatible elements.

KREEP : acronym for rocks high in potassium, rare earth elements, and phosphorus, and usually lower in alumina than other highlands rocks. The light rare earths are enriched over heavy rare earths, and a conspicuous negative Eu anomaly is present.

THE APOLLO 16 MISSION

The Apollo 16 mission (April 1972) to the Descartes landing site in the central lunar highlands was the only Apollo mission restricted to highlands terrain (Figures i,ii). Hence, samples from the site are of fundamental importance in the understanding of lunar crustal evolution. Approximately 95 kg of rocks, mainly feldspathic breccias, and soils were collected during three periods of extravehicular activity. Using the Lunar Roving Vehicle, astronauts John W. Young and Charles M. Duke covered over 20 km of traverses, and samples were collected from 10 different stations (Figure iii).

The mission had two prime sampling objectives: the Cayley Formation, an example of highland plains; and the Descartes Formation, a rugged, hilly, and furrowed terrain. The consensus of premission photogeological interpretation was that both units were of probable volcanic origin; however, it became apparent even during the mission that the samples were not volcanic but predominantly impact-produced feldspathic breccias. The landing site included a portion of the Cayley Plain and two areas of mountainous terrain: Stone Mountain to the south and Smokey Mountain to the north. Traverses were selected to sample 1) the Cayley Plains around the Lunar Module, 2) Descartes material on Stone Mountain, 3) blocky debris around the rim of North Ray Crater, a 1 km wide, 230 m deep crater which lies on the boundary between Smokey Mountain and the Plains, and 4) blocky material from a ray of the younger South Ray Crater, an almost 1 km wide crater in the Cayley Plains. The exploration strategy was to use impact craters of various diameters as stratigraphic probes.

The great majority of samples collected are feldspathic breccias of varied characteristics. They include specimens chipped from boulders up to tens of meters in size, individually collected hand samples, samples raked from the regolith, and samples picked from regolith samples in the laboratory. In all, more than 500 rocks have been individually numbered in addition to the many regolith samples collected. The largest rock collected (61016) is 11,729 g; the smallest include many samples less than 1 g. The samples include friable breccias, coherent breccias, and varied impact melts; many of the latter have clast-free or near clast-free ophitic textures and were almost completely molten during their formation. Glass, glassy breccias, and glass coatings on breccias are common. A significant group are the cataclastic anorthosites, nearly pure plagioclase and certainly shocked igneous cumulates from the early lunar crust.

The Apollo 16 samples confirm that the highlands crust is feldspathic and formed by a process involving plagioclase accumulation. The details of variation between sampling sites have not yet been fully worked out; the most obvious distinction is that samples, including soils, from the North Ray Crater area are more aluminous ($\sim 28-30$ wt% Al_2O_3) than those from other areas ($26-28$ wt% Al_2O_3), and include more friable, fragmental, light-colored breccias. North Ray Crater and South Ray Crater are about 50 m.y. and 2 m.y. old respectively.

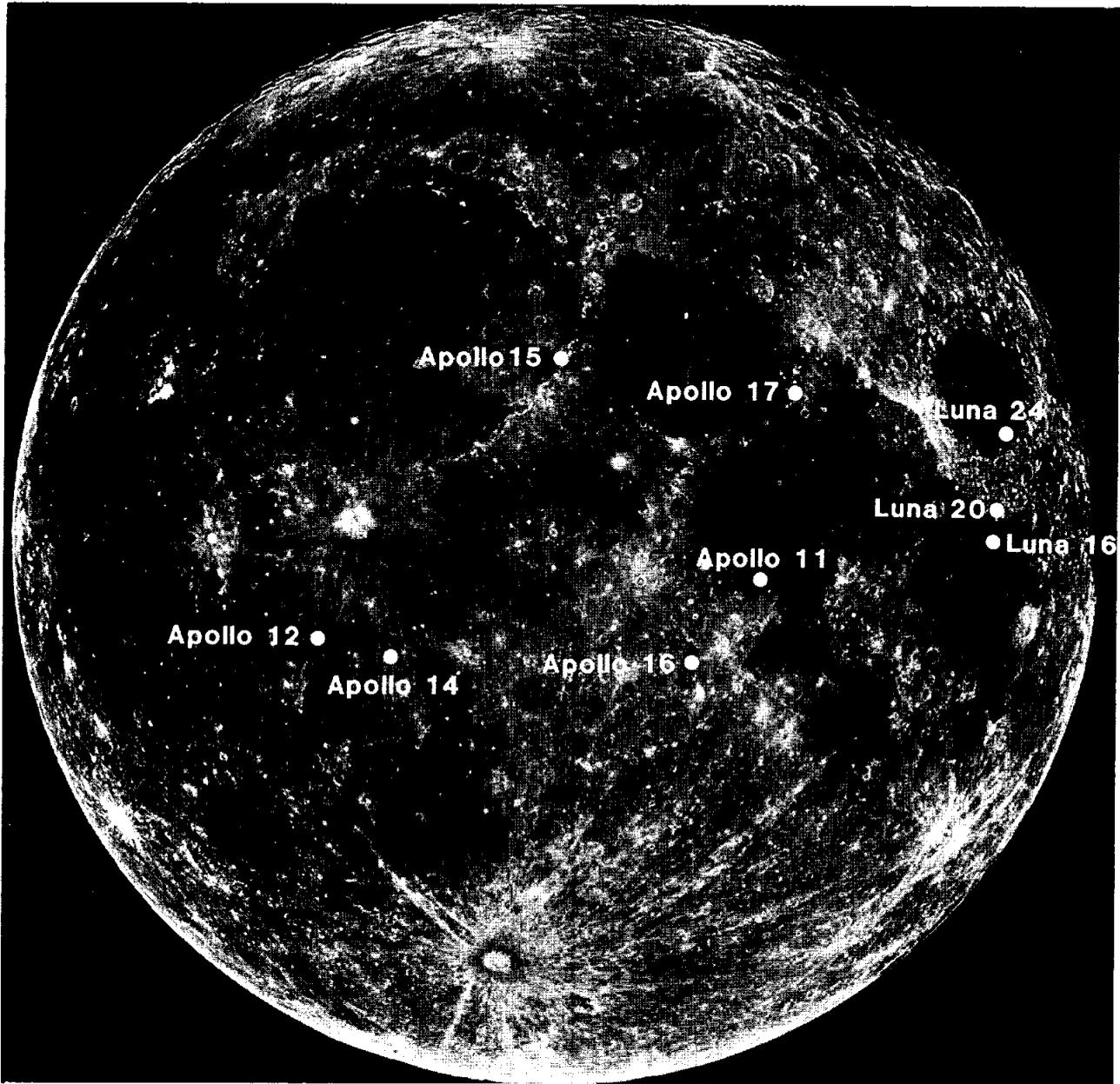


Figure (i). Apollo and Luna sampling locations

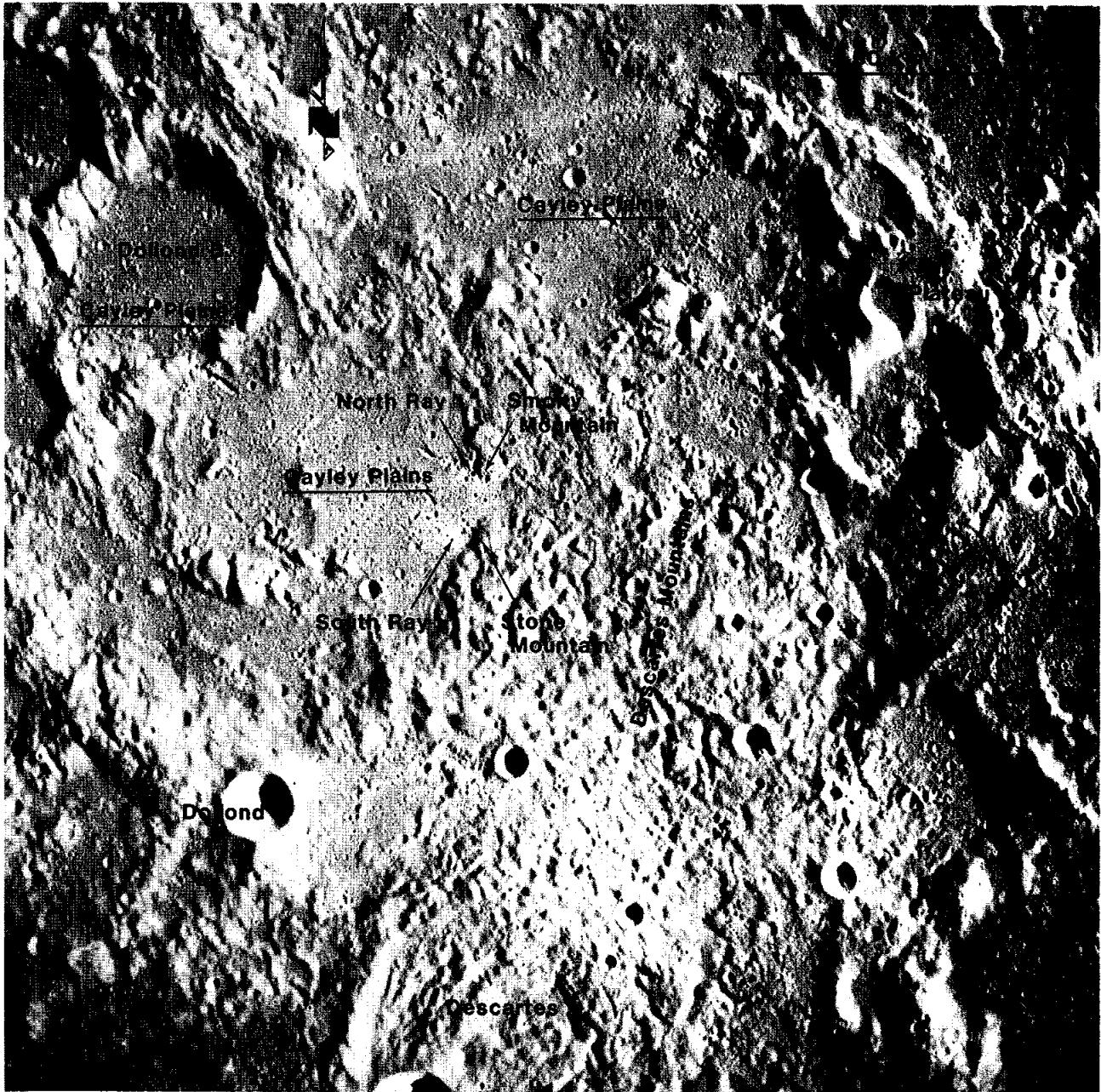


Figure (ii). Apollo 16 landing site area (Apollo 16 metric camera frame 439)

References to detailed studies on the Apollo 16 samples are cited in the individual rock descriptions. The following list is a more general selected bibliography pertaining to the geological interpretation, and rock samples of the Apollo 16 landing site. The Proceedings of the Lunar Science Conferences, in particular the 4th, contain many other relevant papers.

AFGIT (Apollo Field Geology Investigation Team) (1973) Apollo 16 exploration of Descartes: A geologic summary. Science 179, 62-69.

AFGIT (in press) Geology of the Apollo 16 area, central lunar highlands (G.E. Ulrich, C.A. Hodges and W.R. Muehlberger, eds.). U.S. Geol. Survey Open File Report No. 79-1091, 1128 pp. (To be published as U.S. Survey Prof. Paper No. 1048).

Apollo 16 Preliminary Examination Team (1973) The Apollo 16 lunar samples: Petrographic and chemical description. Science 179, 43-54.

Elston D.P., Boudette E.L., Schafer J.P., Muehlberger W.R. and Sevier J.R. (1972) Apollo 16 field trips. Geotimes 17, 27-30.

Head J.W. (1974) Stratigraphy of the Descartes region (Apollo 16): Implications for the origin of samples. The Moon 11, 77-99.

Hinners N.W. (1972) Apollo 16 site selection. Apollo 16 Prelim. Sci. Rep. NASA SP-315, p. 1-1.

Hodges C.A., Muehlberger W.R. and Ulrich G.E. (1973) Geologic setting of Apollo 16. Proc. Lunar Sci. Conf. 4th, p. 1-25.

Hörz F., Carrier W.D., III, Young J.W., Duke C.M., Nagle J.S. and Fryxell R. (1972) Apollo 16 special samples. Apollo 16 Prelim. Sci. Rep. NASA SP-315, p. 7-24 to 7-54.

LSAPT (Lunar Sample Analysis Planning Team) (1973) Fourth Lunar Science Conference. Science 181, 615-622.

Milton D.J. (1968) Geologic map of the Theophilus Quadrangle of the Moon. U.S. Geol. Survey Misc. Geol. Inv. Map I-546 (LAC 78).

Milton D.J. and Hodges C.A. (1972) Geologic maps of the Descartes region of the Moon, Apollo 16 premission maps. U.S. Geol. Survey Misc. Geol. Inv. Map I-748 (2 sheets).

Ulrich G.E. (1973) A geologic model for North Ray Crater and stratigraphic implications for the Descartes region. Proc. Lunar Sci. Conf. 4th, p. 27-39.

Warner J.L., Simonds C.H., and Phinney W.C. (1973) Apollo 16 rocks: Classification and petrogenetic model. Proc. Lunar Sci. Conf. 4th, p. 481-504.

Wilshire H.G., Stuart-Alexander D.G., and Jackson E.D. (1973) Apollo 16 rocks: Petrology and classification. J. Geophys. Res. 78, 2379-2392.

NUMBERING OF APOLLO 16 SAMPLES

Five digit sample numbers were assigned each rock (coherent material greater than about 1 cm), the unsieved portion and each sieve fraction of scooped <1 cm material, the drill bit and each drill stem and drive tube section and each sample of special characteristic. Rocks include samples chipped from boulders, individual hand samples, rake samples, and samples picked from regolith during laboratory processing.

The first digit (6) is the mission designation for Apollo 16 (previous missions used the first two digits). The second digit indicates sampling site, as follows:

<u>Sampling Site</u>	<u>Initial Number</u>
LM, ALSEP	60000
Stations 10 and 10 prime	60000
Station 1	61000
Station 2	62000
Station 4	64000
Station 5	65000
Station 6	66000
Station 8	68000
Station 9	69000
Station 11	67000
Station 13	63000

The only exceptions now known are 60017 which was collected at Station 13, and 61017 which could be from Station 2, not Station 1.

The first numbers for each area were used for drill stems, drive tubes, and special samples (surface samplers), with an omitted number to separate drive tube or drill stem strings. (For example, at Station 9, 69001 is a single core tube and 69003 and 69004 are the two surface samplers.) Drill stem sections and double drive tubes are numbered from the lower-most section upward.

The last digit denotes sample type. Fines from a given documented bag are ascribed numbers according to:

6wxy0	unsieved material (usually <1 cm)
6wxy1	<1 mm
6wxy2	1-2 mm
6wxy3	2-4 mm
6wxy4	4-10 mm

Rocks from a documented bag were numbered 6wxy5 - 6wxy9, usually in order of decreasing size.

Sample number decades were reserved for the contents of each documented bag. In the cases where the number of samples overflowed a decade the next available decade was used for the overflow. For example DB 11 contained soil, numbered 62280 - 62284, and 6 small rocks, numbered 62285 - 62289 and 62305.

Documented bags with predominantly soil samples were assigned even numbered decades and those with rock samples were assigned odd-numbered decades. The decades for rock samples usually only have an unsieved fines number for soil (adhering to the rock or scooped up with it) mixed in with any fragments that may have broken from the rock. For example, the 12 grams of soil and rock fragments in DB 362 are numbered 61130 and the 245 gram rock is 61135.

Paired soil and rake samples for each sampling area were assigned by centuries starting with 6x500. The soil sample documented bag has the first decade or decades of the century, in conformity with the last digit coding for rocks and fines (as explained above), and the rake sample documented bag uses the following decades. For example, 67700 - 67708 were used for the sieve fractions and four rocks from the soil sample in DB 388. Then for the companion rake sample in DB 423, 67710 - 67714 were used for the fractions of soil and the 32 >1 cm rake fragments were numbered 67715 - 67719, 67725 - 67729, ... , 67775, 67776.

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

APOLLO 16 ROCK SAMPLES: BASIC INVENTORY

The following pages are an inventory of all numbered Apollo 16 rock samples and are updated from the Apollo 16 Sample Information Catalog (1972); regolith and core samples are not included. Rock sample columns comprise the type of sample, its mass, a brief descriptive name, and the container (s) in which it was brought to earth.

Under SAMPLE TYPE, a blank indicates that the sample was an individually collected hand sample, in some cases chipped from boulders. An R indicates that the sample was collected with many others by raking the regolith. A P indicates that the sample was picked from a regolith sample during laboratory processing in Houston. Details on sample collection can be found in the Interagency Report: Astrogeology 51 (1972), the Apollo 16 Preliminary Science Report (1972), Bailey and Ulrich (1978), and AFGIT (in press).

The DESCRIPTION is not meant to be a formal classification nor to replace existing classifications. The descriptive names are not entirely mutually exclusive, because the categories are not precisely defined nor are all defined on similar bases, hence fail the criteria for formal classification. For samples for which thin sections have not been made the nature and genesis of a rock is far less well-known than for those for which thin sections do exist. Thus some of the rocks can be more specifically characterized than others, and this is partly reflected in the descriptive name. The descriptions contain few question marks, but actually in some cases are imprecise and may be altered following further study. The name given is not precisely the description given as the title line in the comprehensive descriptions in the main part of this catalog; the title line usually contains more information.

Early classifications of Apollo 16 rocks were given by Wilshire et al. (1973, and in AFGIT, in press) and Warner et al. (1973), and a general classification system for highlands rocks is presented and discussed by Stöffler et al. (1979, 1980).

The descriptive names used in the inventory are:

Basaltic impact melt: homogeneous, mainly subophitic to ophitic igneous texture, with clasts present in some but not all cases. Chemical data show meteoritic contamination.

Variolitic impact melt: homogeneous, igneous texture with radiating clusters of plagioclase, and interstitial glass and mafic minerals. Clasts are usually present, and chemical data show meteorite contamination.

Poikilitic impact melt: homogeneous, generally igneous texture with numerous tiny plagioclase grains embedded in larger oikocrysts of pyroxene (less commonly olivine). Interoikocryst areas contain ilmenite and glass. Clasts are usually conspicuous and more common than basaltic impact melts, and chemical data show meteorite contamination. (Some workers believe this texture to be metamorphic in origin).

The use of the above three terms usually requires that thin section study has been made. In cases where there is evidence that the sample is an impact melt and is not aphanitic, but the texture cannot be identified, we have used the more general term crystalline impact melt.

Fine-grained impact melt: numerous clasts in a seriate size distribution embedded in a fine-grained (<50 µm) melt matrix - the distinction between tiny clasts and the melt is usually difficult, but the melt includes laths of plagioclase and ilmenite.

Glassy impact melt: similar to the fine-grained impact melts but with more glass and larger laths of plagioclase.

The above two terms have been used for samples both with and without thin sections.

Glass, cindery glass, glassy breccia: these terms are used in a loose sense to split a gradational series, from near homogeneous glasses with few clasts through clearly polymict, clast-rich breccias with abundant glass in the matrix. The glassy impact melts are also gradational into this group; the distinction is that the glassy breccias may have several stages of glass production or distinct glass entities, whereas the glassy impact melts have glass produced in a single event. The glasses include both clear and devitrified glasses, and both spherical and irregular bodies.

Fragmental polymict breccia: polymict breccias characterized by angular, unequilibrated mineral and lithic clasts. They are mainly friable, although some are coherent and probably lightly sintered. They are a diverse group with variable colors and clast contents; most of the "light matrix breccias" in published studies are in this group.

Coherent polymict breccia: A catch-all phrase for mainly heterogeneous coherent polymict breccias with varied matrices from crystalline impact melt, to glassy, to those of unidentified character. Most of these are medium to dark gray in color.

Dilithologic breccias: Breccias which consist of two lithologies, one light-colored (cataclastic anorthosite or granoblastic material), the other dark-colored (usually fine-grained crystalline impact melt), generally referred to in published studies as "Black-and-White" breccias.

Regolith breccia: coherent to friable rocks which are lithified soils or at least contain abundant regolith-derived components such as glass beads, glass shards, and agglutinitic material; usually dark gray to brown.

Friable regolith clod: mainly disaggregated, often brown, clods which appear to have been loosely bound regolith.

Cataclastic anorthosite: near-monomineralic (plagioclase) rocks which are brecciated but commonly contain relict plagioclase grains a few millimeters across. If chemical or other data indicates a lack of meteoritic contamination the phrase Pristine cataclastic anorthosite is used. The modifiers noritic and troctolitic are also used.

Other sparsely-used descriptive names, for which explanation see the individual samples, are granoblastic anorthosite (60619), granoblastic troctolitic anorthosite (61577), poikiloblastic impactite (67955, 67746), granoblastic impactite (67566), and polymict granoblastic breccia (60035). They consist largely of materials with clearly metamorphic textures. Such lithic types are fairly common as smaller clasts in other polymict breccias. One sample (61576) is probably a single plagioclase crystal, and one sample (67667) is a pristine feldspathic lherzolite.

Finally, some of the descriptive names are combined forms (e.g. glassy impact melt/breccia) where two lithologies are conspicuous, and the prefix "meta-" is used in a few cases where a dominantly igneous texture has been modified by subsequent thermal effects.

The SAMPLE CONTAINER acronyms are:

DB	Documented bag
PDB	Padded documented bag
SCB	Sample collection bag
SRC	Sample return container

Further details of sample containers can be found in the Interagency Report: Astrogeology 51 (1972), and the Apollo 16 Sample Information Catalog (1972).

References Cited:

AFGIT (in press) Geology of the Apollo 16 area, central lunar highlands (G. E. Ulrich, C. A. Hodges and W. R. Muehlberger, eds.). U. S. Geol. Survey Open File Report No. 79-1091. 1128 pp. (To be published as U. S. Geol. Survey Prof. Paper No. 1048).

Apollo 16 Lunar Sample Information Catalog (1972). MSC 03210. Manned Spacecraft Center, Houston. 372 pp.

Apollo 16 Preliminary Science Report (1972). NASA SP-315. National Aeronautics and Space Administration, Washington, D.C.

Bailey N. G. and Ulrich G. E. (1975) Apollo 16 Voice Transcript. USGS-GD-74-030. United States Geological Survey, Flagstaff. 323 pp.

Interagency Report: Astrogeology 51 (1972) Prepared by the Geological Survey for the National Aeronautics and Space Administration. 252 pp.

Stöffler D., Knoll H.-D., Maerz U. (1979) Terrestrial and lunar impact breccias and the classification of lunar highlands rocks. Proc. Lunar Planet. Sci. Conf. 10th, p. 639-675.

Stöffler D., Knoll H.-D., Marvin U. B., Simonds C. H., and Warren P. H. (1980) Recommended classification and nomenclature of lunar highland rocks - a committee report. Proc. of the Conference on the Lunar Highlands Crust p. 51-70.

Warner J. L., Simonds C. H., and Phinney W. C. (1973) Apollo 16 rocks: Classification and petrogenetic model. Proc. Lunar Sci. Conf. 4th, p. 481-504.

Wilshire H. G., Stuart-Alexander D. G. and Jackson E. D. (1973) Apollo 16 rocks: Petrology and classification. J. Geophys. Res. 78, 2379-2392.

APOLLO 16 ROCK INVENTORY

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION *</u>	<u>SRC/DB OR SCB/DB</u>
60015		5574.0	Pristine cataclastic anorthosite (G)	SCB5/
60016		4307.0	Fragmental polymict breccia	SCB7/
60017		2102.0	Variolitic impact melt/breccia	SCB7/
60018		1501.0	Basaltic impact melt (G)	SCB7/
60019		1887.0	Glassy (regolith?) breccia (G)	SCB4/
60025		1836.0	Pristine cataclastic anorthosite (G)	SCB3/
60035		1052.0	Polymict granoblastic breccia (G)	SRC1/351
60055		35.48	Pristine cataclastic anorthosite	SRC1/355
60056		16.07	Cataclastic anorthosite (G)	SRC1/355
60057		3.10	Cataclastic anorthosite	SRC1/355
60058		2.12	Fragmental polymict breccia	SRC1/355
60059		1.05	Cataclastic anorthosite	SRC1/355
60075		183.8	Fragmental polymict breccia	SRC1/373
60095		46.60	Glass	SCB1/004
60115		132.5	Glassy breccia	SCB1/381
60135		137.7	Cataclastic anorthosite (G)	SCB6/430
60215		385.8	Pristine cataclastic anorthosite (G)	SCB6/13
60235		70.13	Basaltic impact melt	SCB6/15
60255		871.0	Regolith breccia (G)	SCB6/17
60275		255.2	Glassy breccia (regolith?) (G)	SCB7/18
60315		787.7	Poikilitic impact melt	SCB7/20
60335		317.8	Basaltic impact melt	SCB6/331
60515	R	16.74	Cataclastic anorthosite	SCB4/349
60516	R	7.91	Cataclastic anorthosite	SCB4/349
60517	R	1.23	Cataclastic anorthosite	SCB4/349
60518	R	1.12	Cataclastic anorthosite	SCB4/349
60519	R	.50	Cataclastic anorthosite	SCB4/349
60525	R	12.84	Poikilitic impact melt	SCB4/349
60526	R	8.42	Poikilitic impact melt	SCB4/349
60527	R	7.36	Crystalline polymict breccia/glass(G)	SCB4/349
60528	R	2.94	Glassy impact melt	SCB4/349
60529	R	1.24	Basaltic impact melt	SCB4/349

* A (G) following the descriptive name indicates that the rock is at least partly coated with glass.

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
60535	R	7.23	Fragmental polymict (regolith?) breccia (G)	SCB4/349
60615	R	32.97	Basaltic impact melt (G)	SCB4/347
60616	R	3.40	Poikilitic impact melt	SCB4/347
60617	R	2.77	Crystalline impact melt (G)	SCB4/347
60618	R	21.67	Basaltic impact melt/anorthosite	SCB4/347
60619	R	28.00	Granoblastic anorthosite (G)	SCB4/347
60625	R	117.00	Poikilitic impact melt	SCB4/347
60626	R	15.87	Poikilitic impact melt	SCB4/347
60627	R	12.09	Crystalline impact melt (G)	SCB4/347
60628	R	6.86	Cataclastic anorthosite (G)	SCB4/347
60629	R	4.92	Cataclastic anorthosite (G)	SCB4/347
60635	R	15.05	Basaltic impact melt	SCB4/347
60636	R	35.65	Basaltic/poikilitic impact melt (G)	SCB4/347
60637	R	7.98	Fragmental polymict (regolith?) breccia	SCB4/347
60638	R	.72	Fragmental polymict breccia	SCB4/347
60639	R	175.1	Fragmental polymict breccia (G)	SCB4/347
60645	R	33.5	Fine-grained impact melt	SCB4/347
60646	R	3.39	Fine-grained impact melt	SCB4/347
60647	R	1.76	Glassy impact melt	SCB4/347
60648	R	2.84	Glassy breccia	SCB4/347
60649	R	1.03	Glassy breccia	SCB4/347
60655	R	8.63	Glassy impact melt	SCB4/347
60656	R	11.23	Glassy impact melt	SCB4/347
60657	R	6.05	Fragmental polymict breccia (G)	SCB4/347
60658	R	5.47	Glassy impact melt (G)	SCB4/347
60659	R	22.20	Fragmental polymict breccia	SCB4/347
60665	R	90.1	Glass	SCB4/347
60666	R	15.95	Glassy impact melt	SCB4/347
60667	R	7.66	Glassy/basaltic impact melt (G)	SCB4/347
60668	R	2.91	Glassy impact melt	SCB4/347
60669	R	2.54	Glass	SCB4/347
60675	R	1.30	Fine-grained impact melt	SCB4/347
60676	R	8.92	Glassy impact melt	SCB4/347
60677	R	5.23	Glassy breccia	SCB4/347
60678	R	1.25	Glassy impact melt	SCB4/347
60679	R	2.96	Glassy impact melt	SCB4/347
61015		1804.0	Dilithologic breccia (G)	SRC1
61016		11729.0	Basaltic impact melt/pristine anorthosite (G)	BLSLSS
61017		2.62	Cataclastic anorthosite	SRC1/
61135		245.1	Fragmental polymict breccia	SRC1/362

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
61155		47.59	Glassy impact melt	SRC1/371
61156		58.46	Meta-poikilitic impact melt	SRC1/371
61157		11.26	Fragmental polymict breccia	SRC1/371
61158		14.79	Fragmental polymict breccia	SRC1/371
61175		542.7	Fragmental polymict breccia	SRC1/364
61195		587.9	Regolith breccia (G)	SRC1/002
61225		3.52	Crystalline impact melt	SRC1/357
61226		1.53	Cataclastic anorthosite (G)	SRC1/357
61245		8.25	Fine-grained impact melt	SRC1/352
61246		6.05	Fine-grained impact melt	SRC1/352
61247		2.48	Poikilitic impact melt	SRC1/352
61248		1.71	Fragmental polymict breccia	SRC1/352
61249		1.17	Basaltic impact melt	SRC1/352
61255		1.13	Cindery glass	SRC1/352
61295		187.00	Regolith breccia	SRC1/353
61505	P	1.651	Fine-grained impact melt	SRC1/354
61515	R	2.00	Fragmental polymict breccia	SRC1/372
61516	R	2.38	Fragmental polymict breccia	SRC1/372
61517	R	.47	Fragmental polymict breccia	SRC1/372
61518	R	.16	Fragmental polymict breccia	SRC1/372
61519	R	.33	Fragmental polymict breccia	SRC1/372
61525	R	10.35	Glassy breccia	SRC1/372
61526	R	4.08	Fragmental polymict breccia	SRC1/372
61527	R	.52	Fragmental polymict breccia	SRC1/372
61528	R	.24	Fragmental polymict breccia (G)	SRC1/372
61529	R	.28	Fragmental polymict breccia	SRC1/372
61535	R	.23	Fragmental polymict breccia (G)	SRC1/372
61536	R	85.99	Glassy breccia (G)	SRC1/372
61537	R	6.62	Fragmental polymict breccia (G)	SRC1/372
61538	R	4.76	Fragmental polymict breccia (G)	SRC1/372
61539	R	5.78	Glassy breccia	SRC1/372
61545	R	3.61	Fragmental polymict breccia (G)	SRC1/372
61546	R	110.7	Glassy impact melt	SRC1/372
61547	R	17.93	Basaltic impact melt (G?)	SRC1/372
61548	R	24.18	Glassy impact melt	SRC1/372
61549	R	3.76	Basaltic/poikilitic impact melt	SRC1/372

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
61555	R	3.46	Glassy impact melt	SRC1/372
61556	R	2.23	Glass	SRC1/372
61557	R	.93	Glassy impact melt	SRC1/372
61558	R	3.00	Glass	SRC1/372
61559	R	.62	Glassy breccia	SRC1/372
61565	R	.88	Glassy breccia	SRC1/372
61566	R	.66	Glassy impact melt	SRC1/372
61567	R	.19	Glassy impact melt	SRC1/372
61568	R	19.32	Basaltic/poikilitic impact melt	SRC1/372
61569	R	12.02	Poikilitic impact melt	SRC1/372
61575	R	5.26	Crystalline impact melt	SRC1/372
61576	R	5.87	Plagioclase crystal (G)	SRC1/372
61577	R	.21	Granoblastic troctolitic anorthosite (G)	SRC1/372
62235		319.6	Poikilitic impact melt	SRC1/005
62236		57.27	Pristine noritic anorthosite	SRC1/005
62237		62.35	Pristine troctolitic anorthosite	SRC1/005
62238		1.565	Cataclastic anorthosite	SRC1/005
62245	P	6.03	Crystalline impact melt	SRC1/006
62246	P	4.59	Cataclastic anorthosite (G)	SRC1/006
62247	P	2.11	Fragmental polymict breccia	SRC1/006
62248	P	1.61	Fragmental polymict breccia (G)	SRC1/006
62249	P	1.41	Fragmental polymict breccia	SRC1/006
62255		1239.0	Dilithologic breccia (G)	SRC1/007
62275		443.0	Cataclastic anorthosite	SRC1/009
62285	P	3.524	Friable regolith clod	SRC1/011
62286	P	2.917	Friable regolith clod	SRC1/011
62287	P	2.474	Fine-grained impact melt	SRC1/011
62288	P	1.939	Fragmental or crystalline polymict breccia	SRC1/011
62289	P	1.135	Friable regolith clod	SRC1/011
62295		250.8	Basaltic impact melt	SRC1/010
62305	P	.810	Fragmental polymict breccia	SRC1/011
62315	P	.77	Fragmental polymict breccia	SRC1/006
63335		65.4	Fine-grained impact melt/breccia	SCB6/428
63355		68.24	Poikilitic impact melt	SCB6/429

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
63505	P	5.41	Fine-grained impact melt	SCB4/346
63506	P	4.9	Basaltic impact melt	SCB4/346
63507	P	2.78	Fragmental regolith breccia (G)	SCB4/346
63508	P	2.61	Fine-grained impact melt	SCB4/346
63509	P	2.05	Fine-grained impact melt	SCB4/346
63515	P	1.32	Fine-grained impact melt	SCB4/346
63525	R	6.68	Fine-grained impact melt	SCB4/345
63526	R	2.91	Fine-grained impact melt	SCB4/345
63527	R	6.10	Basaltic impact melt (mafic)	SCB4/345
63528	R	4.12	Fine-grained impact melt	SCB4/345
63529	R	23.48	Fine-grained impact melt	SCB4/345
63535	R	6.85	Basaltic impact melt	SCB4/345
63536	R	1.02	Basaltic impact melt	SCB4/345
63537	R	4.78	Basaltic impact melt	SCB4/345
63538	R	35.06	Fine-grained impact melt/glass	SCB4/345
63539	R	.39	Fine-grained impact melt	SCB4/345
63545	R	15.95	Basaltic impact melt	SCB4/345
63546	R	9.23	Fine-grained impact melt	SCB4/345
63547	R	4.90	Poikilitic impact melt	SCB4/345
63548	R	1.13	Fine-grained impact melt	SCB4/345
63549	R	26.57	Basaltic impact melt	SCB4/345
63555	R	3.38	Fine-grained impact melt	SCB4/345
63556	R	18.10	Poikilitic impact melt	SCB4/345
63557	R	7.53	Fine-grained impact melt	SCB4/345
63558	R	7.09	Poikilitic impact melt	SCB4/345
63559	R	6.04	Glass	SCB4/345
63565	R	.94	Glass	SCB4/345
63566	R	19.61	Glass	SCB4/345
63567	R	3.21	Glass	SCB4/345
63568	R	4.06	Glass	SCB4/345
63569	R	.43	Glass	SCB4/345
63575	R	4.72	Glass	SCB4/345
63576	R	1.23	Glass	SCB4/345
63577	R	12.41	Crystalline polymict breccia	SCB4/345
63578	R	19.60	Glassy/fine-grained impact melt breccia	SCB4/345
63579	R	11.35	Fine-grained impact melt	SCB4/345
63585	R	32.62	Basaltic/poikilitic impact melt	SCB4/345
63586	R	1.98	Fine-grained impact melt	SCB4/345
63587	R	20.51	Poikilitic impact melt	SCB4/345
63588	R	2.40	Fragmental polymict breccia	SCB4/345
63589	R	13.51	Fragmental polymict breccia	SCB4/345

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
63595	R	2.10	Fragmental polymict breccia	SCB4/345
63596	R	6.40	Poikilitic impact melt	SCB4/345
63597	R	5.67	Poikilitic impact melt	SCB4/345
63598	R	12.66	Poikilitic impact melt	SCB4/345
64425		14.62	Dilithologic breccia	SCB3/399
64435		1079.0	Fine-grained impact melt (G)	SCB1/394
64455		56.68	Basaltic impact melt (G)	SCB3/397
64475		1032.0	Dilithologic breccia	SCB3/398
64476		125.1	Dilithologic breccia	SCB3/398
64477		19.32	Glassy breccia	SCB3/398
64478		12.34	Poikilitic impact melt (G)	SCB3/398
64505	P	5.392	Fragmental polymict breccia	SCB1/396
64506	P	5.079	Basaltic impact melt (G)	SCB1/396
64507	P	4.474	Dilithologic breccia	SCB1/396
64508	P	4.168	Dilithologic breccia	SCB1/396
64509	P	3.150	Fragmental polymict breccia	SCB1/396
64515	P	3.761	Basaltic impact melt	SCB1/396
64516	P	2.929	Cataclastic anorthosite	SCB1/396
64517	P	1.546	Crystalline polymict breccia	SCB1/396
64518	P	1.490	Fine-grained impact melt	SCB1/396
64519	P	1.124	Cataclastic anorthosite	SCB1/396
64525	P	1.107	Cataclastic anorthosite	SCB1/396
64535	R	256.6	Dilithologic breccia	SCB1/395
64536	R	177.5	Dilithologic breccia	SCB1/395
64537	R	124.3	Dilithologic breccia	SCB1/395
64538	R	30.03	Polyolithologic breccia	SCB1/395
64539	R	17.76	Dilithologic breccia	SCB1/395
64545	R	14.09	Dilithologic breccia	SCB1/395
64546	R	12.80	Dilithologic breccia	SCB1/395
64547	R	10.90	Fragmental polymict or dilithologic breccia	SCB1/395
64548	R	8.49	Dilithologic breccia	SCB1/395
64549	R	6.47	Dilithologic breccia	SCB1/395
64555	R	5.29	Fragmental dilithologic breccia	SCB1/395
64556	R	5.15	Dilithologic or polymict breccia	SCB1/395
64557	R	4.790	Fine-grained impact melt	SCB1/395
64558	R	3.130	Dilithologic breccia	SCB1/395
64559	R	21.82	Basaltic impact melt	SCB1/395

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
64565	R	14.73	Glassy impact melt	SCB1/395
64566	R	14.13	Fine-grained impact melt	SCB1/395
64567	R	13.86	Poikilitic impact melt	SCB1/395
64568	R	9.379	Poikilitic impact melt	SCB1/395
64569	R	14.32	Poikilitic impact melt	SCB1/395
64575	R	6.837	Poikilitic impact melt	SCB1/395
64576	R	6.916	Basaltic impact melt	SCB1/395
64577	R	5.692	Glassy breccia	SCB1/395
64578	R	5.596	Fine-grained impact melt (G)	SCB1/395
64579	R	4.802	Fine-grained impact melt	SCB1/395
64585	R	4.696	Basaltic/poikilitic impact melt	SCB1/395
64586	R	3.337	Fine-grained impact melt (G)	SCB1/395
64587	R	7.180	Fragmental polymict breccia (G)	SCB1/395
64588	R	2.546	Fragmental polymict breccia	SCB1/395
64589	R	4.039	Cataclastic anorthosite	SCB1/395
64815	R	20.90	Meta-poikilitic impact melt	SCB3/401
64816	R	3.83	Poikilitic impact melt	SCB3/401
64817	R	8.98	Basaltic impact melt	SCB3/401
64818	R	15.98	Dilithologic breccia	SCB3/401
64819	R	11.76	Pristine cataclastic anorthosite(G)	SCB3/401
64825	R	21.50	Fragmental polymict breccia	SCB3/401
64826	R	11.33	Fragmental polymict breccia	SCB3/401
64827	R	8.11	Fragmental polymict breccia	SCB3/401
64828	R	.97	Fragmental polymict breccia	SCB3/401
64829	R	2.20	Fragmental polymict breccia	SCB3/401
64835	R	2.32	Fragmental polymict breccia	SCB3/401
64836	R	1.76	Fragmental polymict breccia	SCB3/401
64837	R	2.18	Fragmental polymict breccia (G)	SCB3/401
65015		1802.0	Poikilitic impact melt	SCB3/
65016		21.02	Glass	SCB1/
65035		446.1	Cataclastic anorthosite (G)	SCB1/404
65055		500.8	Basaltic impact melt	SCB3/337
65056		64.78	Variolitic impact melt	SCB3/337
65075		107.9	Basaltic impact melt (G)	SCB1/403
65095		560.1	Fragmental polymict (regolith?) breccia (G)	SCB3/336
65315		300.4	Pristine cataclastic anorthosite (G)	SCB1/405

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
65325	R	67.87	Pristine cataclastic anorthosite (G)	SCB1/405
65326	R	36.40	Cataclastic anorthosite	SCB1/405
65327	R	6.97	Pristine cataclastic anorthosite (G)	SCB1/405
65328	R	1.28	Cataclastic anorthosite (G)	SCB1/405
65329	R	1.92	Cataclastic anorthosite	SCB1/405
65335	R	1.63	Cataclastic anorthosite	SCB1/405
65336	R	.60	Cataclastic anorthosite (G)	SCB1/405
65337	R	11.57	Fragmental polymict breccia	SCB1/405
65338	R	2.65	Fragmental polymict breccia	SCB1/405
65339	R	1.62	Fragmental polymict breccia	SCB1/405
65345	R	.86	Fragmental polymict breccia	SCB1/405
65346	R	.80	Fragmental polymict breccia	SCB1/405
65347	R	.43	Fragmental polymict breccia	SCB1/405
65348	R	11.66	Glass	SCB1/405
65349	R	7.58	Glassy impact melt	SCB1/405
65355	R	4.94	Glassy impact melt	SCB1/405
65356	R	2.53	Glassy impact melt	SCB1/405
65357	R	18.76	Poikilitic impact melt	SCB1/405
65358	R	7.02	Poikilitic impact melt	SCB1/405
65359	R	2.53	Fragmental polymict breccia (G)	SCB1/405
65365	R	2.16	Poikilitic impact melt	SCB1/405
65366	R	8.48	Glass	SCB1/405
65515	R	50.25	Fragmental polymict breccia (regolith clod)	SRC2/332
65516	R	10.49	Fragmental polymict breccia (regolith clod)	SRC2/332
65517	R	11.85	Fragmental polymict breccia (regolith clod)	SRC2/332
65518	R	9.477	Fragmental polymict breccia (regolith clod)	SRC2/332
65519	R	10.58	Fragmental polymict breccia (regolith clod)	SRC2/332
65525	R	7.483	Fragmental polymict breccia (regolith clod)	SRC2/332
65526	R	3.545	Fragmental polymict breccia (regolith clod)	SRC2/332
65527	R	2.890	Fragmental polymict breccia (regolith clod)	SRC2/332
65528	R	3.082	Fragmental polymict breccia (regolith clod)	SRC2/332
65529	R	2.555	Fragmental polymict breccia (regolith clod)	SRC2/332

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
65535	R	2.658	Fragmental polymict breccia (regolith clod)	SRC2/332
65536	R	1.575	Fragmental polymict breccia (regolith clod)	SRC2/332
65537	R	2.426	Fragmental polymict breccia (regolith clod)	SRC2/332
65538	R	2.342	Fragmental polymict breccia (regolith clod)	SRC2/332
65539	R	2.180	Fragmental polymict breccia (regolith clod)	SRC2/332
65545	R	1.797	Fragmental polymict breccia (regolith clod)	SRC2/332
65546	R	1.346	Fragmental polymict breccia (regolith clod)	SRC2/332
65547	R	1.587	Fragmental polymict breccia (regolith clod)	SRC2/332
65548	R	3.023	Fragmental polymict breccia (regolith clod)	SRC2/332
65549	R	2.094	Fragmental polymict breccia (regolith clod)	SRC2/332
65555	R	2.202	Fragmental polymict breccia (regolith clod)	SRC2/332
65556	R	1.170	Fragmental polymict breccia (regolith clod)	SRC2/332
65557	R	1.114	Fragmental polymict breccia (regolith clod)	SRC2/332
65558	R	1.695	Fragmental polymict breccia (regolith clod)	SRC2/332
65559	R	1.533	Fragmental polymict breccia (regolith clod)	SRC2/332
65565	R	.852	Fragmental polymict breccia (regolith clod)	SRC2/332
65566	R	1.998	Fragmental polymict breccia (regolith clod)	SRC2/332
65567	R	1.289	Fragmental polymict breccia (regolith clod)	SRC2/332
65568	R	.808	Fragmental polymict breccia (regolith clod)	SRC2/332
65569	R	.873	Fragmental polymict breccia (regolith clod)	SRC2/332

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
65575	R	.907	Fragmental polymict breccia (regolith clod)	SRC2/332
65576	R	.906	Fragmental polymict breccia (regolith clod)	SRC2/332
65577	R	.706	Fragmental polymict breccia (regolith clod)	SRC2/332
65578	R	.320	Fragmental polymict breccia (regolith clod)	SRC2/332
65579	R	.612	Fragmental polymict breccia (regolith clod)	SRC2/332
65585	R	9.294	Cindery glass	SRC2/332
65586	R	6.763	Fragmental polymict breccia (regolith clod) (G)	SRC2/332
65587	R	2.141	Fragmental polymict breccia (regolith clod) (G)	SRC2/332
65588	R	9.629	Fragmental polymict breccia	SRC2/332
65715	R	31.36	Fragmental polymict breccia	SCB1/334
65716	R	14.28	Fragmental polymict breccia	SCB1/334
65717	R	7.415	Fragmental polymict breccia	SCB1/334
65718	R	10.61	Fragmental polymict breccia	SCB1/334
65719	R	7.04	Fragmental polymict breccia	SCB1/334
65725	R	6.67	Fragmental polymict breccia	SCB1/334
65726	R	5.19	Fragmental polymict breccia	SCB1/334
65727	R	4.30	Fragmental polymict breccia	SCB1/334
65728	R	4.22	Fragmental polymict breccia	SCB1/334
65729	R	3.81	Fragmental polymict breccia	SCB1/334
65735	R	4.26	Fragmental polymict breccia	SCB1/334
65736	R	2.74	Fragmental polymict breccia	SCB1/334
65737	R	.85	Fragmental polymict breccia	SCB1/334
65738	R	1.17	Fragmental polymict breccia	SCB1/334
65739	R	.95	Fragmental polymict breccia	SCB1/334
65745	R	7.76	Fragmental polymict (regolith?) breccia	SCB1/334
65746	R	4.19	Regolith breccia	SCB1/334
65747	R	.82	Fragmental polymict (regolith?) breccia	SCB1/334
65748	R	.97	Fragmental polymict (regolith?) breccia	SCB1/334
65749	R	.95	Fragmental polymict (regolith?) breccia	SCB1/334
65755	R	1.42	Glassy impact melt or regolith breccia	SCB1/334
65756	R	.77	Fragmental polymict breccia	SCB1/334
65757	R	26.20	Glassy impact melt	SCB1/334
65758	R	5.95	Dilithologic or crystalline polymict breccia	SCB1/334
65759	R	3.11	Cataclastic anorthosite (G)	SCB1/334

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
65765	R	1.12	Dilithologic breccia or melt-coated anorthosite (G?)	SCB1/334
65766	R	1.01	Cataclastic anorthosite	SCB1/334
65767	R	17.51	Glass	SCB1/334
65768	R	3.25	Fragmental polymict breccia (G)	SCB1/334
65769	R	2.74	Fragmental polymict breccia (G)	SCB1/334
65775	R	3.50	Fragmental polymict breccia (G)	SCB1/334
65776	R	2.33	Glassy impact melt	SCB1/334
65777	R	16.53	Poikilitic impact melt (G)	SCB1/334
65778	R	12.22	Poikilitic impact melt	SCB1/334
65779	R	12.71	Basaltic impact melt	SCB1/334
65785	R	5.16	Basaltic impact melt	SCB1/334
65786	R	83.02	Glassy breccia (G)	SCB1/334
65787	R	8.28	Crystalline polymict breccia (G)	SCB1/334
65788	R	9.32	Glassy impact melt	SCB1/334
65789	R	12.24	Cataclastic anorthosite (G)	SCB1/334
65795	R	6.84	Basaltic impact melt	SCB1/334
65905	P	12.08	Basaltic impact melt	SCB1/406
65906	P	6.584	Basaltic impact melt (G)	SCB1/406
65907	P	4.658	Fragmental polymict breccia	SCB1/406
65908	P	2.162	Glass	SCB1/406
65909	P	2.024	Cataclastic anorthosite	SCB1/406
65915	P	2.060	Glassy or fine-grained impact melt	SCB1/406
65916	P	0.994	Cataclastic anorthosite	SCB1/406
65925	R	3.82	Fragmental polymict (regolith?) breccia	SCB1/335
65926	R	3.03	Fragmental polymict (regolith?) breccia	SCB1/335
65927	R	.72	Fragmental polymict (regolith?) breccia	SCB1/335
66035		211.4	Fragmental polymict breccia (G)	SCB1/407
66036		4.384	Fragmental polymict breccia	SCB1/407
66037		3.718	Glassy breccia	SCB1/407
66055		1306.0	Polymict or dilithologic breccia	SCB1/408
66075		347.1	Fragmental polymict breccia	SRC2/409
66085		3.66	Fragmental polymict breccia	SRC2/339
66086		2.027	Fragmental polymict breccia	SRC2/339
66095		1185.0	Basaltic impact melt (G)	SCB1/410

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
67015		1194.0	Fragmental polymict breccia	SCB7/
67016		4262.0	Fragmental polymict breccia	BSLSS
67025		16.06	Basaltic impact melt (G)	BSLSS
67035		245.2	Fragmental polymict breccia	SCB7/382
67055		221.9	Fragmental polymict breccia	SCB7/383
67075		219.2	Cataclastic anorthosite	SCB7/384
67095		339.8	Basaltic impact melt (G)	SCB7/385
67115		240.0	Fragmental polymict breccia (G)	SCB7/386
67215		276.2	Fragmental (monomict granoblastic) breccia	SCB6/PDB1
67235		937.2	Poikilitic impact melt	SCB6/PDB2
67415		174.9	Cataclastic noritic anorthosite	SCB6/387
67435		353.5	Crystalline polymict breccia (G)	SCB6/415
67455		942.2	Fragmental polymict breccia	SCB6/416
67475		175.1	Glassy impact melt/breccia	SCB6/418
67485	P	6.55	Fine-grained impact melt	SCB6/419
67486	P	5.80	Glass	SCB6/419
67487	P	2.65	Fine-grained impact melt	SCB6/419
64788	P	2.25	Fine-grained impact melt	SCB6/419
67489	P	2.06	Basaltic impact melt	SCB6/419
67495	P	1.34	Fine-grained impact melt	SCB6/419
67515	R	60.8	Fragmental polymict breccia	SCB6/420
67516	R	14.38	Crystalline polymict breccia	SCB6/420
67517	R	9.65	Fragmental polymict breccia	SCB6/420
67518	R	3.74	Fragmental polymict breccia or cataclastic anorthosite	SCB6/420
67519	R	2.04	Fragmental polymict breccia	SCB6/420
67525	R	2.52	Cataclastic anorthosite	SCB6/420
67526	R	2.44	Fragmental polymict breccia	SCB6/420
67527	R	2.40	Fragmental polymict breccia	SCB6/420
67528	R	1.24	Fragmental polymict breccia	SCB6/420
67529	R	1.13	Cataclastic anorthosite	SCB6/420

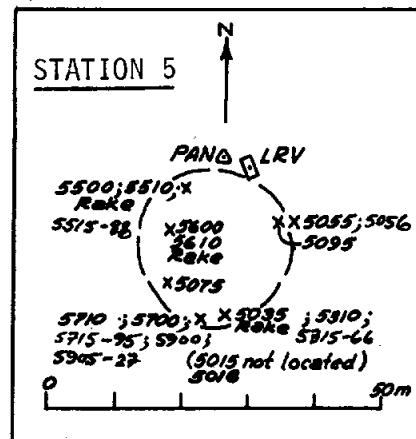
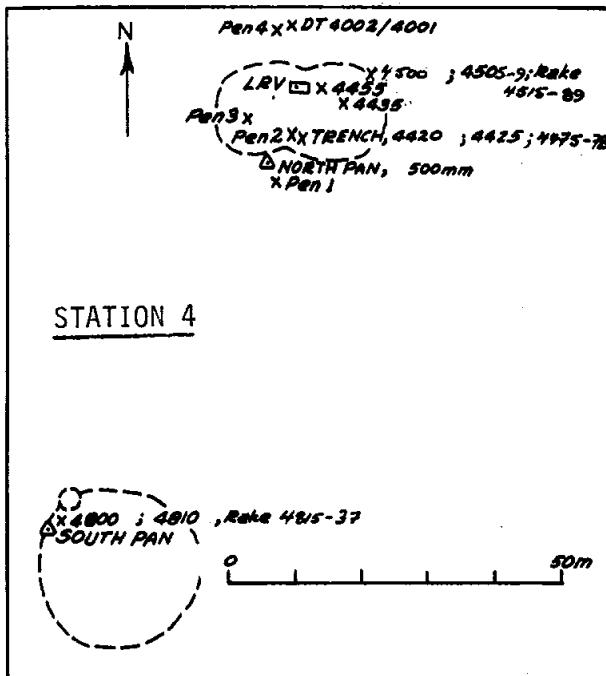
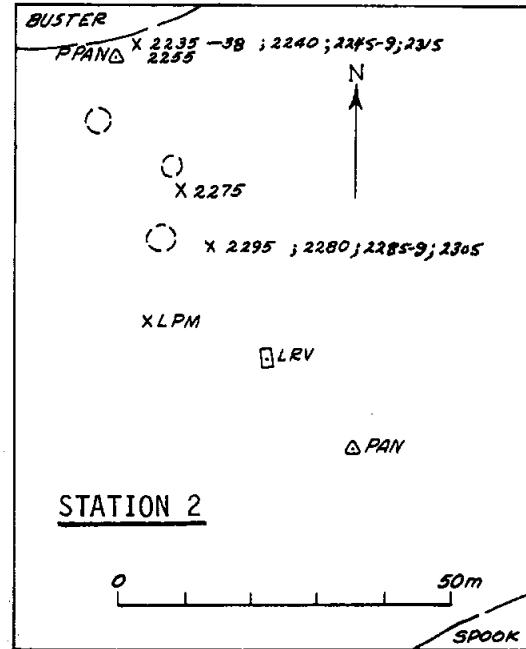
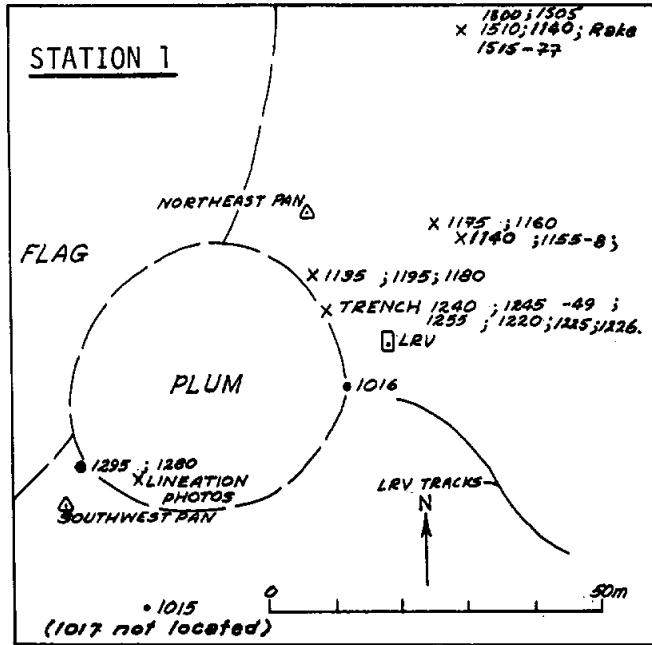
<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
67535	R	.99	Fragmental breccia or cataclastic anorthosite	SCB6/420
67536	R	1.20	Fragmental breccia or cataclastic anorthosite	SCB6/420
67537	R	1.29	Cataclastic anorthosite	SCB6/420
67538	R	1.77	Fragmental polymict breccia	SCB6/420
67539	R	2.12	Fragmental polymict breccia	SCB6/420
67545	R	1.88	Fragmental polymict breccia	SCB6/420
67546	R	1.50	Fragmental polymict breccia	SCB6/420
67547	R	.83	Fragmental polymict breccia	SCB6/420
67548	R	1.36	Fragmental polymict breccia	SCB6/420
67549	R	43.1	Fragmental polymict breccia	SCB6/420
67555	R	3.54	Glassy breccia	SCB6/420
67556	R	82.1	Basaltic impact melt	SCB6/420
67557	R	3.30	Regolith breccia	SCB6/420
67558	R	2.56	Fragmental polymict breccia	SCB6/420
67559	R	32.9	Basaltic impact melt	SCB6/420
67565	R	10.43	Poikilitic impact melt	SCB6/420
67566	R	4.31	Granoblastic impactite	SCB6/420
67567	R	11.51	Glass	SCB6/420
67568	R	11.05	Glass	SCB6/420
67569	R	7.27	Glass	SCB6/420
67575	R	4.47	Glassy breccia	SCB6/420
67576	R	3.98	Glassy breccia (regolith?)	SCB6/420
67605	P	44.52	Fragmental polymict breccia	SCB6/422
67615	R	8.77	Fine-grained impact melt	SCB6/421
67616	R	21.29	Fine-grained impact melt	SCB6/421
67617	R	14.32	Fine-grained impact melt	SCB6/421
67618	R	11.17	Crystalline breccia (G)	SCB6/421
67619	R	6.15	Fine-grained impact melt	SCB6/421
67625	R	6.72	Fine-grained impact melt	SCB6/421
67626	R	19.19	Crystalline polymict breccia	SCB6/421
67627	R	79.64	Glass	SCB6/421
67628:renumbered 67685-88				
67629	R	5.43	Glass	SCB6/421
67635	R	9.12	Pristine cataclastic anorthosite	SCB6/421
67636	R	3.23	Pristine cataclastic anorthosite	SCB6/421
67637	R	2.34	Pristine cataclastic anorthosite	SCB6/421
67638	R	7.23	Fragmental/glassy polymict breccia	SCB6/421
67639	R	7.34	Crystalline polymict breccia	SCB6/421

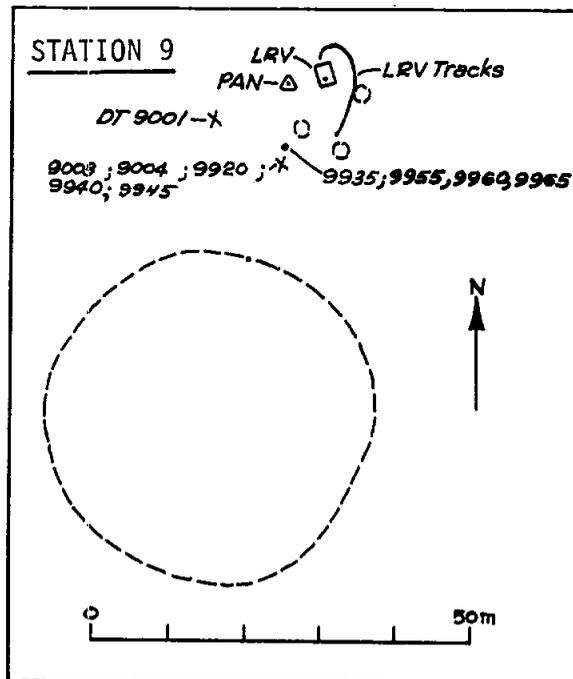
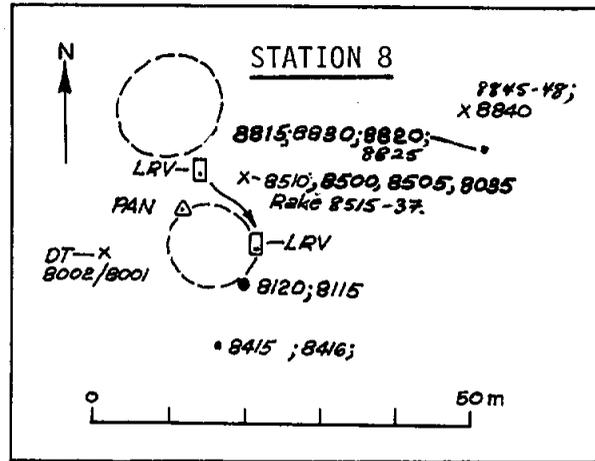
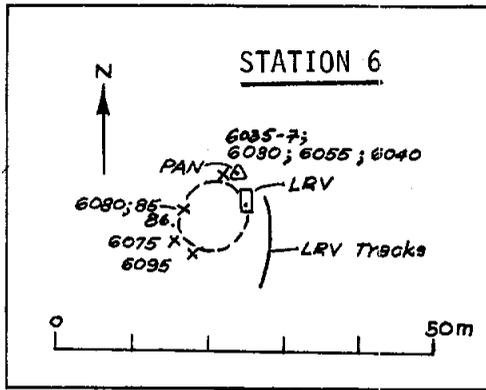
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67645	R	.84	Fragmental polymict breccia	SCB6/421
67646	R	3.94	Fragmental polymict breccia	SCB6/421
67647	R	47.72	Regolith breccia	SCB6/421
67648	R	7.88	Crystalline(?) polymict breccia	SCB6/421
67649	R	1.60	Fragmental polymict breccia	SCB6/421
67655	R	4.11	Crystalline polymict breccia	SCB6/421
67656	R	1.93	Fragmental polymict breccia	SCB6/421
67657	R	1.70	Fragmental polymict breccia	SCB6/421
67658	R	1.35	Fragmental polymict breccia	SCB6/421
67659	R	1.62	Crystalline or fragmental polymict breccia	SCB6/421
67665	R	5.88	Fragmental polymict breccia	SCB6/421
67666	R	5.47	Glassy breccia	SCB6/421
67667	R	7.89	Pristine feldspathic lherzolite	SCB6/421
67668	R	3.58	Poikilitic impact melt	SCB6/421
67669	R	12.54	Fragmental polymict breccia	SCB6/421
67675	R	1.07	Glass	SCB6/421
67676	R	2.33	Variolitic impact melt	SCB6/421
67685	R	28.04	Cindery glass	SCB6/421
67686	R	11.75	Cindery glass	SCB6/421
67687	R	7.60	Cindery glass	SCB6/421
67688	R	2.32	Cindery glass	SCB6/421
67695	R	14.02	Glass	SCB6/421
67696	R	7.85	Glass	SCB6/421
67697	R	5.54	Glassy breccia	SCB6/421
67705	P	5.82	Glass	SCB4/388
67706	P	1.52	Fragmental polymict breccia	SCB4/388
67707	P	1.42	Fragmental polymict breccia	SCB4/388
67708	P	1.33	Fragmental polymict breccia (G)	SCB4/388
67715	R	9.44	Fine-grained impact melt	SCB4/423
67716	R	17.02	Fine-grained impact melt	SCB4/423
67717	R	5.56	Glassy breccia	SCB4/423
67718	R	41.05	Fine-grained impact melt and fragmental breccia	SCB4/423
67719	R	2.13	Fine-grained impact melt	SCB4/423
67725	R	5.85	Crystalline polymict breccia (G)	SCB4/423
67726	R	4.53	Crystalline polymict breccia	SCB4/423
67727	R	1.80	Fine-grained impact melt	SCB4/423
67728	R	9.25	Fine-grained impact melt	SCB4/423
67729	R	73.2	Glassy breccia	SCB4/423

<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
67735	R	13.30	Glassy impact melt/breccia	SCB4/423
67736	R	14.92	Crystalline impact melt	SCB4/423
67737	R	4.56	Fine-grained impact melt	SCB4/423
67738	R	5.84	Fine-grained impact melt	SCB4/423
67739	R	2.03	Fine-grained impact melt	SCB4/423
67745	R	3.53	Fine-grained impact melt	SCB4/423
67746	R	3.47	Poikiloblastic impactite	SCB4/423
67747	R	6.30	Basaltic impact melt	SCB4/423
67748	R	4.74	Fine-grained impact melt	SCB4/423
67749	R	11.47	Fragmental polymict breccia	SCB4/423
67755	R	3.53	Fine-grained impact melt	SCB4/423
67756	R	4.82	Crystalline polymict breccia	SCB4/423
67757	R	4.83	Basaltic/poikilitic impact melt	SCB4/423
67758	R	4.06	Crystalline polymict breccia	SCB4/423
67759	R	4.56	Fragmental polymict breccia	SCB4/423
67765	R	1.73	Fine-grained impact melt	SCB4/423
67766	R	5.47	Crystalline polymict breccia	SCB4/423
67767	R	1.67	Fragmental polymict breccia	SCB4/423
67768	R	.99	Fragmental polymict breccia	SCB4/423
67769	R	3.05	Poikilitic impact melt	SCB4/423
67775	R	6.58	Fine-grained impact melt	SCB4/423
67776	R	3.10	Fragmental polymict breccia	SCB4/423
67915		2559.0	Crystalline polymict breccia	SCB4/
67935		108.9	Basaltic impact melt	SCB4/389
67936		61.82	Basaltic impact melt	SCB4/389
67937		59.67	Basaltic impact melt	SCB4/389
67945		4.37	Basaltic impact melt (G?)	SCB4/390
67946		3.20	Variolitic impact melt	SCB4/390
67947		2.43	Basaltic impact melt	SCB4/390
67948		1.59	Basaltic impact melt	SCB4/390
67955		162.6	Poikiloblastic impactite	SCB4/390
67956		3.70	Basaltic impact melt	SCB4/390
67957		1.73	Glassy breccia	SCB4/390
67975		446.6	Fragmental polymict breccia (G)	SCB4/392
68035		20.96	Crystalline polymict breccia (G)	SCB3/413
68115		1191.0	Glassy breccia	SRC2/340
68415		371.2	Basaltic impact melt	SRC2/341-2
68416		178.4	Basaltic impact melt	SRC2/341

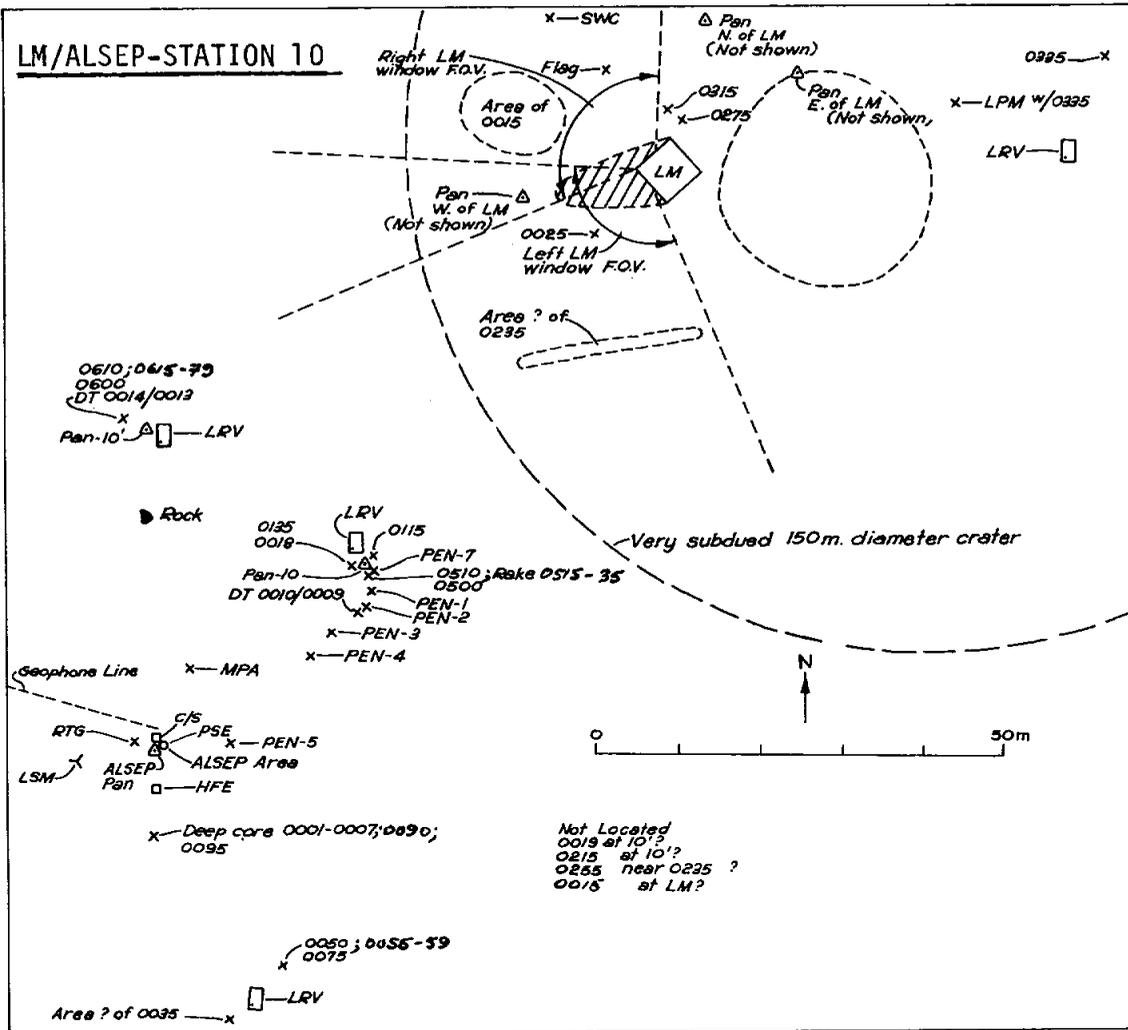
<u>SAMPLE NUMBER</u>	<u>SAMPLE TYPE</u>	<u>MASS g</u>	<u>DESCRIPTION</u>	<u>SRC/DB OR SCB/DB</u>
68505	P	1.30	Poikilitic impact melt	SCB3/412
68515	R	236.1	Dilithologic or polymict breccia(G)	SCB3/411
68516	R	34.04	Fine-grained/glassy impact melt	SCB3/411
68517	R	13.13	Crystalline of fragmental polymict breccia (G)	SCB3/411
68518	R	29.82	Glass	SCB3/411
68519	R	10.56	Basaltic impact melt (G)	SCB3/411
68525	R	38.96	Poikilitic impact melt (G)	SCB3/411
68526	R	7.21	Poikilitic impact melt	SCB3/411
68527	R	3.03	Crystalline polymict breccia (poikilitic impact melt?)	SCB3/411
68528	R	1.08	Crystalline polymict breccia	SCB3/411
68529	R	7.03	Glass	SCB3/411
68535	R	8.04	Glassy breccia	SCB3/411
68536	R	1.85	Basaltic impact melt	SCB3/411
68537	R	1.41	Fine-grained impact melt (G?)	SCB3/411
68815		1826.0	Glassy breccia	SRC2/343
68825	P	8.658	Glassy impact melt	SCB1/375
68845	P	4.556	Fine-grained impact melt	SCB1/344
68846	P	2.284	Fine-grained impact melt	SCB1/344
68847	P	2.854	Fine-grained impact melt	SCB1/344
68848	P	1.770	Basaltic impact melt (G)	SCB1/344
69935		127.6	Glassy breccia	SCB3/378
69945		6.88	Poikilitic impact melt (G)	SCB3/377
69955		75.94	Cataclastic anorthosite	SCB3/380
69965		1.12	Fragmental polymict breccia (G)	SCB3/379

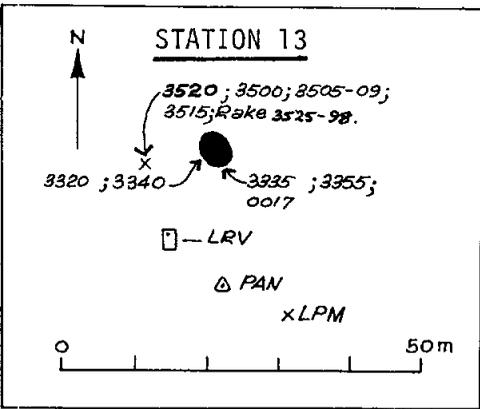
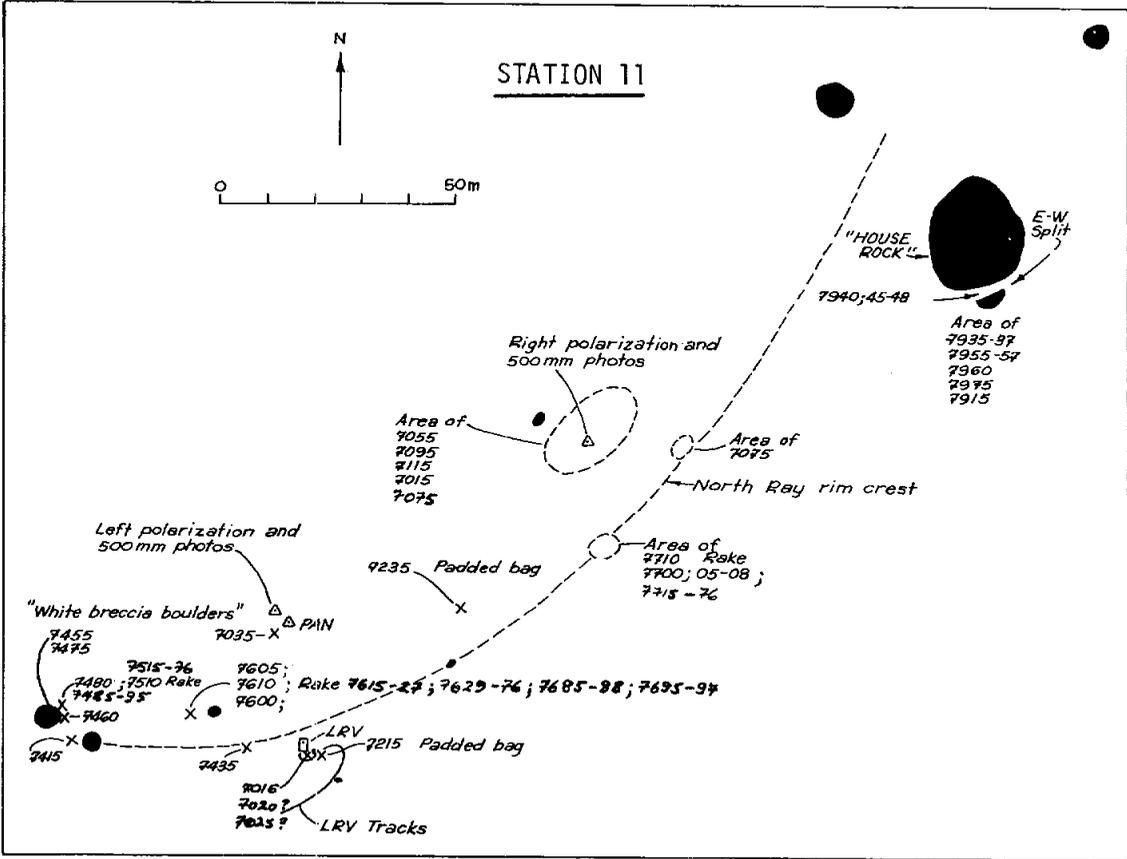
PLANIMETRIC SKETCH MAPS AND SAMPLE LOCATIONS FOR APOLLO 16 SAMPLING SITES;
MODIFIED FROM THE APOLLO 16 SAMPLE INFORMATION CATALOG (1972).





LM/ALSEP-STATION 10

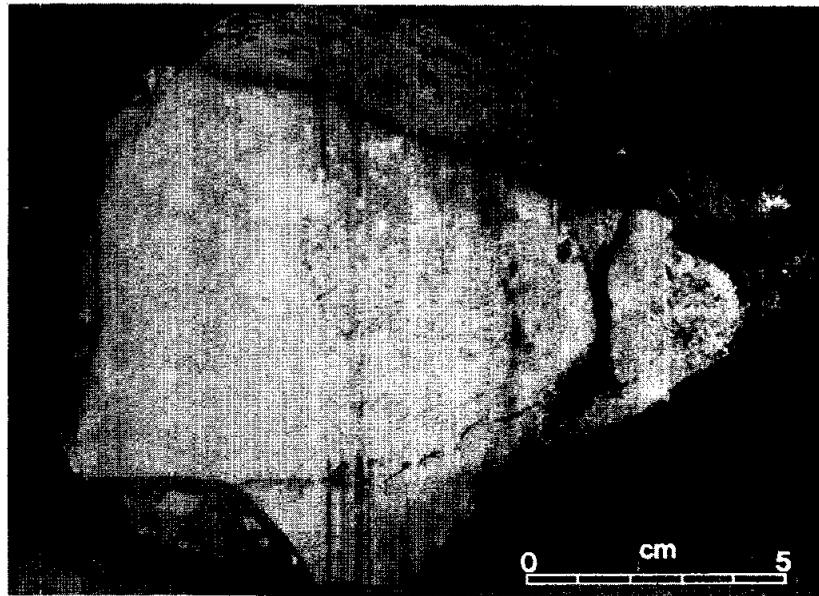




INTRODUCTION: 60015 is a coherent, very light gray, shock-melted and cataclastic anorthosite which is probably chemically pristine. It is largely coated with a vesicular glass up to 1 cm thick (Fig. 1). The glass contains a few white inclusions and the glass-anorthosite contact is macroscopically sharp.

60015 was probably collected about 30 m west-northwest of the Lunar Module but details of its collection, situation, and orientation are not known. It is blocky with rare fractures. Zap pits are common on two surfaces with a few on the others.

FIGURE 1.



PETROLOGY: Petrographic descriptions are given by Sclar et al. (1973), Sclar and Bauer (1974), Dixon and Papike (1975) and Juan et al. (1974). All note the brecciation and intense shock damage to the anorthosite (Fig. 2) which took place prior to the emplacement of the glass coat. The anorthosite consists of more than 98% plagioclase (An_{95-98}) with 1-2% orthopyroxene (En_{63}) and augite (Fig. 3). Ishii et al. (1976) calculate an equilibration temperature of $987^{\circ}C$ from the augite-orthopyroxene data of Dixon and Papike (1975). Olivine is absent, but ilmenite, Cr-spinel, troilite and minor Fe-metal are present (Dixon and Papike, 1975).

There is a bimodal grain size with grains of plagioclase 1-3 mm in diameter set in a finer-grained matrix. Plagioclases are strained with undulose and patchy extinction and some well-developed sets of shock lamellae exist. Maskelynite is not present. The intergranular areas include columnar, feathery plagioclases (Fig. 2) interpreted as resulting from a rapidly cooled intergranular shock melt. No intergranular movement took place during the shock event and



FIGURE 2. 60015,120

- a) anorthosite, xpl. width 2mm.
- b) columnades in anorthosite, xpl. width 0.5mm
- c) glass coat, ppl. width 2mm.

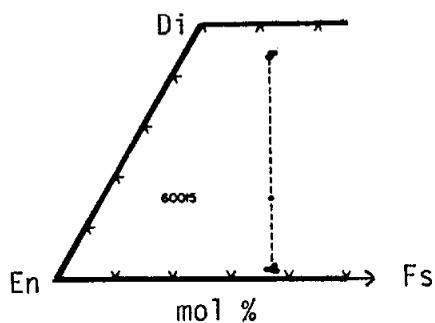


FIGURE 3. Pyroxenes; from Dixon and Papike (1975).

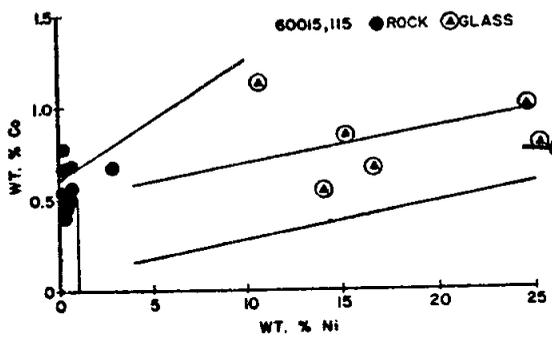


FIGURE 4. Metals; from Hewins and Goldstein (1975a).

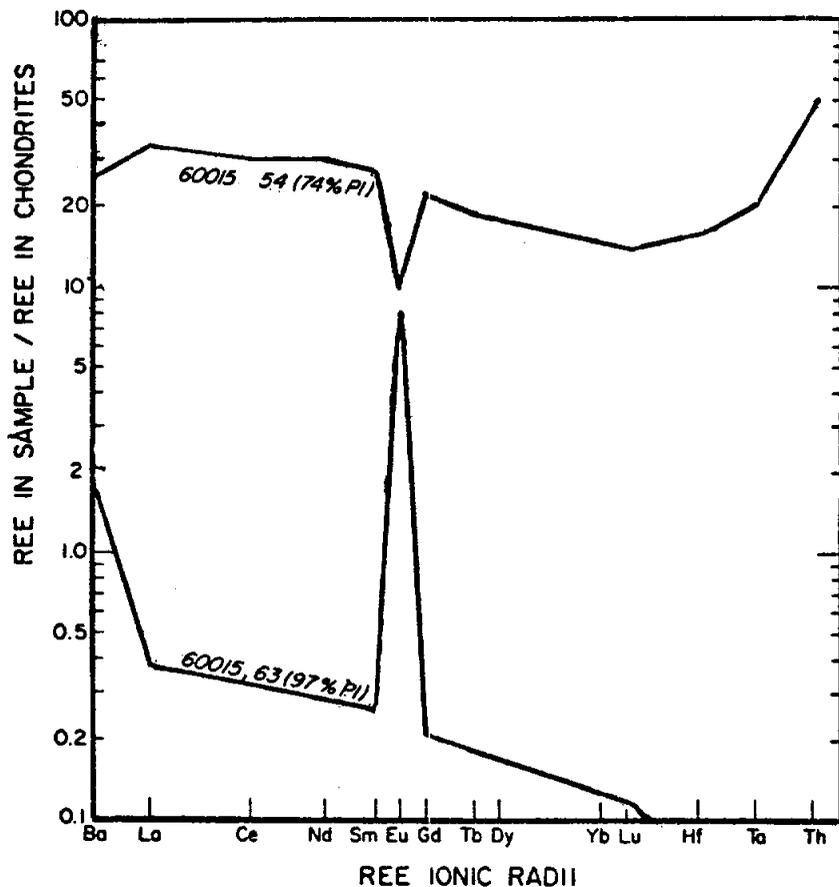


FIGURE 5. Rare earths; from Lau and Schmitt (1973).

temperatures are believed to have risen to over 1500°C. The progenitor was possibly porous (Sclar and Bauer, 1974). Fe-metal in the anorthosite contains little Co or Ni (Fig. 4) (Hewins and Goldstein, 1975a; Sclar and Bauer, 1974; Mao and Bell, 1976). The lowest values, which occur in the feathery plagioclase regions may be the result of shock reduction of Fe²⁺ from plagioclase (Sclar and Bauer, 1974).

The glass coat is brown, vesicular and partly crystallized into skeletal microlites of plagioclase. The plagioclase-rich xenoliths and xenocrysts in the glass show no evidence of reaction with the glass, which is similar in composition to Apollo 16 soils (Table 2). Metal in the glass contains up to 30% Ni, in the meteoritic range (Fig. 4) (Hewins and Goldstein, 1975a; Mao and Bell, 1976). Mao and Bell (1976) show that metals are altered from their original meteoritic composition by reaction with the anorthosite, and that the higher Ni contents occur in metals associated with troilite and schreibersite.

The contact relationships of glass coat and anorthosite are described in detail by Sclar and Bauer (1974). The peripheral 6 mm of anorthosite lacks feathery plagioclase, but a 200 µm boundary layer of pure, columnar plagioclase exists, and is interpreted as quenched liquid derived by melting the surface of the anorthosite. Two distinct liquids, one the anorthosite surface, the other the glass coat, existed momentarily. The heat to melt the anorthosite surface must have been mainly from the shock event which produced the glass coat, not from the glass coat itself (Sclar and Bauer, 1974).

CHEMISTRY: Chemical studies are listed in Table 1 and summary chemistries of the anorthosite and of the glass coat in Table 2. Representative incompatible element patterns are shown as Figure 5.

For the anorthosite, Laul and Schmitt (1973) note that the REEs are low and identical to 15415 (Fig. 5). Volatile and light elements are very low in abundance (Jovanovic and Reed, 1973; Moore and Lewis, 1976; and others) as are Zr and Hf, with the lowest Zr/Hf of any sample (Garg and Ehmann, 1976). The level of meteoritic contamination, if any, is uncertain because Au, Ir (etc.) have not been measured. Co values are low (1 ppm or less) except for the analysis by Juan et al. (1974) which has 44 ppm Co, and 30 ppm Ni. The low Co contents and the Co/Ni ratios of the metal suggest that most of the anorthosite is uncontaminated. The glass coat was analyzed by Laul and Schmitt (1973) with results in agreement with microprobe data by Dixon and Papike (1975) and Sclar and Bauer (1974). Although similar to Apollo 16 soils, subtle chemical differences exist e.g. lower TiO₂ (Laul and Schmitt, 1973). The Ni/Au/Ir ratios suggest that the glass was created by the impact of an iron meteorite.

STABLE ISOTOPES: Clayton et al. (1973) reported δ¹⁸O values of 5.67 for the anorthosite plagioclase and 5.68 for the glass coat, typical lunar values.

TABLE 1
Chemical studies of 60015

Reference	Split #	Description	Elements analyzed
S.R. Taylor <u>et al.</u> (1973)	,64	anorthosite	majors, REEs, other trace
Janghorbani <u>et al.</u> (1973)	,65	"	majors
Laul and Schmitt (1973)	,6	"	majors, REEs, other trace
"	,54	glass coat	"
Juan <u>et al.</u> (1974)	,67	anorthosite	majors, some trace
Nunes <u>et al.</u> (1973)	,50	"	U, Th, Pb
Ehmann and Chyj (1974)	,65B	"	Zr, Hf
Garg and Ehmann (1976)	,65A	"	Eu, Zr, Fe, Cr, Sc, Co, Hf
Miller <u>et al.</u> (1974)	,65B	"	Fe, Cr, Sc, Co, Eu
Schaeffer and Husain (1974)	,22 ,69	"	K, Ca
Jovanovic and Reed (1973)	,60	"	F, Cl, Br, I, Te, U, P ₂ O ₅
Moore <u>et al.</u> (1973)	,61	"	C
"	,53	glass coat	C
Cripe and Moore (1974)	,61	anorthosite	S
"	,53	glass coat	S
Moore and Lewis (1976)	,61	anorthosite	N
"	,53	glass coat	N
Phinney <u>et al.</u> (1975)	?	"	K, Ca
Nyquist <u>et al.</u> (1975)	,50I ,50II	"	Rb, Sr
Papanastassiou and Wasserburg (1976)	,36 ,95	"	Rb, Sr, K
Nunes <u>et al.</u> (1974)	,46	glass coat	Rb, Sr, K, U, Th

TABLE 2
Summary chemistries of anorthosite and
glass coat in 60015

	Anorthosite	Glass Coat
SiO ₂	44	44
TiO ₂	0.02	0.4
Al ₂ O ₃	36	27
Cr ₂ O ₃	<0.01	0.1
FeO	0.35	5
MnO	<0.01	0.05
MgO	~0.3	6 - 9
CaO	19	15
Na ₂ O	0.4	~0.45
K ₂ O	<0.01	0.08
P ₂ O ₅	0.01	
Sr	178	157
La	0.13	11
Lu	0.003	0.49
Rb	?	1.9
Sc	0.6	5.8
Ni		900
Co	1	42
Ir ppb		23
Au ppb		8
C	20	59
N	23	50
S	27	890
Zn		
Cu	2	

Oxides in wt%, others in ppm except as noted.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Rb-Sr data are summarized in Table 3. The low measured $^{87}\text{Sr}/^{86}\text{Sr}$ give calculated ratios at 4.6 b.y. close to BABI. Nyquist et al. (1975) calculate an isochron age from two whole rock samples as 3.8 ± 1.7 b.y. but because of the large error do not attribute significance to it. Two plagioclase clasts from the glassy rind have $^{87}\text{Sr}/^{86}\text{Sr}$ at 4.6 b.y. even lower than the anorthosite (Nunes et al., 1974).

TABLE 3. Summary of Rb-Sr data* for 60015

Sample	Description	Rb/Sr	$^{87}\text{Sr}/^{86}\text{Sr}$ Measured	$^{87}\text{Sr}/^{86}\text{Sr}$ Calc. at 4.6 b.y.	Reference
,50 I	Anorthosite	0.00165	0.69934 \pm 4	0.69902	Nyquist et al. 1975
,50 II	"	0.00044	0.69915 \pm 5	0.69907	"
,50	"	0.00073	0.69904 \pm 6	0.69890	Nunes et al. 1974
,36	"	0.00016	0.69903 \pm 3	0.69900	Papanastassiou and Wasserburg 1976
,95	"	0.00067	0.69908 \pm 4	0.69895	"
,46	Plag. in glass	0.00083	0.69900 \pm 7	0.69884	Nunes et al. 1974
,46	"	0.00044	0.69887 \pm 3	0.69878	"
,46	Glass coat	0.01218	0.70120 \pm 6	0.69888	"

*Not corrected for interlaboratory bias.

Ar-Ar ages of 3.5 ± 0.05 b.y. (Fig.6) (Schaeffer and Husain 1974) and 3.54 ± 0.05 b.y. (Fig.7) (Phinney et al., 1975) demonstrate that the shock melting of the anorthosite was later than the ~ 4.0 b.y. cataclysm. These ages may just be lower limits but a good plateau was obtained by Schaeffer and Husain (1974).

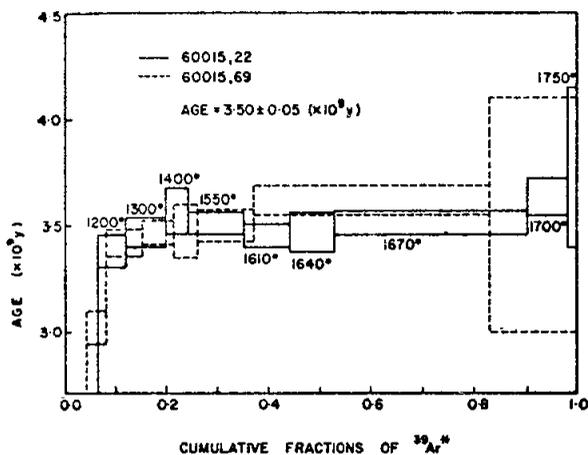


FIGURE 6. Ar release; from Schaeffer and Husain (1974).

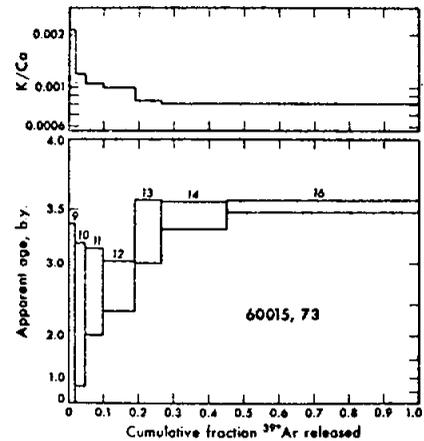


FIGURE 7. Ar release; from Phinney et al. (1975).

The U-Th-Pb data (Nunes *et al.*, 1973, 1974) indicate an enrichment in Pb at 3.57 b.y. (2-stage model) or 3.8 b.y. (3-stage model). The Pb introduction was presumably contemporaneous with the shock-melting event. These theoretically valid model-dependent ages may not be as precise as first believed because up to 3% of the Pb may be contamination (Nunes *et al.*, 1974).

RARE GAS/EXPOSURE AGES: Leich and Niemeyer (1975) provide Xe, Ar and Kr isotopic data and report an ^{81}Kr -Kr exposure age of 1.96 ± 0.08 m.y., or 1.93 ± 0.08 m.y. if the trapped xenon in the rock is terrestrial. The latter interpretation of the origin of the trapped xenon is preferred following experiments (Niemeyer and Leich, 1976) which showed much more Ar, Xe and Kr in crushed samples, even though temperatures greater than 1000° were required to release 75% of the trapped Kr and Xe.

Phinney *et al.* (1975) and Schaeffer and Husain (1974) report Ar isotopic data and calculate ^{38}Ar -Ca exposure ages of 3 ± 1 m.y., and 4.6 ± 0.6 and 6.1 ± 0.5 m.y. respectively. These are significantly higher than the ^{81}Kr -Kr age which Leich and Niemeyer (1975) consider more reliable.

MICROCRATERS AND TRACKS: Several studies of microcraters on the glass surface of 60015 have been made. The surface is in production, not equilibrium. Size-frequency data is provided by Neukum *et al.* (1973), Hörz *et al.* (1974), Fechtig *et al.* (1974), Mandeville (1976), and Hartung *et al.* (1977) (Fig. 8). Neukum *et al.* (1973), Nagel *et al.* (1975), and Mandeville (1976) provide measurements of pit characters. Flavill *et al.* (1978) discuss some of the craters as being of secondary or tertiary origin rather than of direct micrometeoroid origin, and Hartung *et al.* (1977) note that the data do not specify that there was a variation of the meteoroid flux with time. Carey and McDonnell (1976) find no evidence for the build-up of sputtered weld material on the surface. Storzer *et al.* (1973) plot the solar flare track density against depth, as deduced from cratering statistics.

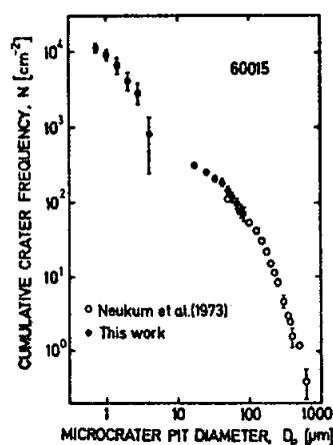


FIGURE 8. Microcraters; from Fechtig *et al.* (1974).

PHYSICAL PROPERTIES: The remanent magnetism characteristics of the anorthosite have been studied by Runcorn's group (Collinson et al., 1973; Stephensen et al., 1974, 1975) using the anhysteretic remanent magnetization method (ARM). The rock does not appear to possess a measurable hard NRM, although grains capable of holding such an NRM are present. This is probably due to the extremely low iron content. The initial susceptibility and the saturation remanence are very low. Weeks (1973) studied electron paramagnetic resonance characteristics and noted that Fe^{3+} and Ti^{3+} are higher than in several other Apollo 16 rocks.

P and S wave velocities of the anorthosite from 0.5 to 7 kb are reported in Chung (1978) (Table 4, Fig.9). Herminghaus and Berckhemer (1974) measured Q with ultrasonic absorption measurements at 10^{-4} torr and $+20^{\circ}C$ to $-180^{\circ}C$. Q is quite low, independent of T, and at $20^{\circ}C$ only 20% higher than at atmospheric pressure. The measurements suggest that the anorthosite has a high microcrack density.

TABLE 4. Elastic wave velocities of anorthosite in 60015

	Confining pressure (Kb)									
	0.5	1.0	1.5	2	3	4	5	6	7	10*
P Km/s	5.5	6.0	6.27	6.52	6.75	6.86	6.90	6.94	6.97	7.02
S Km/s	2.6	2.9	3.21	3.40	3.58	3.68	3.74	3.86	3.88	3.91

*Estimated by linear extrapolation. Reference: Chung (1973)

FIGURE 9. from Chung (1973).

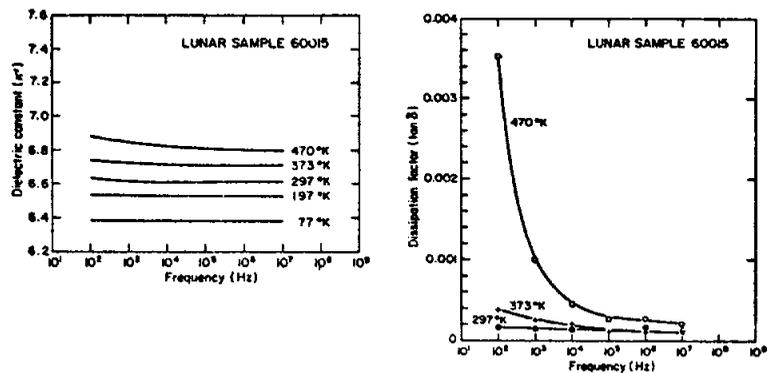
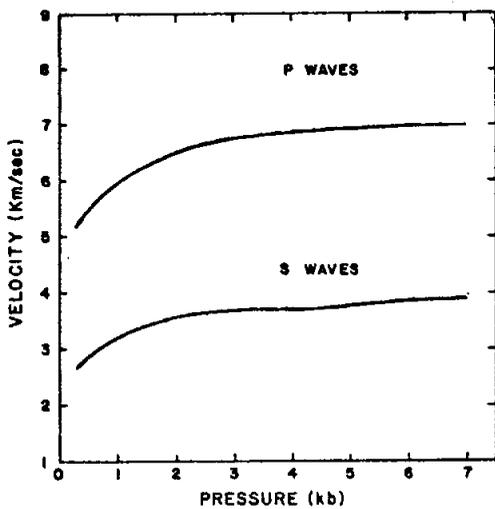


FIGURE 10. Dielectric properties; from Chung and Westphal (1973).

Dielectric constants and losses for the anorthosite are presented in Chung and Westphal (1973) (Fig.10).

Mandeville and Dollfus (1977) determined polarimetric properties of surface portions of 60015, one cratered and dust-free, others cratered and dust-covered.

PROCESSING AND SUBDIVISIONS: In 1972, 60015 was sawn into 5 main pieces (Fig.11). The large pieces ,1 and ,2 are preserved intact and ,3 was subdivided into 3 pieces for display purposes. All allocations are from the two slabs produced during sawing. The main subdivision of these slabs and the locations of the splits are shown in Figures 12 and 13. Several subsequent splits and renumbering of returned/consumed samples are not shown.

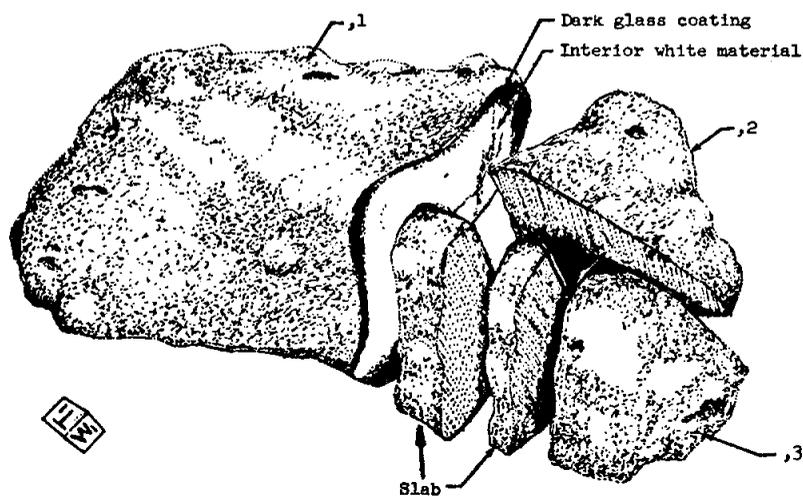


FIGURE 11.

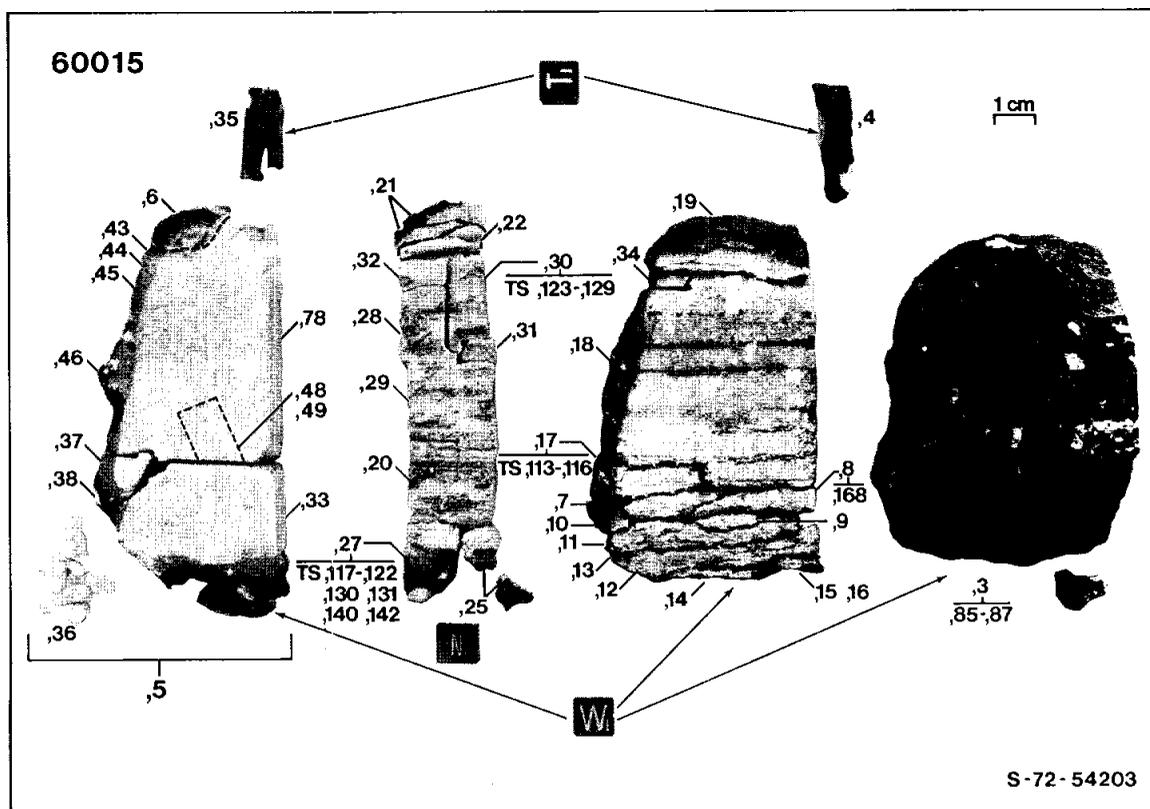
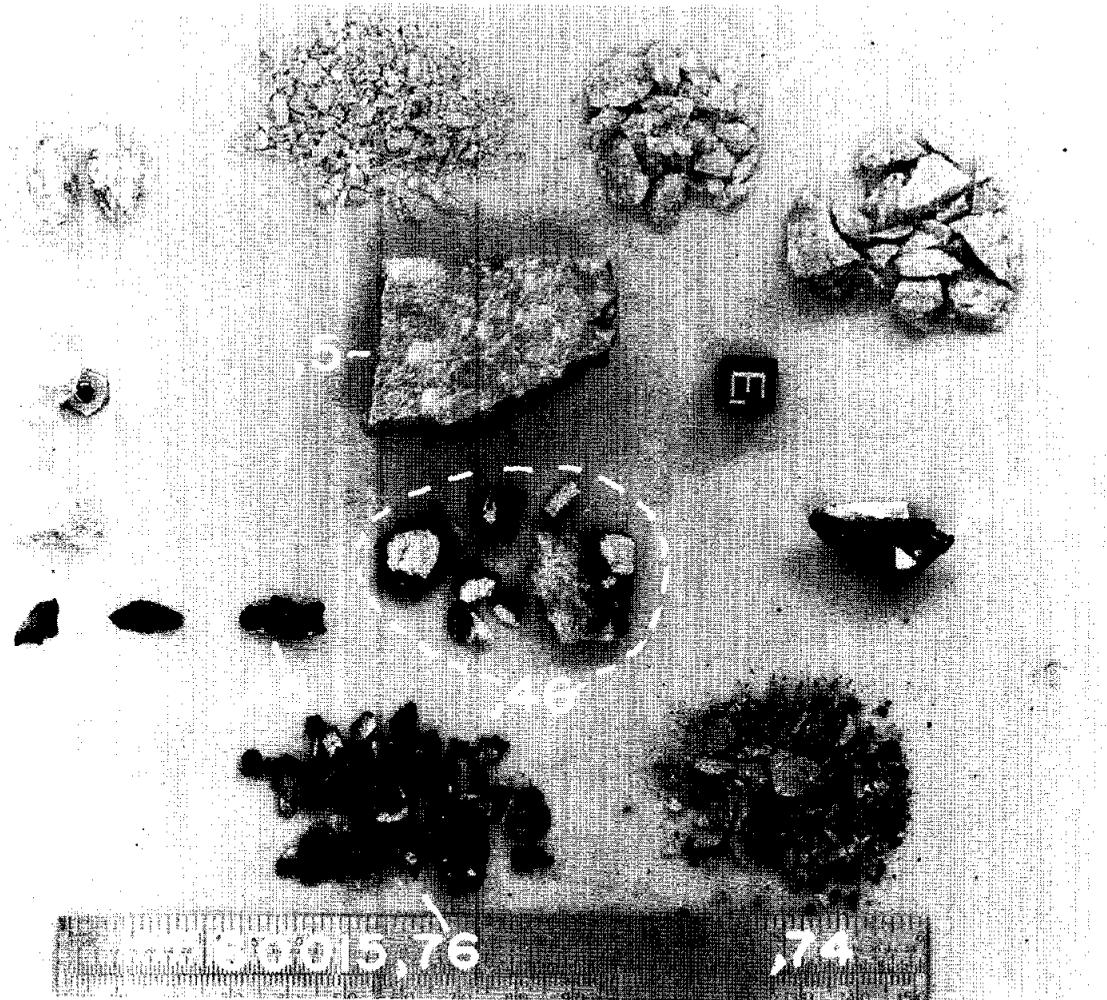


FIGURE 12.

FIGURE 13.

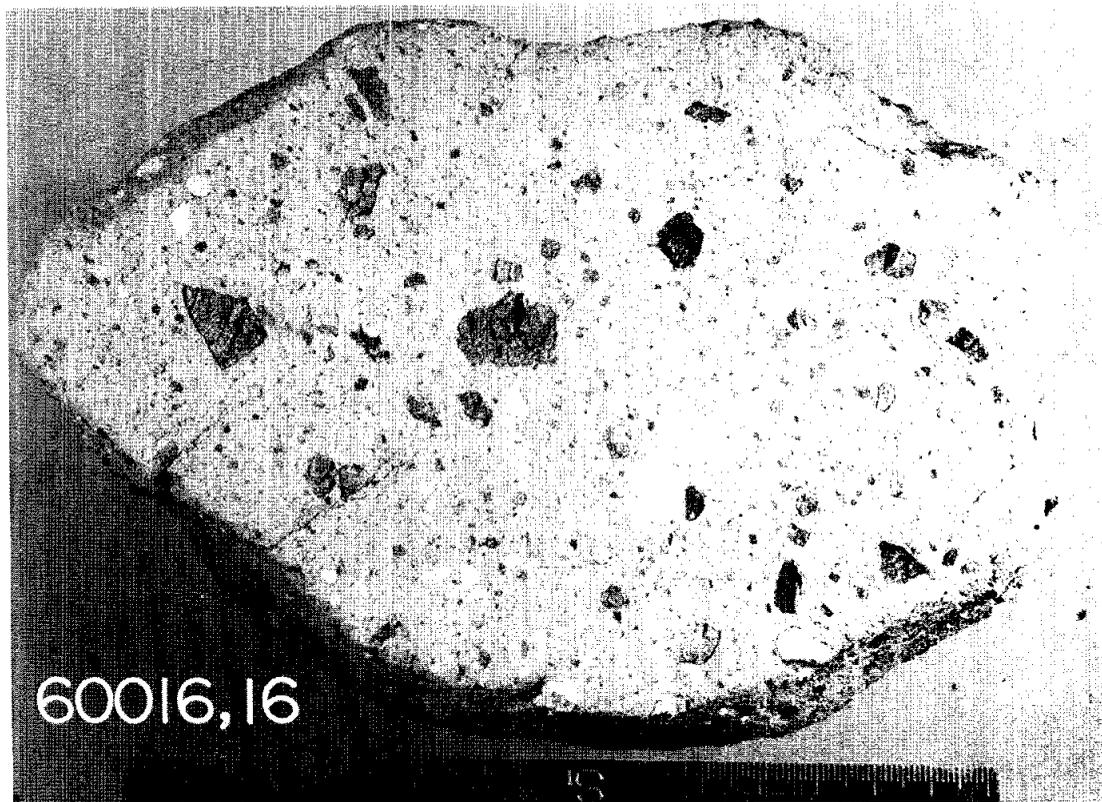


S-72-55505

INTRODUCTION: 60016 is a friable, medium gray breccia with a porous clastic matrix and abundant light and dark clasts of various sizes (Fig.1).

The sample was collected 14-15 m southwest of the Lunar Module where it had a poorly developed fillet. Its orientation is known. It is subrounded and zap pits are present on all surfaces.

FIGURE 1. S-78-34417. Scale in mm.

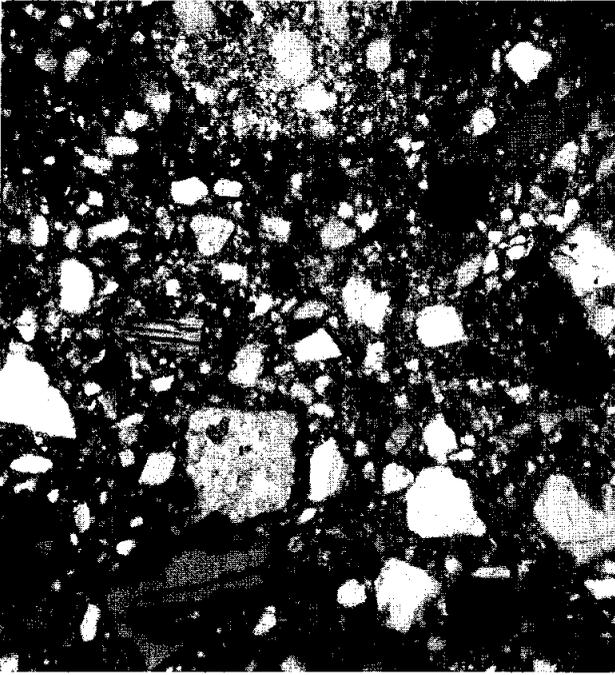


PETROLOGY: Johan and Christophe (1974), Haselton and Nash (1975a,b), Takeda et al. (1979), Misra and Taylor (1975) and LSPET (1973) provide limited petrographic information. The rock is polyict with a variety of clast types in a porous, unequilibrated matrix that is essentially free of glass (Fig.2). Grain size is seriate from several mm downwards. Some rust is present.

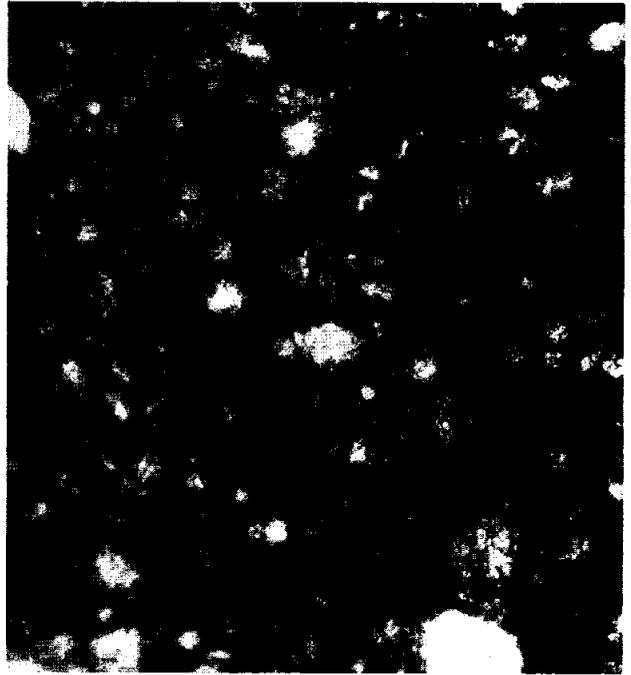
Mineral fragments of plagioclase, pyroxene, olivine, spinel and metal are present. Lithic clasts include cataclastic and recrystallized anorthosite, coarse- and fine-grained poikilitic impact melt, granoblastic material, noritic

FIGURE 2.

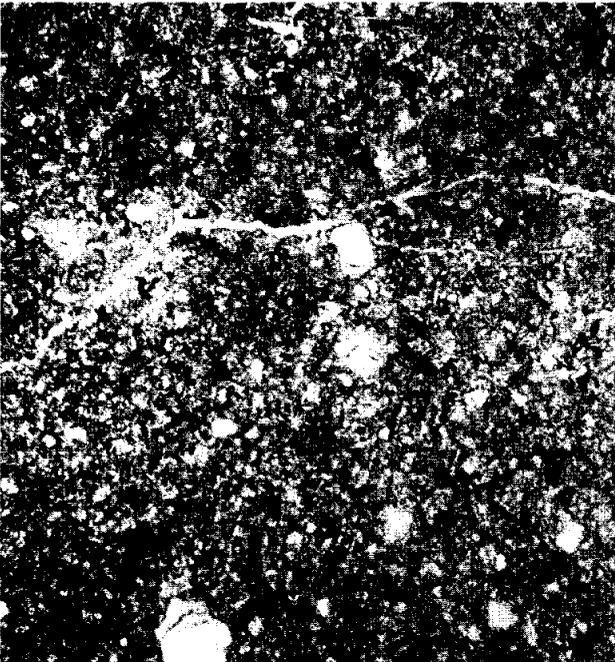
a



b



c



d



a) 60016,83. general matrix, ppl. width 2mm.

c) 60016,86. fine-grained poikilitic melt clast, ppl. width 2mm.

b) 60016,83. vitric breccia clast, ppl. width 0.5mm.

d) 60016,98. feldspathic granoblastic impactite, xpl. width 2mm.

anorthosite with relict cumulate texture, dark-to-vitric matrix breccia and clast-bearing basaltic impact melt. Also present are several types of glass beads and fragments in various stages of devitrification, and rare agglutinates. Most of the clasts show minimal effects of shock or thermal metamorphism.

Plagioclase in mineral and anorthosite clasts is of typical highlands composition (An_{96-98} , low Fe, Mg; Johan and Christophe, 1974). These authors also report systematic variations of Fe, Mg and Na in plagioclase with respect to twin lamellae and associated intergrowths of exsolved pyroxene and silica (Fig.3). Pyroxene clast compositions are given in Figure 4. One discrete grain of orthopyroxene (En_{79}) with ilmenite lamellae yielded an equilibration temperature of 900-1000°C based on the coexisting mineral compositions (Fig.5) (Haselton and Nash, 1975a,b). Metal grains in the matrix that are large enough to analyze by microprobe are homogeneous with 4-6% Ni (Fig.6) (Misra and Taylor, 1975).

Nearly all of the dark clasts (Fig.1) are aphanitic melts. In thin section they are glassy with an obvious melt texture. Most are packed with abundant plagioclase clasts and could also be called vitric matrix breccias (Fig.2). Poikilitic clasts occur as both coarse- and fine-grained varieties (Fig.2). They are very similar to typical Apollo 16 poikilitic rocks such as 60315 and 65015. Macroscopically they appear as pale gray crystalline clasts.

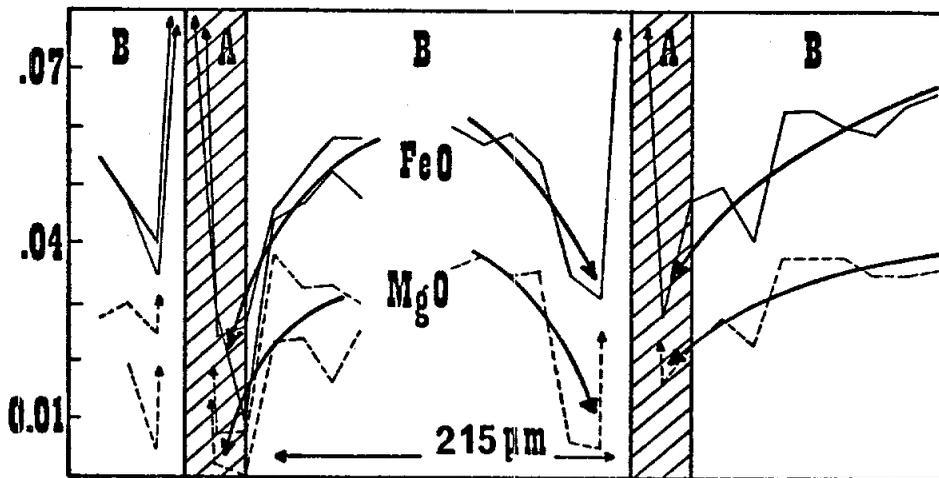


FIGURE 3. Plagioclase; from Johan and Christophe (1974)

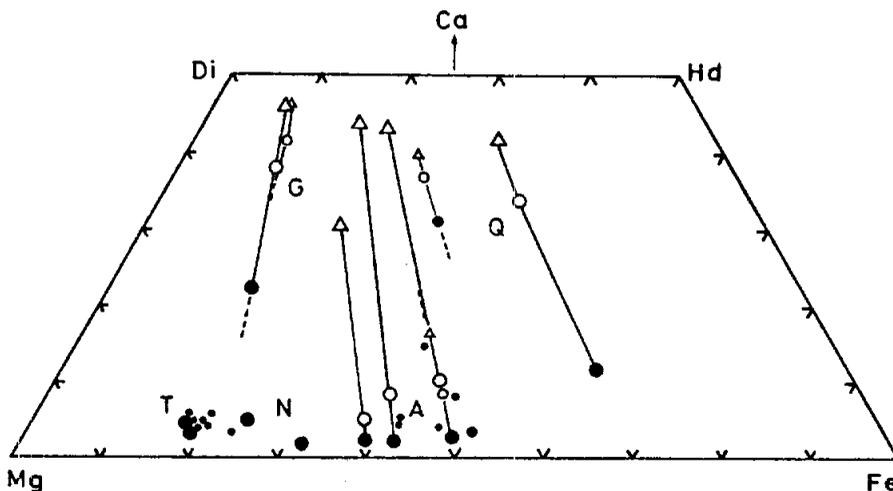


FIGURE 4. Pyroxenes; from Takeda *et al.* (1979).

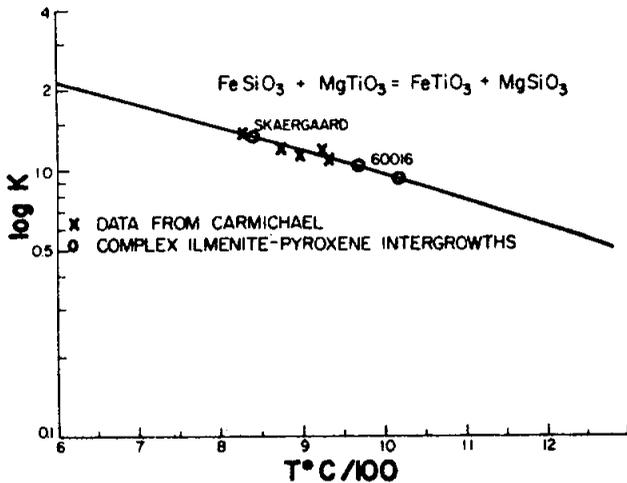


FIGURE 5. Equilibration temperature; from Haselton and Nash (1975b).

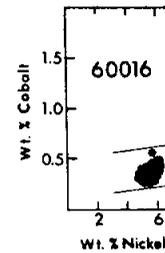


FIGURE 6. Metals; from Misra and Taylor (1975).

CHEMISTRY: Bulk rock major element analyses are given by Janghorbani *et al.* (1973) and S.R. Taylor *et al.* (1974). Bulk trace element data are provided by these authors and Krähenbühl *et al.* (1973), Ganapathy *et al.* (1973), Garg and Ehmann (1976), Jovanovic and Reed (1976a,b) and Goel *et al.* (1975). All of these analyses are of splits of a single sample of chips and fines subdivided at the LCL. Wänke *et al.* (1975) give major and trace element chemistry on an aphanitic clast, a poikilitic clast and a granoblastic impactite clast. Goel *et al.* (1975) report nitrogen data on separated light and dark clasts.

The bulk rock is compositionally very similar to the local soils, but with slightly lower TiO_2 and Cr_2O_3 (Table 1). Its REE pattern (Fig. 7) and Zr/Hf ratio is typical of a highland breccia with trace element chemistry dominated by KREEP (S.R. Taylor *et al.*, 1974; Garg and Ehmann, 1976). Krähenbühl *et al.* (1973) detect an enrichment of volatile relative to involatile elements (e.g. high Tl/Cs and Tl/U) and conclude that the rock is probably enriched in a fumarolic component.

Clast analyses by Wänke *et al.* (1975) are reproduced in Table 1. Both the aphanite and the poikilitic clast are rich in KREEP and in siderophiles indicating a probable impact origin. The granoblastic impactite has low levels of incompatibles and may be low in siderophiles based on Co (Table 1). No other siderophile data are available on this clast.

STABLE ISOTOPES: Clayton *et al.* (1973) report $\delta^{18}O$ values, listed in Table 2. The uniform values indicate a dominant plagioclase component in all samples.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Weber and Schultz (1978) report K-Ar gas retention ages of 3.8 ± 0.1 b.y. for both the poikilitic and the dark aphanite clasts analyzed by Wänke *et al.* (1975).

FIGURE 7.

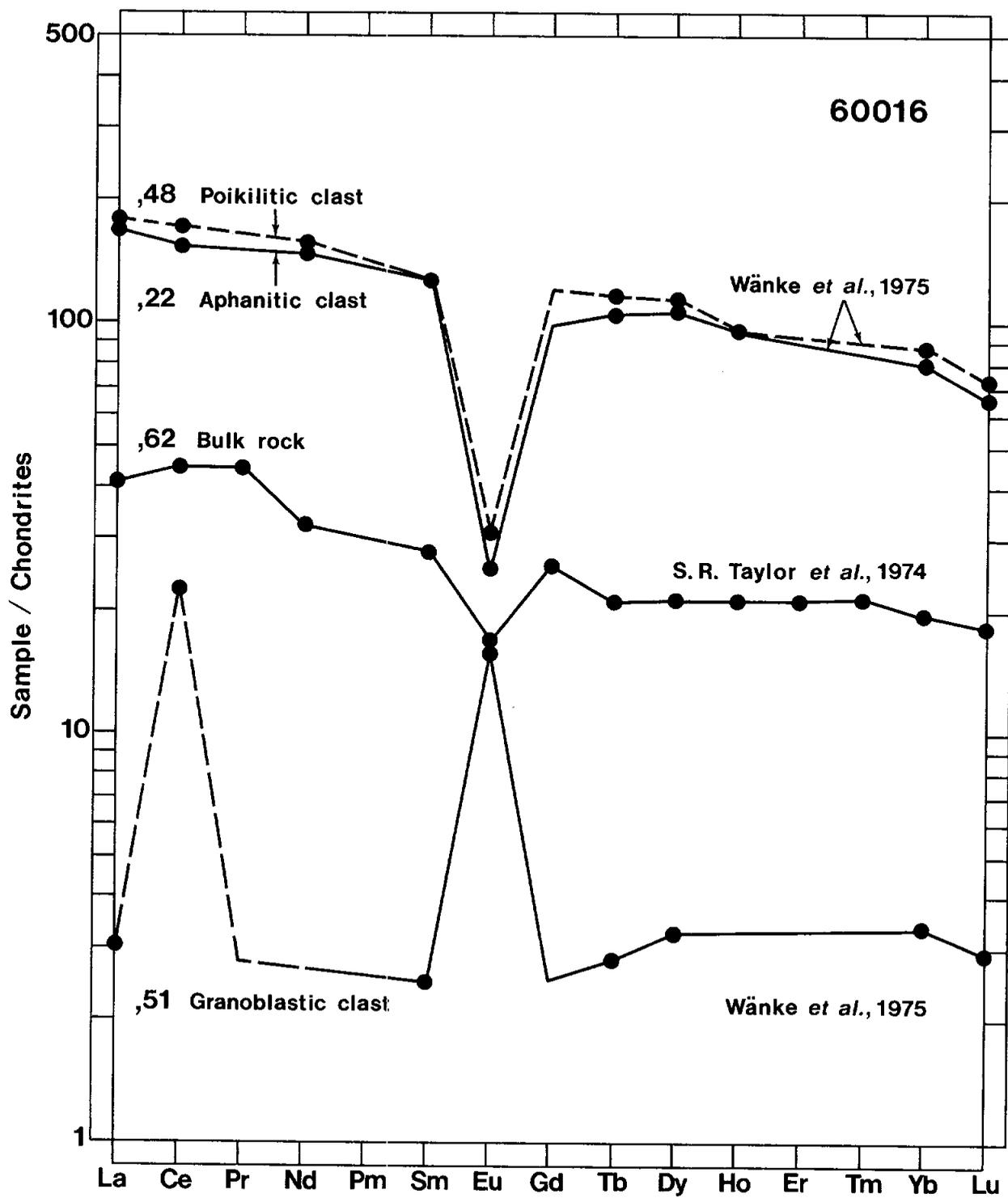


TABLE 1. Summary chemistry of 60016 bulk rock and clasts

	Bulk rock	,22.4 aphanite	,48.4 poikilitic	,51.4 granoblastic
SiO ₂	45.5	43.0	44.7	44.3
TiO ₂	0.29			0.27
Al ₂ O ₃	27.4	20.03	15.88	29.48
Cr ₂ O ₃	0.07	0.15	0.21	0.09
FeO	4.8	7.42	11.5	4.0
MnO	0.057	0.09	0.12	0.63
MgO	6.2	7.64	12.45	3.82
CaO	15.2	11.9	10.8	17.2
Na ₂ O	0.48	0.49	0.60	0.31
K ₂ O	0.10	0.29	0.33	0.01
P ₂ O ₅				
Sr		160		190
La	13.3	55.9	58.5	0.99
Lu	0.6	2.27	2.46	0.10
Rb	2.3			
Sc	8.2	13.6	15.6	7.43
Ni	300	740	1940	
Co	27	42.3	105	6.19
Ir ppb	5.7	15	36	
Au ppb	5.9	15	36	
C				
N	28			
S				
Zn	7.6			
Cu				

All clast analyses by Wänke *et al.* (1975).
Oxides in wt%; others in ppm except as noted.

TABLE 2	
δO^{18} of various portions of 60016	
matrix	5.73
plagioclase	5.78
light clasts	5.62
dark clasts	5.67

RARE GAS/EXPOSURE AGES: Bogard *et al.* (1973) and Weber and Schultz (1978) provide noble gas data for the bulk rock. The matrix of 60016 contains a large amount of trapped solar gas, probably indicating a significant regolith component.

Noble gas data and ²¹Ne and ³⁸Ar exposure ages for clasts (Table 3) are also given by Weber and Schultz (1978).

TABLE 3. ^{21}Ne and ^{38}Ar exposure ages (m.y.) of three clasts

	from 60016	
	^{21}Ne	^{38}Ar
,22.4 aphanite	1.2 ± 0.2	3.0 ± 4.0
,48.4 poikilitic	3.5 ± 0.7	4.0 ± 1.5
,51.4 granoblastic	0.3 ± 0.1	1.2 ± 0.4

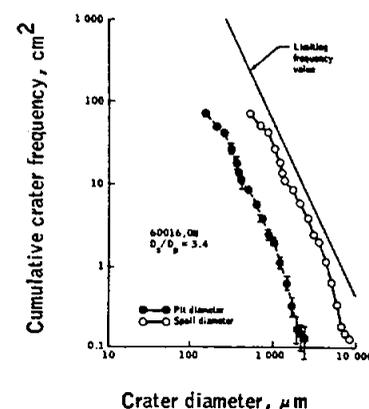


FIGURE 8. Microcraters; from Morrison et al. (1973).

MICROCRATERS: 60016 is subrounded in shape with microcraters on all sides. This suggests a complex exposure history that includes tumbling. The surface is probably in cratering equilibrium (Fig. 8) (Morrison et al. 1973; Neukum et al., 1973). Total exposure of the rock after lithification may have been on the order of 15-20 million years, assuming a constant micrometeoroid flux rate (Morrison et al., 1973).

PHYSICAL PROPERTIES: Intrinsic and structure sensitive magnetic parameters and some characteristics of the natural remanent magnetization of 60016 were measured by Nagata et al. (1974,1975) and Cisowski et al. (1975). No significant NRM residue remains in the rock after 250 Oe•rms demagnetization. Therefore there is no magnetic component present which can be attributed to ordinary thermoremanent magnetization although the relatively stable component up to 250 Oe•rms may have some significance for lunar magnetism (Nagata et al., 1974).

The proportions of Fe-bearing phases, the $\text{Fe}^0/\text{Fe}^{2+}$ ratio and the average composition of the ferromagnetic metal component have also been determined by magnetic and Mossbauer techniques (Huffman et al., 1974; Nagata et al., 1974). Iron metal makes up ~0.33 wt% of the rock. About 71% of this ferromagnetic metal can be attributed to a kamacite component averaging ~5 wt% Ni (erroneously reported as 15 wt% Ni in Nagata et al., 1974). The remainder of the metal is apparently pure iron. This contrasts with the microprobe data of Misra and Taylor (Fig. 6) which show no metal with <4 wt% Ni. Nagata et al. (1975) conclude that this discrepancy can be resolved if the pure iron component exists as micron-size particles too small to analyze by microprobe and possibly forming by subsolidus reduction of oxide and silicate phases. FMR studies show that the metal was annealed at 700-900°C (Fig. 9) (Tsay and Bauman, 1975).

The reflectance (albedo) of the 60016 matrix has been measured by Adams and McCord (1973) and Charette and Adams (1977) (Fig. 10). Dollfus and Geake (1975) report polarimetric properties of both the poikilitic and the aphanite clast analyzed by Wänke et al. (1975).

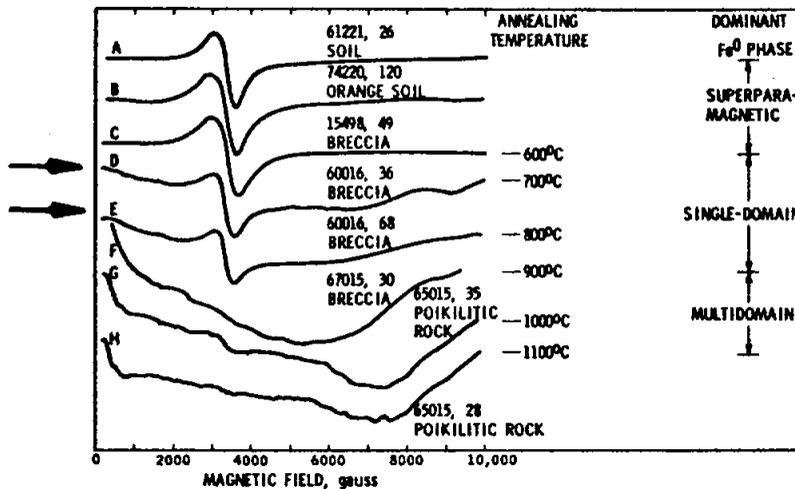


FIGURE 9. Correlation between ferromagnetic resonance and annealing temperature for metal phases; from Tsay and Baumann (1975)

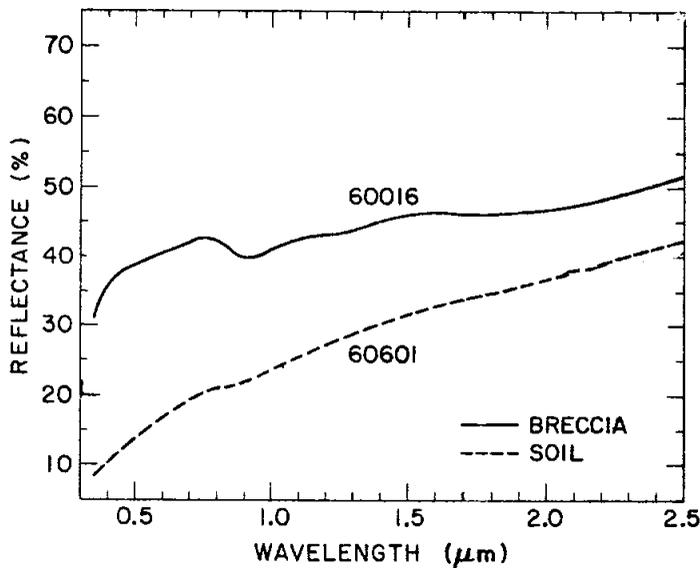


FIGURE 10. Spectral reflectance compared to mature soil; from Adams and McCord (1973).

PROCESSING AND SUBDIVISIONS: In 1972, 60016 was sawn into three main pieces and the slab extensively subdivided and allocated (Fig. 11). All of the various "whole rock" properties published so far were measured on splits of the slab. Bulk chemistry, the oxygen isotopes and rare gases were measured on splits of one undocumented sample of chips and fines (originally ,49-not shown on Fig. 11). The aphanite clast analyzed for chemistry, rare gases, exposure age and polarimetric properties was an interior clast (,48). The poikilitic clast also analyzed for the same properties was a pale gray exterior clast (,22 and ,23). The granoblastic clast was a large white exterior clast (,51 and ,53). Not all splits of the rock are shown in Figure 11.

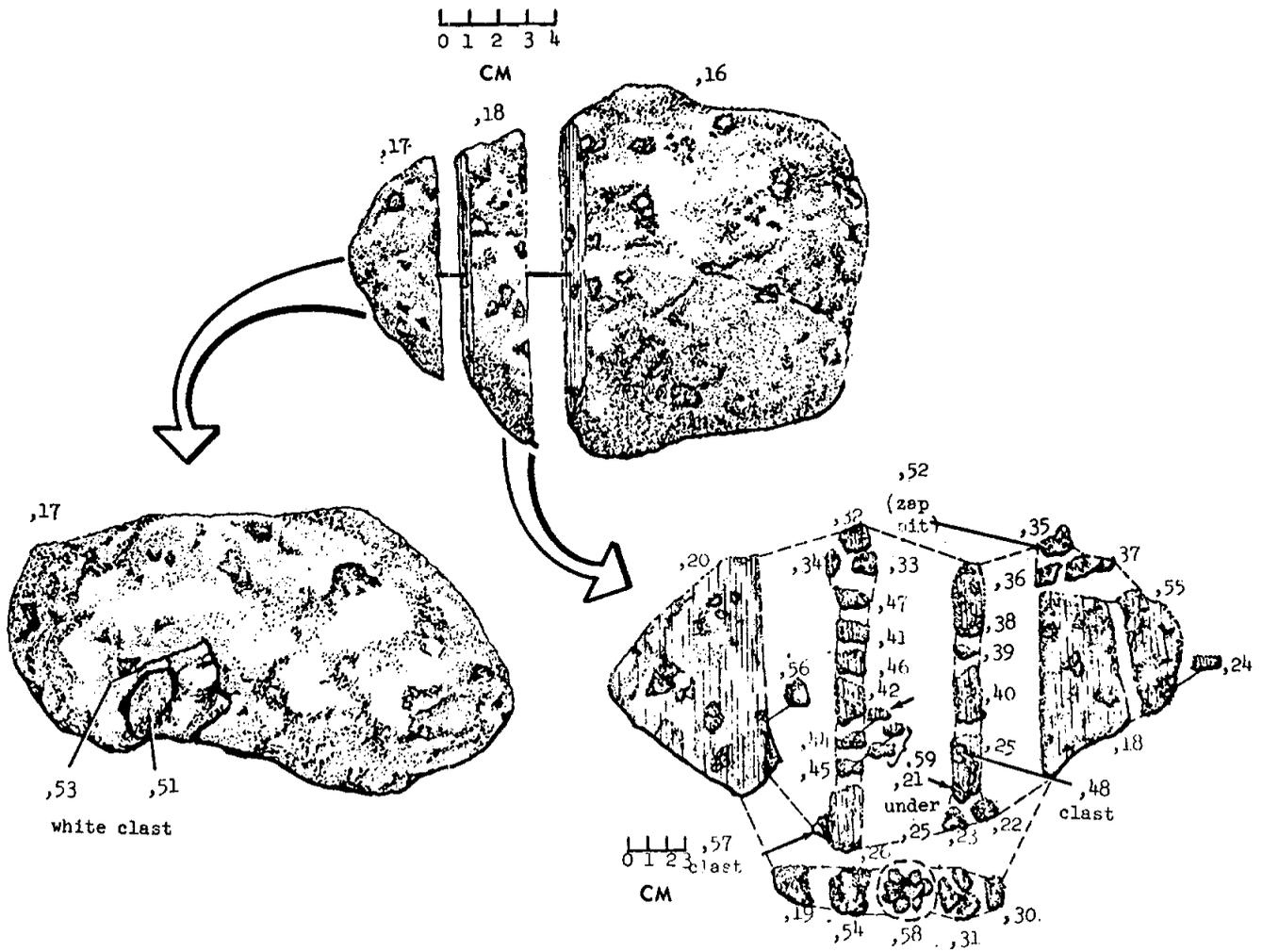
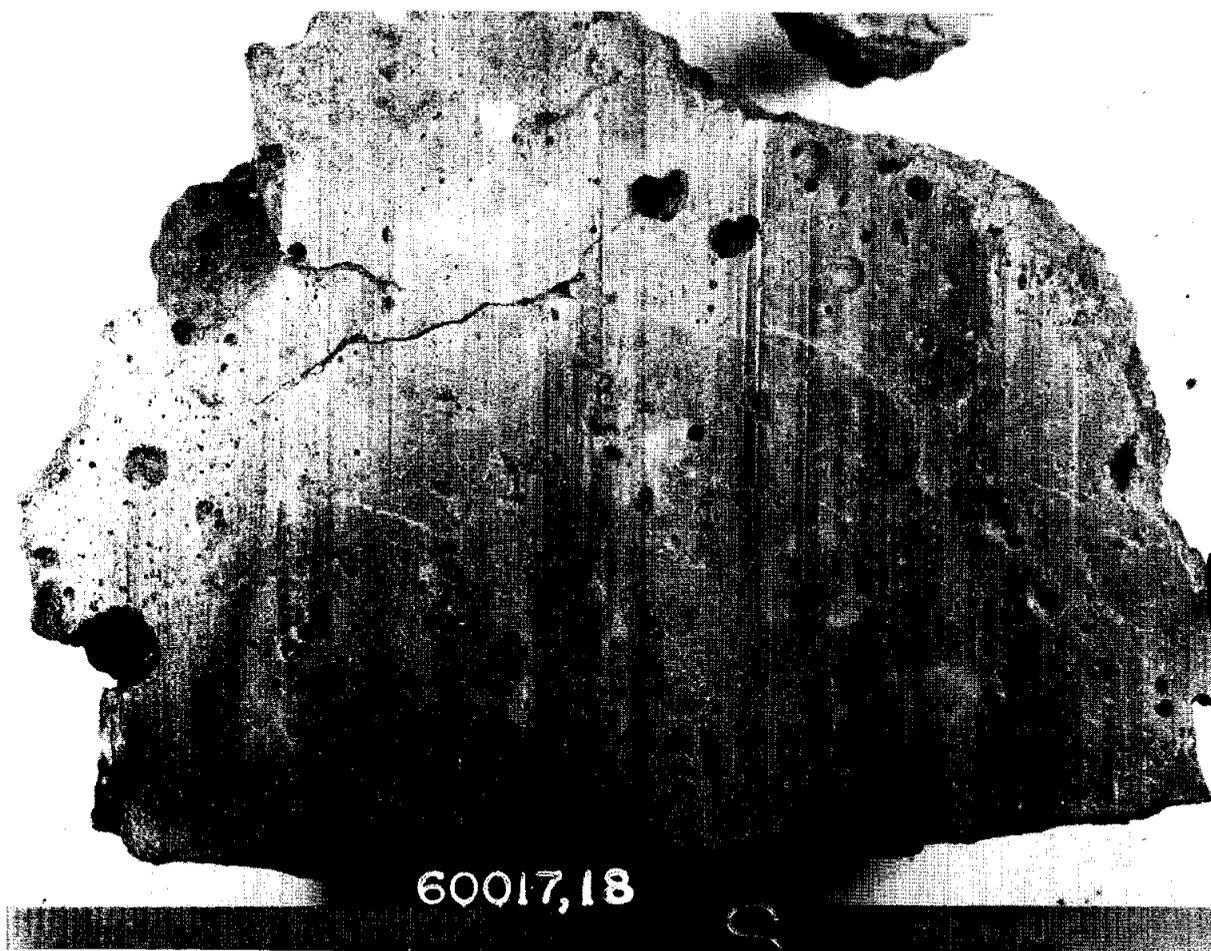


FIGURE 11.

INTRODUCTION: 60017 is a crystalline, medium to dark gray, vesicular melt rock, containing clasts which are mainly dark melt breccia and macroscopically indistinct (Fig. 1). The melt, which has a variolitic texture, contains ~ 30% Al_2O_3 .

Despite its number, 60017 was collected from Shadow Rock at Station 13 but its precise location on the boulder is unknown. Because it was broken from the boulder, one surface (B) is fresh while the others are subrounded. Few zap pits occur even on the surfaces that were exposed on the lunar surface.

FIGURE 1. Saw cut face. S-75-33756. Scale in mm.



PETROLOGY: The rock contains two dominant lithologies: ~70% variolitic melt and ~30% dark aphanitic clasts (Fig. 2). The rock is heterogeneous at the thin section scale such that some thin sections contain only variolitic melt whereas others contain very little of it. Petrographic information of various thin sections is provided by Kridelbaugh *et al.* (1973), Nord *et al.* (1975), Misra and Taylor (1975), Ganapathy *et al.* (1974), and Englehardt (1979). Cadenhead and Brown (1976) provide some details of a surface chip.

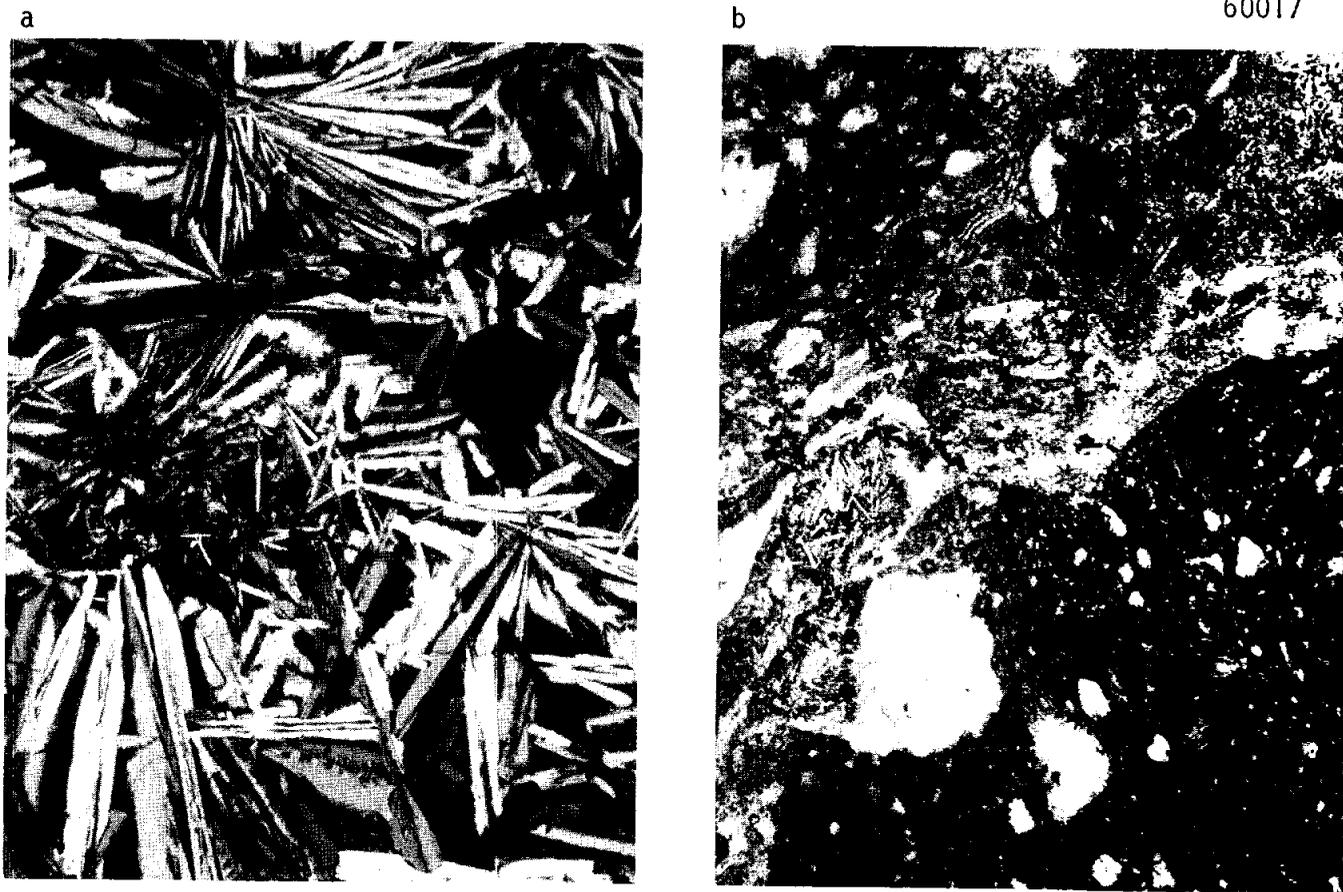
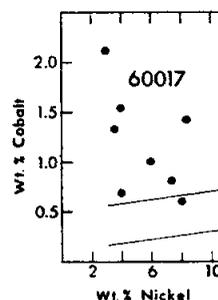


FIGURE 2. a) 60017,116. variolitic melt, xpl. width 2mm.
b) 60017,119. aphanitic melts,pl. width 2mm.

The variolitic melt consists of plagioclase laths with interstitial mafic minerals, minor ilmenite and Fe-metal, and very rare troilite and cryptocrystalline material. Although referred to as "devitrified glass" by Kridelbaugh *et al.* (1973) and Misra and Taylor (1975) the evidence leading to this conclusion is not stated. The typical textures are shown in Figure 2. The plagioclase laths which are up to ~ 2 mm long have compositions of An_{93-95} (Kridelbaugh *et al.*, 1973). They are frequently skeletal and mainly untwinned. Spherulites are often cored by plagioclase xenocrysts. Analyses of mafic minerals by Kridelbaugh *et al.* (1973) show only olivine (Fe_{68}), although Nord *et al.* (1975) and Engelhardt (1979) refer to the mafic mineral as pyroxene. Analyses of metal by Misra and Taylor (1975) have an average of 5.7% Ni, 1.3% Co, 0.05% P and 0.01% S. Co shows a wide scatter and is mainly out of the meteoritic range (Fig. 3). Nord *et al.* (1975), in a high voltage electron microscopy study, found no glass or evidence of deformation.

The variolitic melt is generally finer-grained towards the dark breccia clasts, and contains rare xenocrysts of pink spinel and a few small lithic clasts, including dunitic material.

FIGURE 3. Metals; from Misra and Taylor (1975).



The dark breccia clasts are brown, aphanitic and inhomogeneous melt breccias. In places they are flow banded and deformed (Fig. 2). They are plagioclase-rich (>85%) and contain numerous plagioclase-rich xenocrysts and xenoliths which have various reaction rims. Petrographic descriptions are given by Kridelbaugh *et al.* (1973) and Nord *et al.* (1975). The former in particular note the bulk composition of "gabbroic anorthosite" and the variety of xenoliths, including shocked, re-crystallized anorthosite (An_{94-96}) and small "anorthositic gabbro" (actually basalt-textured) clasts(?) which have plagioclase laths (An_{95}), interstitial olivine (FO_{62-74}) and thin dark rims. Nord *et al.* (1975) note the presence of some isotropic material and deformation with low dislocation densities within the dark breccia material.

The boundary between the variolitic melt and the dark breccia clasts is generally distinct, but in places it is diffuse and irregular, suggesting considerable digestion of the clasts. Cadenhead and Brown (1976) describe the characteristics of a surface chip (,43) using various methods. The petrography of the chip is not known but they find it to be heterogeneous, not porous at sub-micron scales, and of low density (2.78 g/cc). The surface is enriched in volatiles and surface iron is reduced more than the interior.

CHEMISTRY: Major and trace element analyses of bulk rock (Table 1) are presented by Janghorbani *et al.* (1973), Rose *et al.* (1973), Laul and Schmitt (1973), Laul *et al.* (1974), Morrison *et al.* (1973) and S.R. Taylor *et al.* (1973). Krahenbühl *et al.* (1973) and Ganapathy *et al.* (1974) report siderophile and other trace elements, Garg and Ehmann (1976) report trace elements, Tera *et al.* (1974) report U, Th, and Pb abundances, and Flory *et al.* (1973) report hydrocarbon and light element abundances. The latter suggest the presence of indigenous lunar methane. MacDougall *et al.* (1973) give a U abundance (~ 0.2 ppm) from fission track mapping. These are probably mainly analyses of variolitic melt.

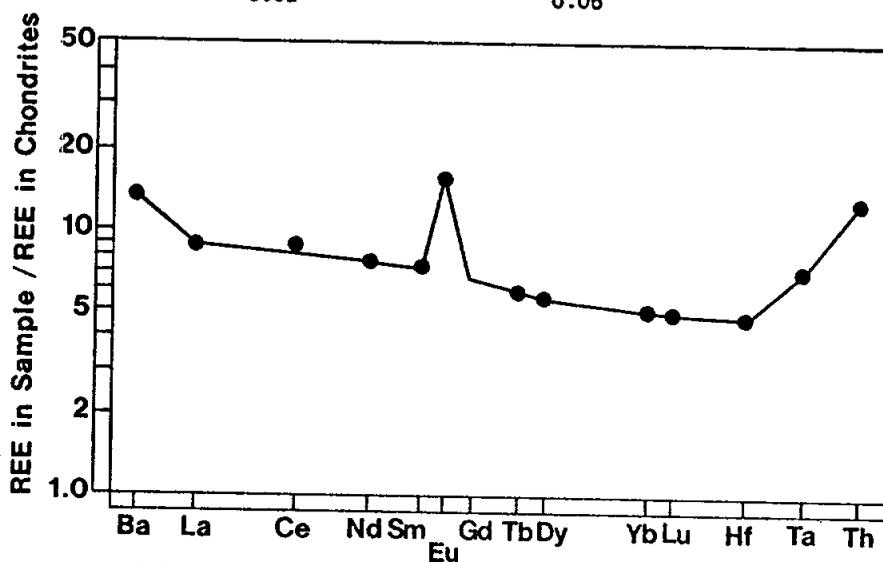
Although Morrison *et al.* (1973) state that they received and analyzed a white chip, photodocumentation demonstrates that they received a dark vesicular chip. Nonetheless their analysis is significantly different from other analyses, in particular being lower in alumina and higher in magnesia. Krahenbühl *et al.* (1973) and Ganapathy *et al.* (1974) give incorrect split numbers; they actually analyzed ,80.

60017 is significantly more aluminous than local soil compositions and has a positive Eu anomaly (Fig. 4). It is similar to sample 63335 taken from the same boulder. The trace siderophiles are low (although not at indigenous levels) as are many North Ray Crater samples. The siderophile element ratios place the sample in meteoritic Group 6 of Ganapathy *et al.* (1974). Rose *et al.* (1973) obtained higher Ni and Ni/Co than other analysts.

Defocussed beam microprobe analyses of the dark breccia and their included "anorthositic gabbro" clasts are reported by Kridelbaugh *et al.* (1973). The dark breccia is similar in composition to the bulk breccia analyses, while the "anorthositic gabbro" clasts are much less aluminous (Table 1).

TABLE 1. Summary chemistry of 60017

	Bulk rock or variolitic melt	dark breccia*	"anorthositic gabbro"*
SiO ₂	44	46	46
TiO ₂	0.3	0.2	1.1
Al ₂ O ₃	31.0	31.2	22.9
Cr ₂ O ₃	0.06		
FeO	3	3.3	9.2
MnO	0.04		
MgO	3	2.4	6.4
CaO	17.0	17.4	14.0
Na ₂ O	0.53	0.03	0.76
K ₂ O	0.07	0.43	0.05
P ₂ O ₅	0.02	0.02	0.06
Sr	140 ?		
La	3.0		
Lu	0.16		
Rb	0.8		
Sc	6		
Ni	50		
Co	7		
Ir ppb	1.4		
Au ppb	0.4 ?		
C	30-105		
N	7-24		
S	120		
Zn	5		
Cu	2		



Oxides in wt%; others in ppm except as noted

*from DBA, Kridelbaugh et al. (1973)

FIGURE 4. Rare earths; from Laul and Schmitt (1973).

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Murthy and Coscio (1977) and Murthy (1978) report $^{87}\text{Sr}/^{86}\text{Sr}$ for two hand-picked plagioclase clasts, which extrapolate to values close to BABI at 4.6 b.y. (Table 2)

	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$ at 4.6 b.y*
I	0.69933 \pm 5	0.69900 \pm 5
II	0.69928 \pm 5	0.69899 \pm 5

* adjusted for bias by subtracting 0.00006 to be equivalent to Caltech data

Tera et al. (1974) report U, Th and Pb isotopic data for 60017,72, a bulk rock sample. The sample contains predominantly initial radiogenic lead rather than in situ-produced lead. The sample falls off a reference isochron which encompasses most other highlands samples on a $^{207}\text{Pb}/^{206}\text{Pb}$ v. $^{238}\text{U}/^{206}\text{Pb}$ evolution diagram (Fig. 5). The departure can be accounted for by assuming that the sample formed at ~ 4.0 b.y. from a source ~ 4.4 b.y. old or formed at ~ 3.9 b.y. from a source 4.5 b.y. old.

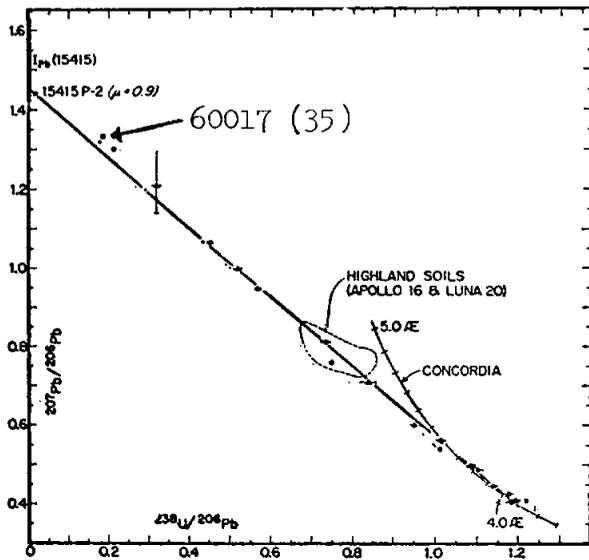


FIGURE 5. U-Pb evolution diagram. Reference isochron passes through total rock and plagioclase for rock 68415. Number in parentheses is μ value; from Tera et al. (1974).

TRACKS AND RELATED STUDIES: MacDougall et al. (1973) measured the U content from fission tracks, but found no solar flare tracks in olivine or feldspar. Fireman et al. (1973) report count rates for ^3H , which is less abundant in the interior than the surface.

PHYSICAL PROPERTIES: Housley et al (1976) found that 60017,84 (bulk rock) has a very weak ferromagnetic resonance and is thus unlike either soils or soil breccias. Gold et al. (1974, 1975, 1976a) used 60017 for calibration in Auger electron spectroscopy of samples. They found that the albedo (0.5) of 60017 does not decrease to highland soil albedo levels merely by crushing.

PROCESSING AND SUBDIVISIONS: A few small fragments were chipped off the samples prior to its sawing in late 1972. During sawing several fragments were produced (Fig. 6). The two largest pieces, 18 and 52 and several small pieces are preserved intact. Slab A was dissected as shown in Figure 7, and 17 was dissected to give splits 53 through 88 (Fig. 6). Most allocations have been made from the subdivisions of 17.

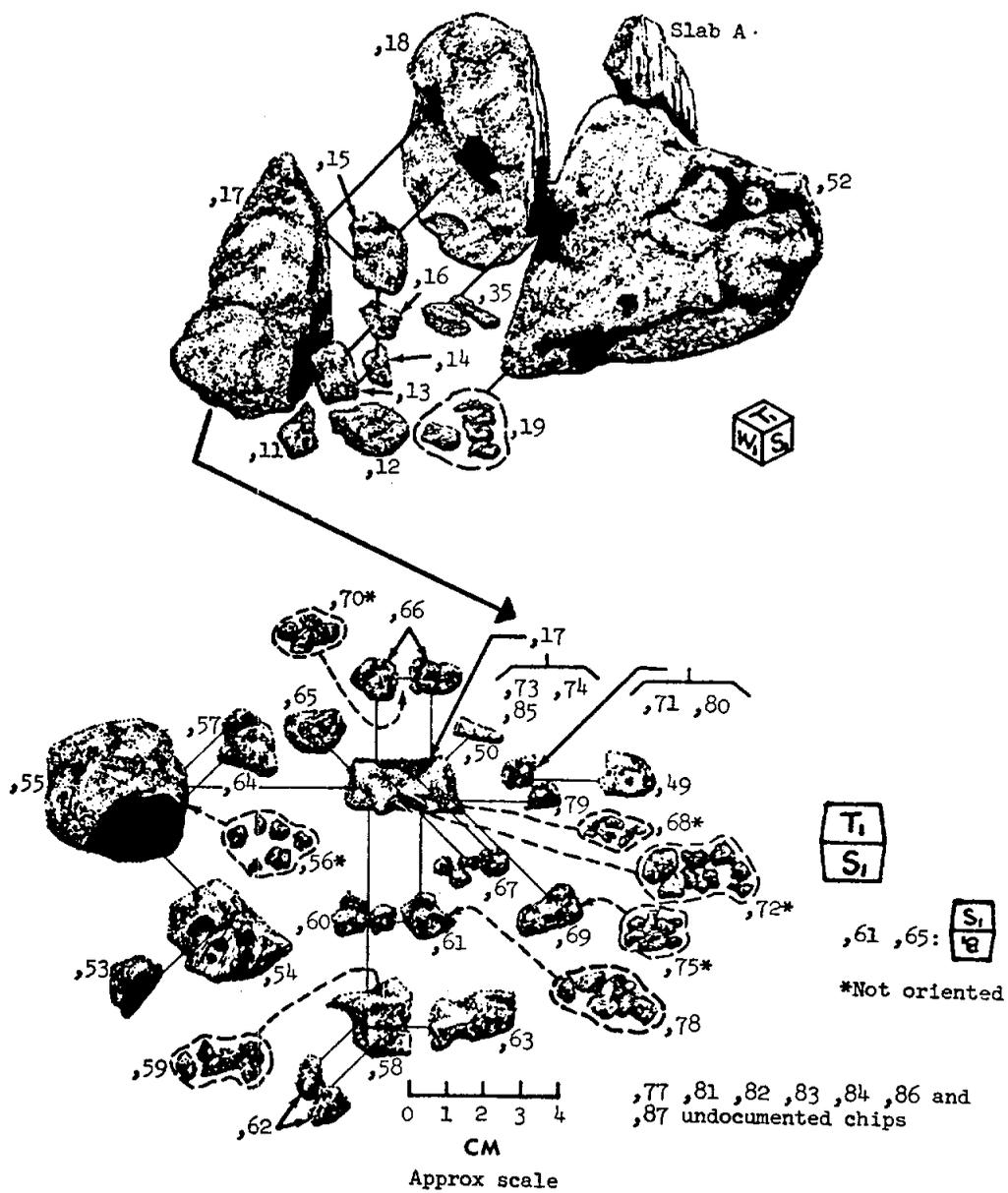
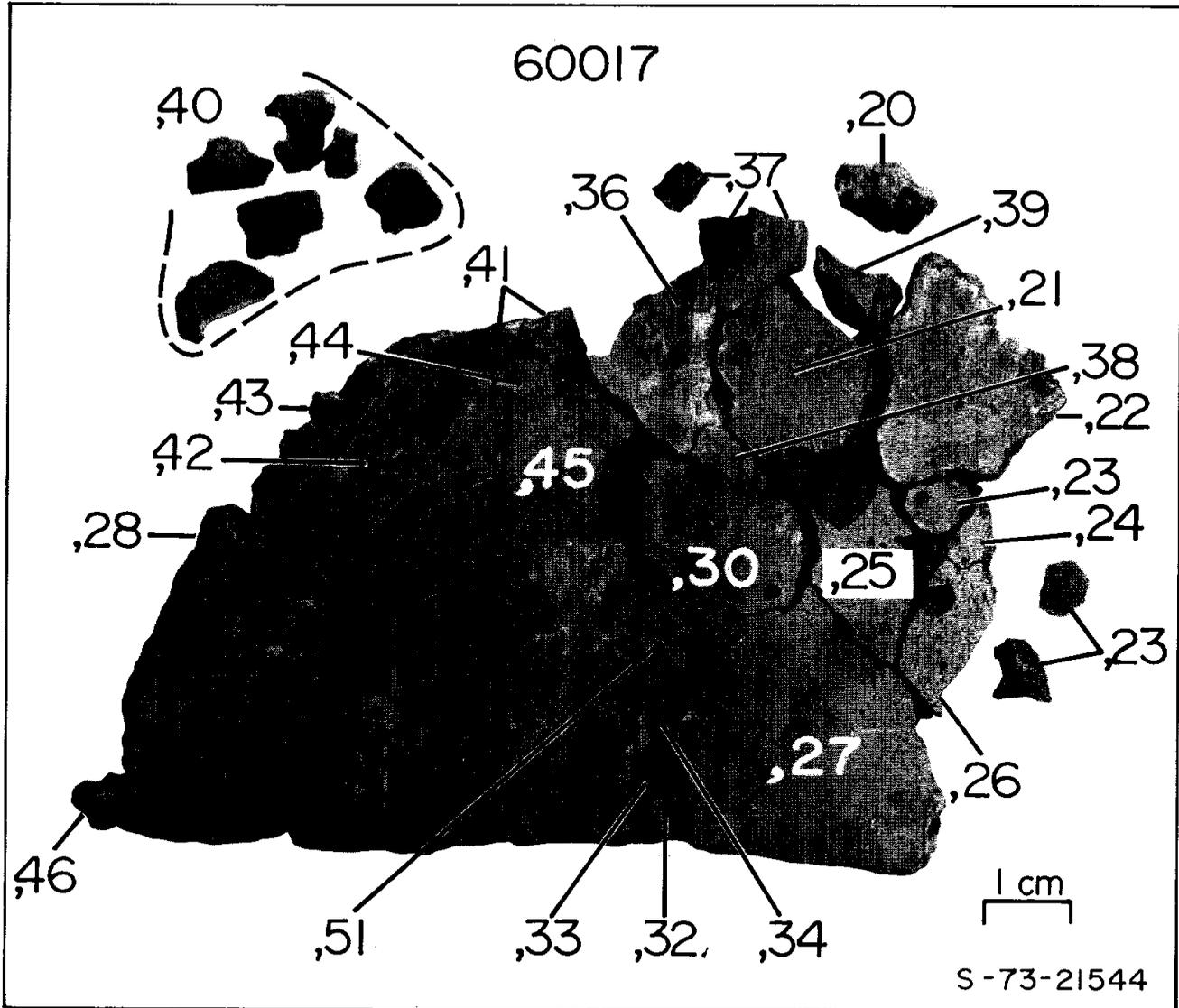


FIGURE 6. Cutting diagram

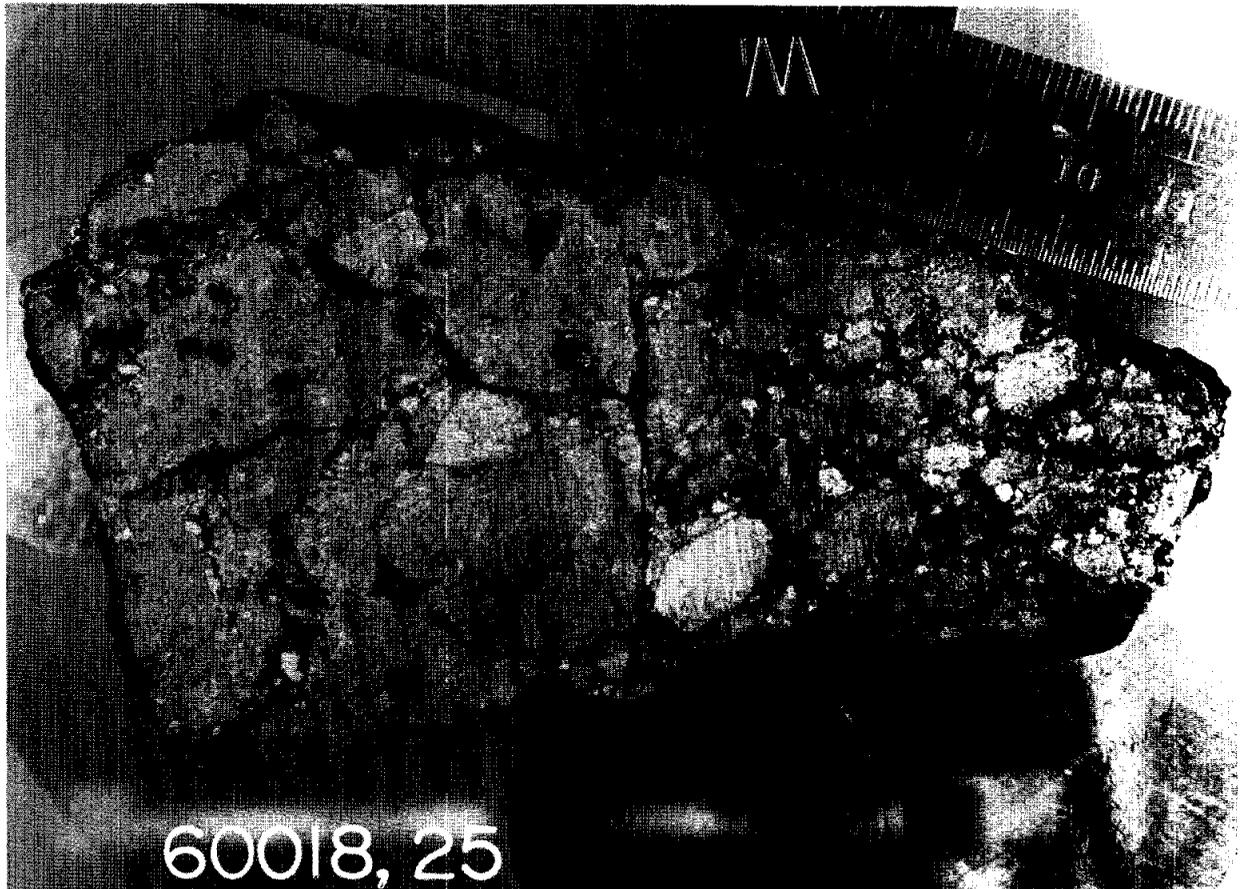
FIGURE 7. Subdivision of slab.
S-73-21544.



INTRODUCTION: 60018 is a coherent, medium gray, basaltic impact melt that suffered a variety of shock effects after lithification. Extensive fractures and a network of glass veins penetrate the rock (Fig. 1). A dark, vesicular glass coats the exterior surfaces.

60018 was chipped from a 50 cm boulder 100 m southwest of the Lunar Module. This boulder was perched and subrounded. The location and orientation of 60018 are known. Many zap pits are present on the lunar-exposed surface.

FIGURE 1. Saw cut face. S-78-31788. Scale in mm.



PETROLOGY: Although intensely shocked, a relict melt texture is clearly discernable over much of the rock. An intergranular basaltic texture is most common with plagioclase laths often forming radial clusters (Fig. 2). Areas of fine-grained breccia and patches with a poikilitic to subophitic texture are also present. Grain size of the melt matrix varies dramatically over short distances; maximum crystal length is ~ 1 mm.

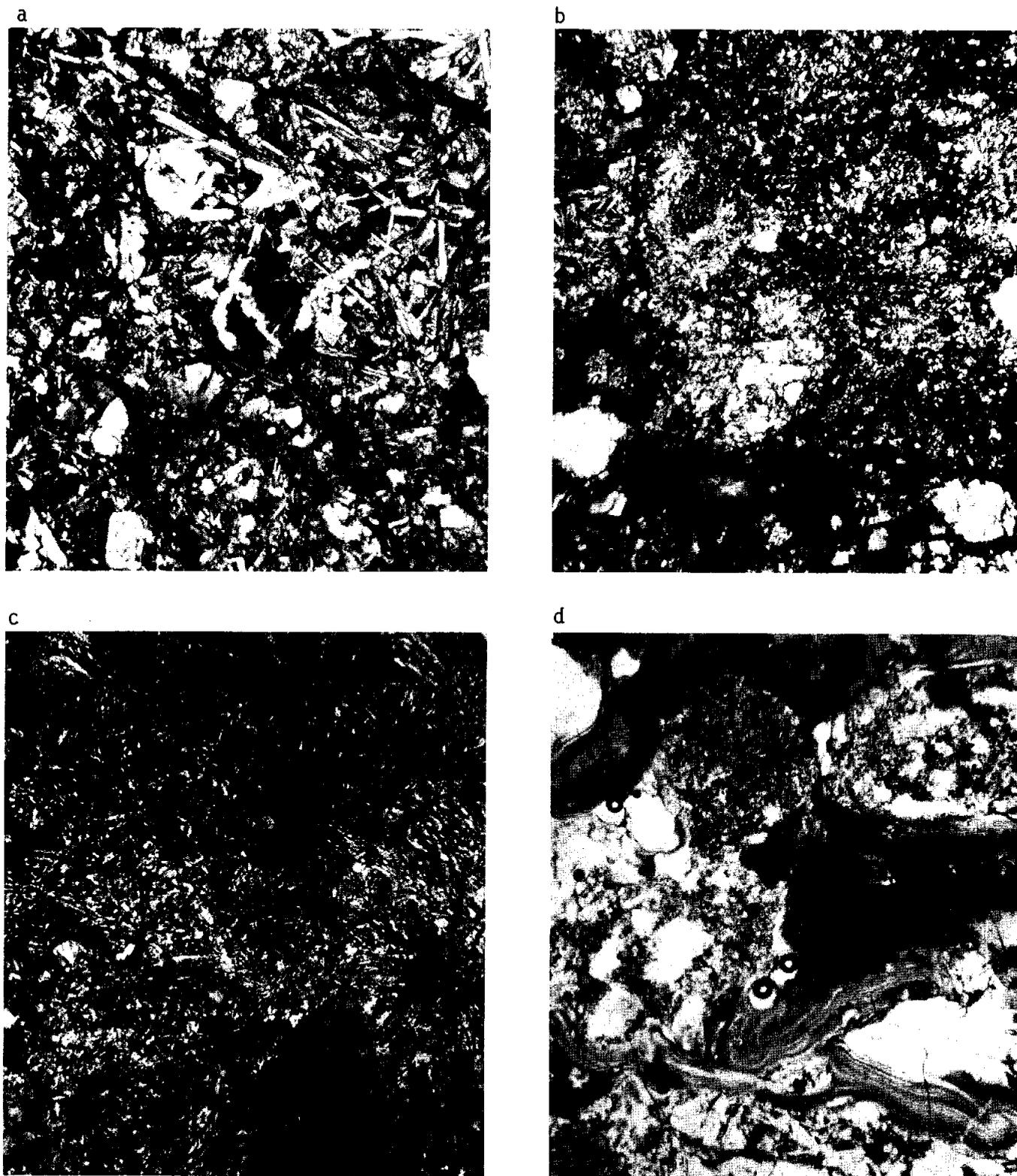


FIGURE 2. a) 60018,53. general view, basaltic, xpl. width 2mm.
 b) 60018,57. general view, poikilitic and glassy, xpl. width 2mm.
 c) 60018,51. spherulitic, glassy, xpl. width 2mm.
 d) 60018,51. glass veins, ppl. width 2mm.

Plagioclase xenocrysts are abundant. Clasts of anorthosite and noritic anorthosite (up to ~1 cm) are somewhat less common. Metal fragments have Ni and Co contents which plot within the "meteoritic field" (Reed and Taylor, 1974). Troilite and schreibersite are occasionally associated with the metal. Figure 3 shows that many of the kamacite particles not associated with schreibersite are nevertheless enriched in P relative to meteoritic metal. Some rust is also present. Late stage silicate-liquid immiscibility is apparent in some interstitial areas.

Both the clasts and the host basalt show extreme shock effects. Many of the plagioclase laths and clasts have been converted to maskelynite or recrystallized. In the most severely altered zones interstitial mafics have been converted to small rounded grains (Fig. 2).

A complex network of glass veins penetrates the rock and is probably related to the glass coat. In thin section these veins are green to brown, often contain schlieren and debris, and seem especially common along clast-matrix boundaries. The intrusion of these glass veins appears to postdate the lithification of the rock and is probably related to the event which caused the intense shock metamorphism.

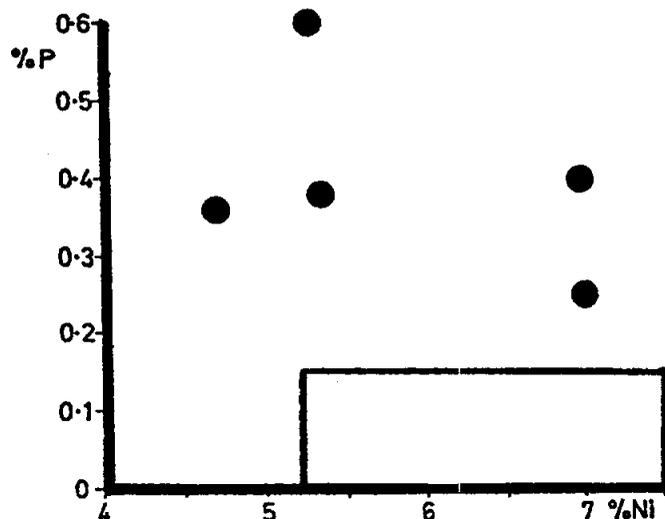


FIGURE 3. P v. Ni for metal; from Reed and Taylor (1974).

CHEMISTRY: S.R. Taylor *et al.* (1973) and Haskin (unpublished) have analyzed bulk rock samples for major and trace elements. Haskin (unpublished) has also analyzed clasts and glass samples. Cripe and Moore (1974), Moore and Lewis (1976), Moore *et al.* (1973) and Goel *et al.* (1975) provide carbon, nitrogen and sulfur data. Nunes *et al.* (1974) provide U, Th, and Pb abundances.

REEs in the basalt are high (Fig. 4). This, along with the high bulk Ni values and metal compositions, indicates that the rock was a clast-laden impact melt with significant KREEP and meteoritic components. Also notable is the extreme enrichment in sulfur relative to the other light elements (Table 1).

The glass veins are significantly more aluminous than the basalt and have lower levels of incompatible elements (Table 1). Thus the glass is not a whole rock

melt of the basalt.

White clasts analyzed by Haskin are virtually pure plagioclase or anorthosite based on their low contents of FeO and REEs (Table 1). One black clast, also analyzed by Haskin, is ultramafic with high FeO and very low levels of REEs (Table 1).

TABLE 1. Summary chemistry of
the melt matrix (basalt), clasts and glass veins of 60018

	<u>Basalt</u>	<u>Glass *</u>	<u>White clasts *</u>	<u>Black clasts *</u>
SiO ₂	45.7	44.9		
TiO ₂	0.65	0.359		
Al ₂ O ₃	24.0	28.5		
Cr ₂ O ₃	0.11	0.086	0.006	0.04
FeO	5.6	4.60	0.3	34.8
MnO	0.07	0.048	0.015	1.07
MgO	8.9	4.83		
CaO	13.8	16.6		
Na ₂ O	0.54	0.492	0.424	0.02
K ₂ O	0.23	0.103		
P ₂ O ₅				
Sr				
La	25	10.7	0.38	(Sm=0.042)
Lu	1.1	0.46	0.003	
Rb	7.7	3.1		
Sc	9.1	6.0	0.44	7.1
Ni	400	520		
Co	29	43	0.54	71
Ir ppb				
Au ppb				
C	32			
N	29			
S	2250			
Zn	2.2	2.6		
Cu				

Oxides in wt%; others in ppm except as noted.

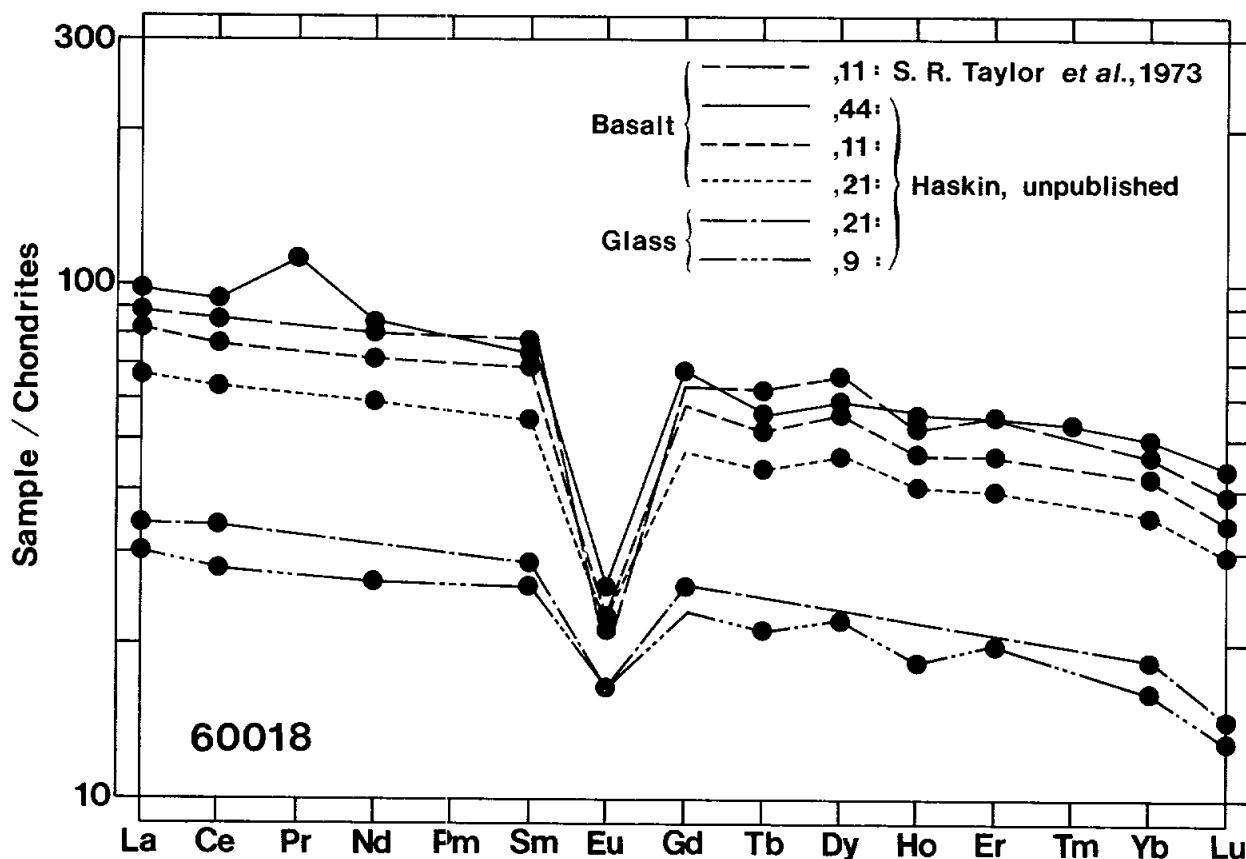
*from Haskin (unpublished)

TABLE 2. Oxygen isotope data

	δO^{18}	δO^{17}
Whole rock	5.69	
Light clast	5.60	
"Cataclastic anorthosite"*	5.60	2.75

*Listed in Clayton and Mayeda (1975) as 60018,43.
Photodocumentation shows that this split is mostly
basalt but also contains a large white clast.

FIGURE 4. Rare earths.



STABLE ISOTOPES: Clayton *et al.* (1973) and Clayton and Mayeda (1975) report $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ data for clasts and the bulk rock (Table 2).

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Nunes *et al.* (1974, 1977) provide U-Th-Pb data for several splits of the rock. Many of their samples had sawn surfaces and were significantly (up to 77%) contaminated with terrestrial lead (Fig. 5). Only their "whole rock" and hand-picked glass samples do not appear to be contaminated. The "whole rock" analysis is nearly concordant at 4.2 b.y. but the glass contains excess Pb relative to U suggesting that the glass may be fused soil (Nunes *et al.*, 1974, 1977).

PHYSICAL PROPERTIES: Sugiura *et al.* (1978) report the results of paleointensity experiments performed while heating the sample under controlled f_{O_2} (Thellier's method) (Fig. 6). The natural remanent magnetization (NRM) of the rock is fairly strong and stable against AF-demagnetization although an ancient remanent magnetization probably is not present. As most of the NRM is thermally demagnetized by 400°C, low temperature shock events may have been responsible for the remanent magnetization that is present. Some of the magnetic properties can also be accounted for by the chemical changes produced by heating.

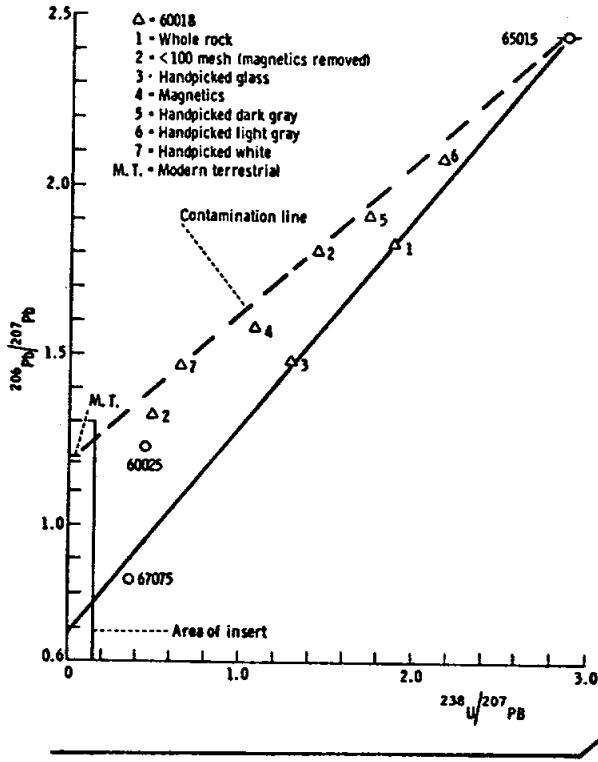
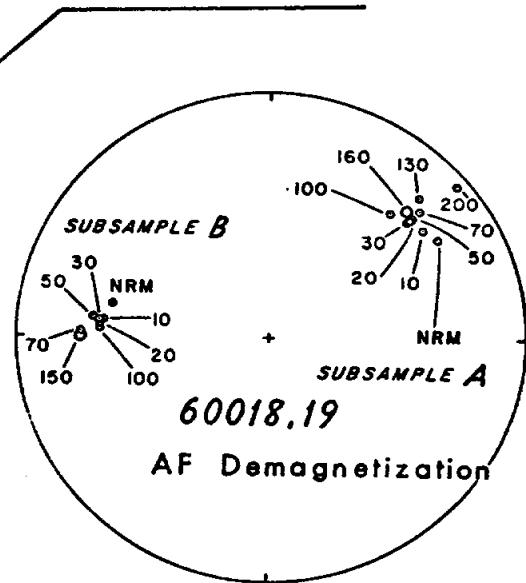
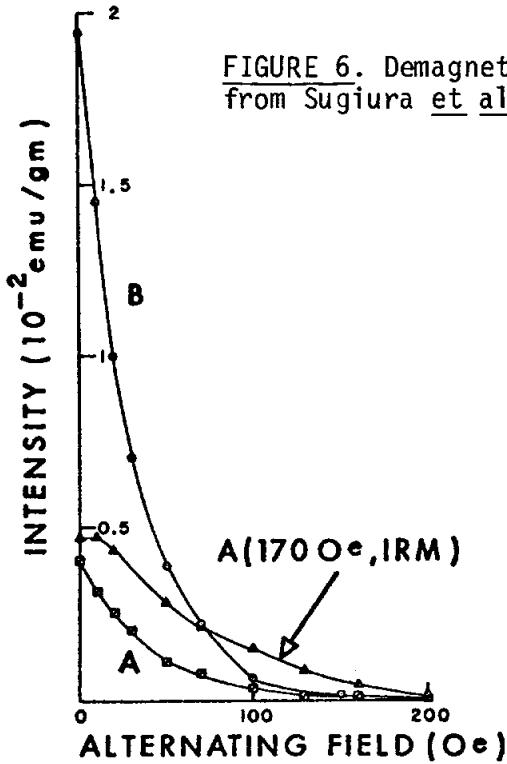


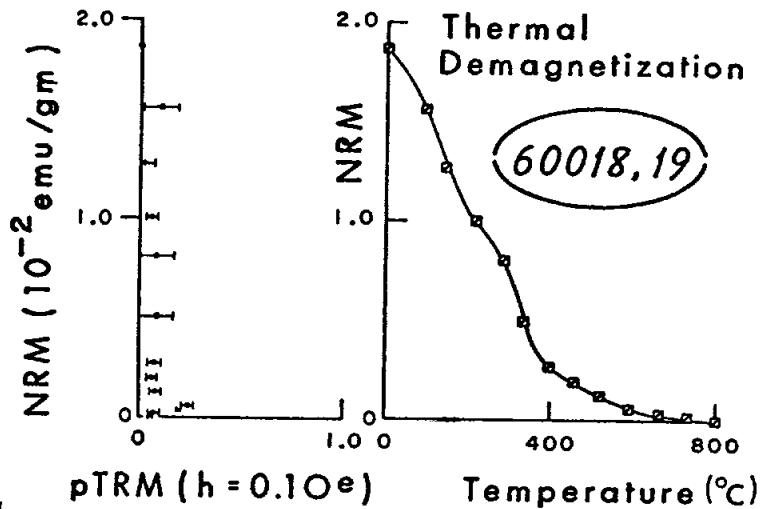
FIGURE 5. U-Pb data; from Nunes et al. (1977).



Directional change of NRM during AF demagnetization for two pieces of 60018.19. Relative orientation of these two pieces is not known.



AF demagnetization of NRM for two pieces (A and B) of 60018.19 and of IRM for piece A.



NRM vs. pTRM plot and thermal demagnetization for 60018.19.

PROCESSING AND SUBDIVISIONS: In 1972 this rock was cut into three main pieces, one being a slab (Fig. 7). The slab was entirely subdivided with most of the allocations being taken from it. Not all splits are shown in the diagram.

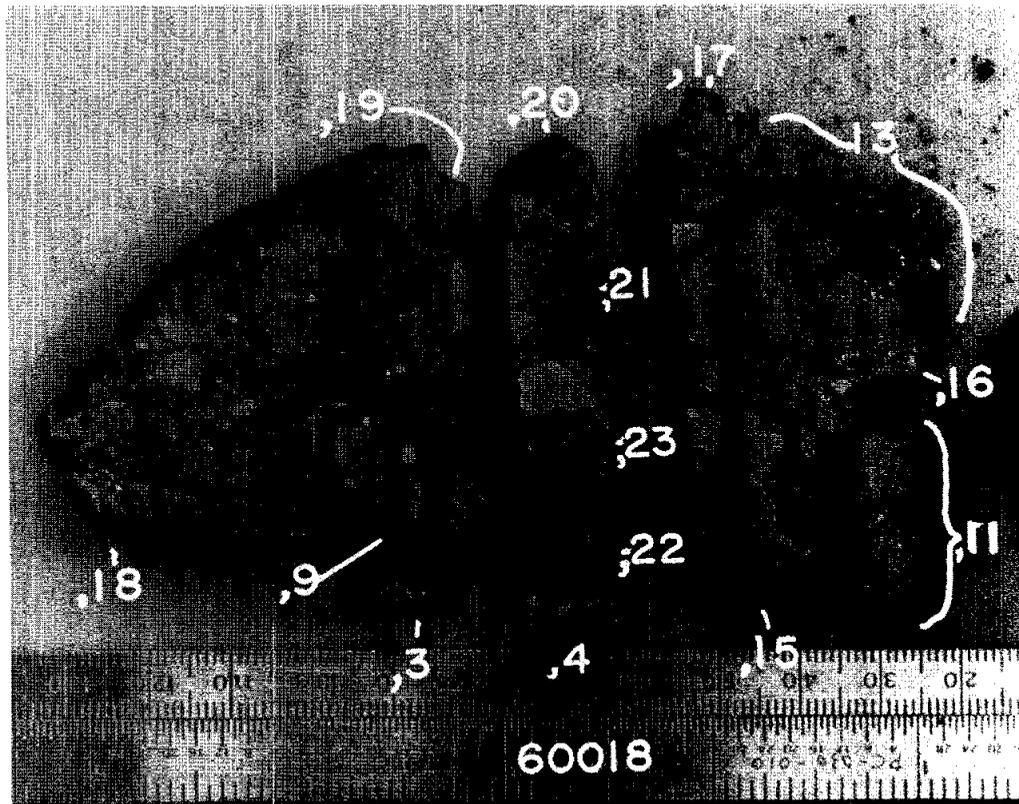
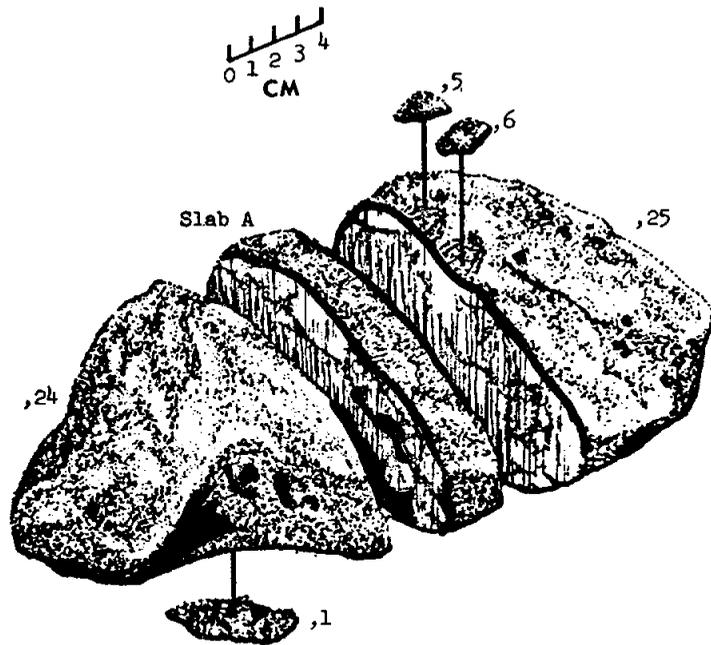


FIGURE 7. top: cutting diagram. bottom: slab dissection. S-73-21540.

INTRODUCTION: 60019 is a coherent, medium-gray glassy breccia containing several large, light colored clasts (Fig. 1) which are mainly poikilitic and (more rarely) basaltic impact melts. Part of its surface has a rough glass coating.

The sample location is not known precisely but was approximately 115 m west south-west of the Lunar Module. It was partly buried (poorly developed fillet). The sample is subrounded. The orientation is known and zap pits are present on some surfaces.

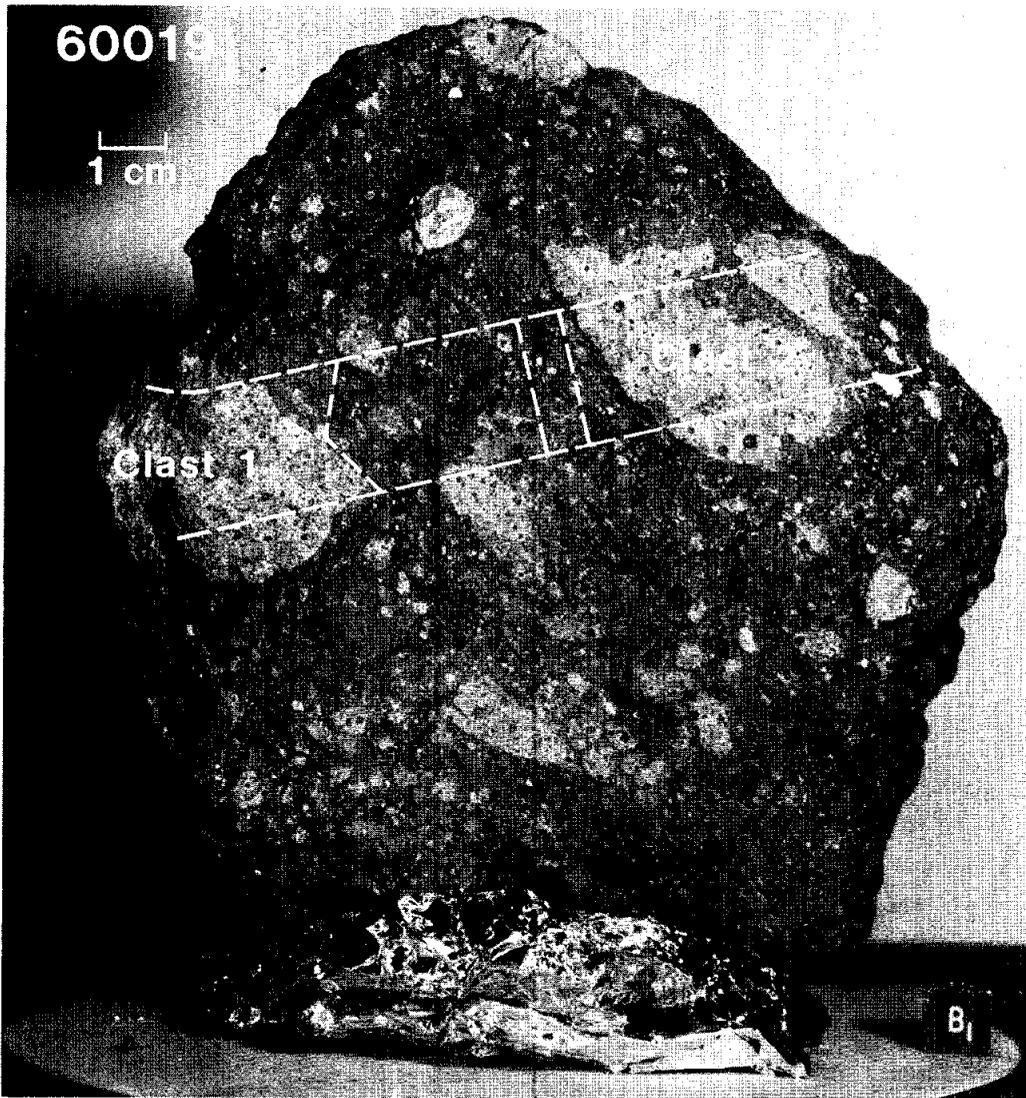


FIGURE 1.

PETROLOGY: Macroscopically the rock consists of a dark aphanitic matrix with abundant clasts up to 5 cm (Fig. 1). Clasts vary from fine-grained, crystalline lithic fragments to glass and mineral fragments. The matrix has glass-lined cracks and glassy veins. Rust patches occur in both the matrix and the larger clasts.

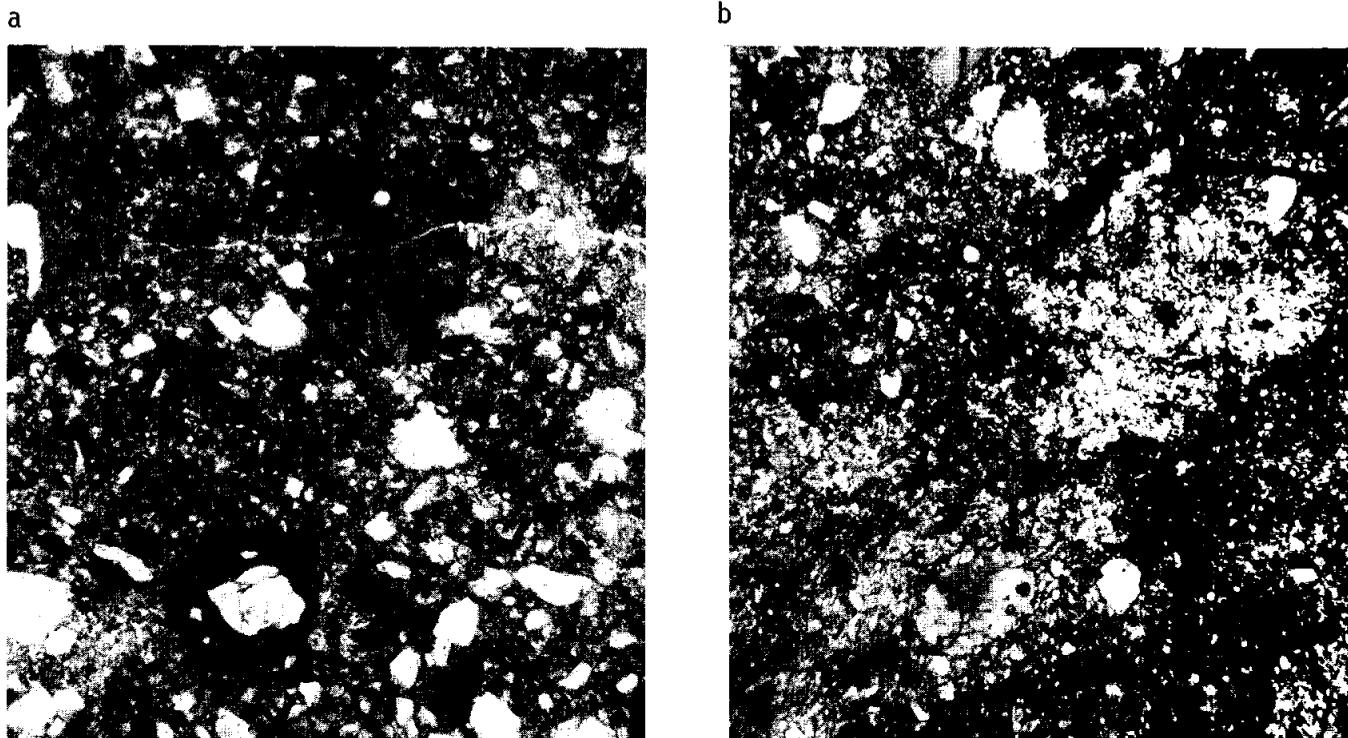


FIGURE 2. a) 60019,14. general view, ppl. width 2mm.
b) 60019,77. Clast 1, poikilitic, xpl. width 2mm.

Thin sections show that the matrix is brown, glassy, partly vesicular and contains glass fragments (Fig. 2). These characteristics and its chemistry (below) suggest that 60019 is lithified regolith or is largely derived from regolithic material. Most of the large clasts (e.g. clasts 1 and 2, Fig. 1) are poikilitic impact melts. Clast 1 is poikilitic with abundant fragments (Fig. 2) including granoblastic impactites, cataclastic anorthosite, and aluminous basalt. In places the poikilitic texture, characterized by pyroxene oikocrysts up to 1 mm, grades into basaltic texture. Other smaller clasts in the matrix include coarse, aluminous, impact basalts, aluminous breccias, and plagioclase and mafic mineral grains. One small (2x3 mm) coarse basalt may be of mare affinity; it is mafic and has conspicuous ilmenite.

Hansen *et al.* (1979b and unpublished) investigated a granoblastic impactite clast in 60019. Plagioclase compositions show little dispersion of major (An_{94-95}) or minor (K_2O 0.053%; FeO 0.098%; MgO 0.135%) elements. Olivine is Fo_{79} .

CHEMISTRY: Rose et al. (1975) report major and trace element analyses of both the matrix and clast 1. Cripe and Moore (1975) and Moore and Lewis (1976) report light elements for these same two lithologies. The matrix is chemically indistinguishable from Apollo 16 soils in all respects with the exception of rare-earths which are enriched in 60019. The poikilitic clast is more aluminous and less enriched in incompatible elements than most other Apollo 16 poikilitic rocks; this is at least in part a consequence of its abundant clasts.

RARE GASES: Bernatowicz et al. (1978) report xenon and krypton isotopic abundances from heating studies of a matrix sample. The sample contains substantial excess fission xenon and ^{129}Xe , suggesting that excess fission xenon is a global characteristic. The sample is rich in solar wind components, again suggestive of a significant regolith component.

PROCESSING AND SUBDIVISIONS: In October, 1974, two end pieces (,4 and ,5) and a slab were cut from 60019 (Figs. 1, 3). The slab itself was subdivided leaving two large pieces (,18 and ,23). Most subdivisions were made from a column down the center of the slab and from the region of clast 1.

TABLE 1. Chemistry of 60019

	<u>Matrix</u>	<u>Clast 1 (Poikilitic)</u>
SiO ₂	45.3	45.3
TiO ₂	0.35	0.46
Al ₂ O ₃	26.3	23.2
Cr ₂ O ₃	0.10	0.14
FeO	5.3	6.9
MnO	0.06	0.08
MgO	6.7	9.5
CaO	14.9	13.6
Na ₂ O	0.46	0.48
K ₂ O	0.14	0.18
P ₂ O ₅	0.19	0.27
Sr	131	136
La	20	26
Lu		
Rb	3.1	4.2
Sc	11	11
Ni	795	810
Co	49	45
Ir ppb		
Au ppb		
C	162	110
N	56	28
S	920	910
Zn	13	<4
Cu	7.8	7.5

Oxides in wt %; others in ppm except as noted.

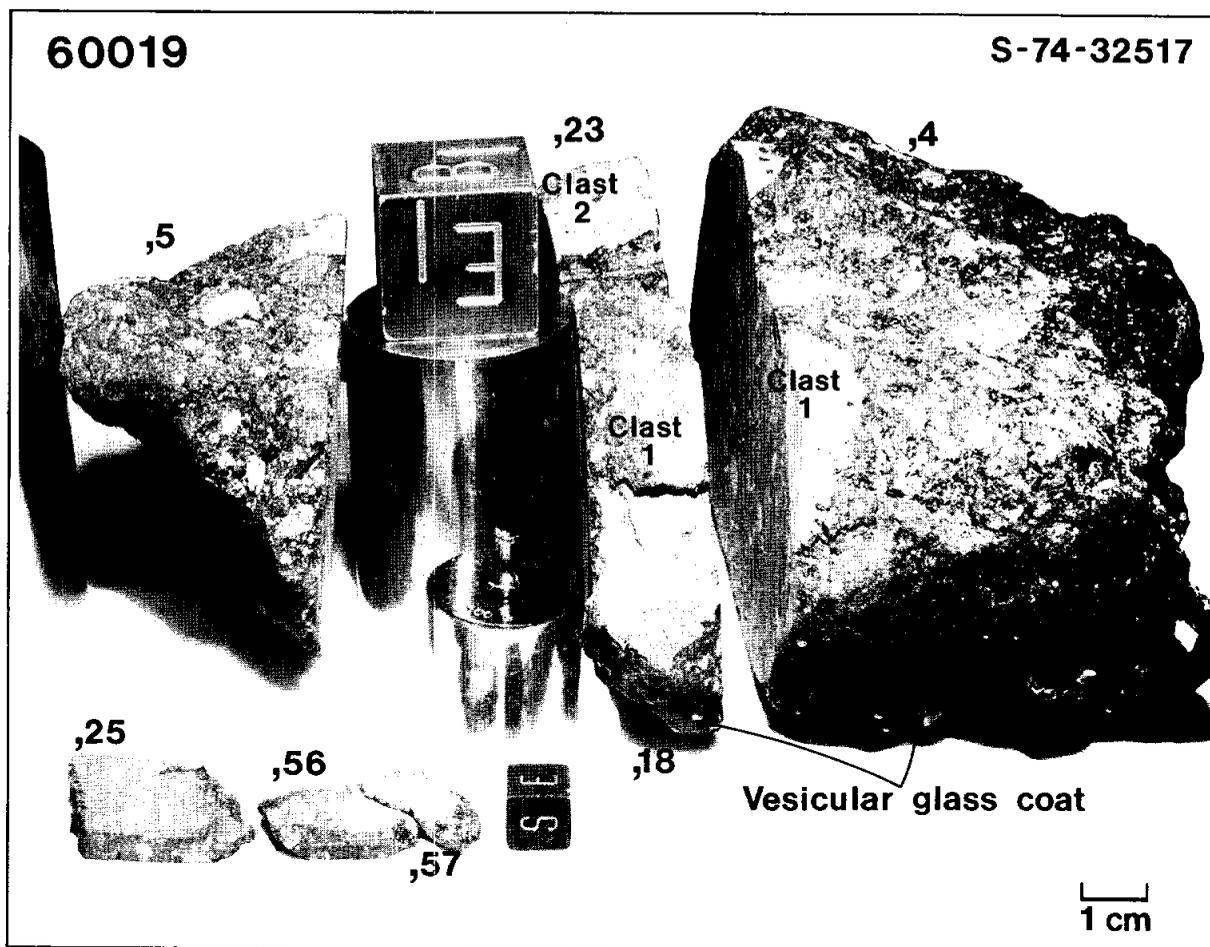
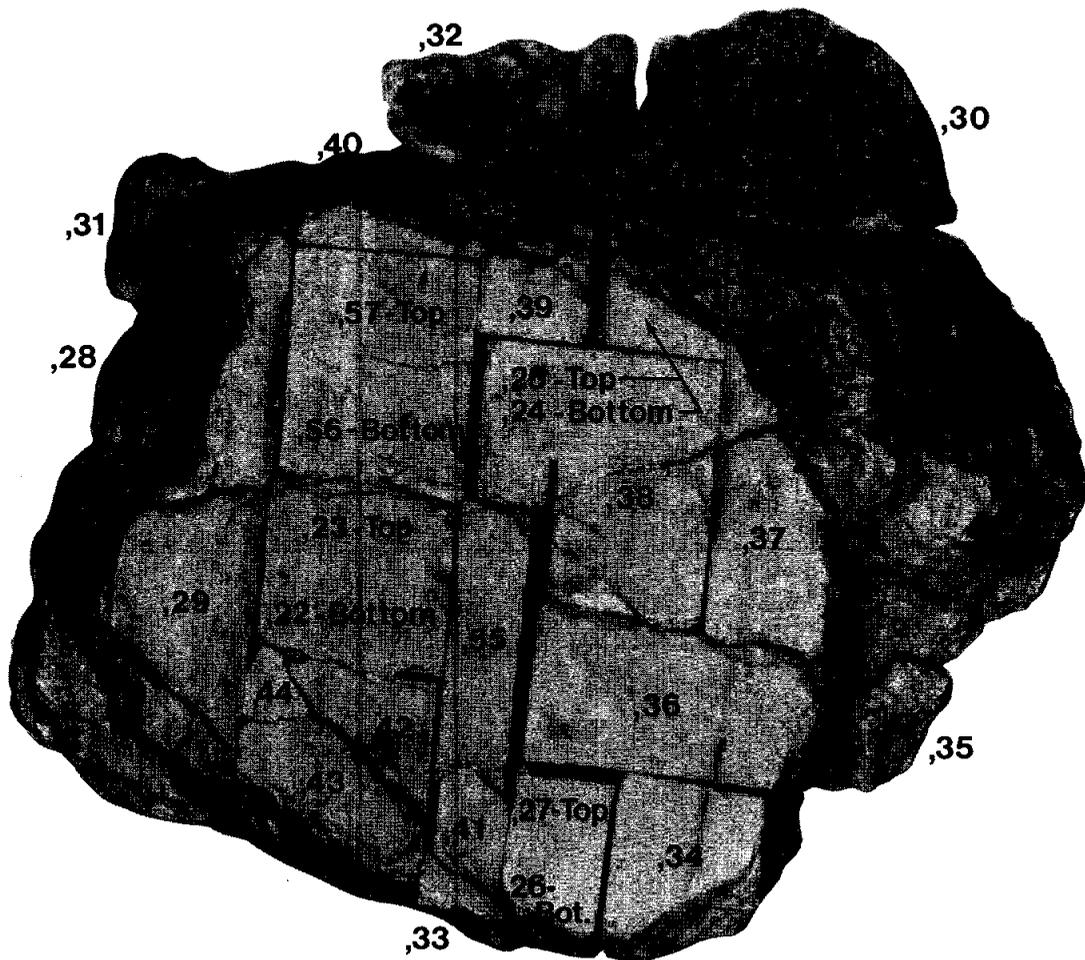


FIGURE 3. Saw cut subdivisions.

INTRODUCTION: 60025 is a coarse-grained, moderately shocked and cataclastic ferroan anorthosite which is monomict and is free of meteoritic siderophiles (i.e. chemically pristine). A small patch of dark vesicular glass is present on one surface (Fig. 1). 60025 was collected 15 m southwest of the Lunar Module where it was perched. It is moderately coherent with some penetrative fractures. Its orientation is known and zap pits occur on all surfaces, though not equally distributed.

FIGURE 1. Saw cut slab. S-72-49095. Scale in mm.



60025

PETROLOGY: Walker et al. (1973), Hodges and Kushiro (1973), Dixon and Papike (1975), Warren and Wasson (1978) and LSPET (1973) provide general petrographic information. Takeda et al. (1976) studied pyroxenes in detail and Longhi et al. (1976), Hansen et al. (1979a) and Meyer (1979) report data on minor elements in plagioclase.

The rock is a true anorthosite with > 90% plagioclase (An_{94-98}). Shock-twinned and fractured clasts up to 4 mm long rest in a fine-grained and often recrystallized matrix of granulated plagioclase (Fig. 2). Mafics are ferroan and irregularly distributed. Walker et al. (1973), Hodges and Kushiro (1973) and Dixon and Papike (1975) report < 2% pyroxene and no olivine whereas LSPET (1973) indicates ~ 10% olivine, and a "mafic-rich" portion described by Warren and Wasson (1978) contains 20% olivine (Fo_{57-65}) and 10% pyroxene. A 2x2 mm optically continuous zone of pyroxene and a 4x4 mm zone of olivine attest to the coarse-grained nature of the rock prior to cataclasis (Warren and Wasson, 1978). Traces of silica, ilmenite, Cr-spinel and glassy inclusions in plagioclase are scattered throughout the rock.

Anhedra pyroxenes (most < 0.5 mm) are concentrated as discrete grains in the matrix but also occur as rods, stringers and irregular blotches along plagioclase twin planes and grain boundaries. The dominant pyroxene is orthopyroxene. Some grains show well developed exsolution lamellae of high-Ca pyroxene and were probably primary pigeonite. Augite is also present as discrete grains. Apparently three primary pyroxenes-orthopyroxene, pigeonite and augite - were present at the time of crystallization (Hodges and Kushiro, 1973). Pyroxene compositions are shown in Figure 3.



FIGURE 2. 60025,130. general view, xpl. width 2mm.

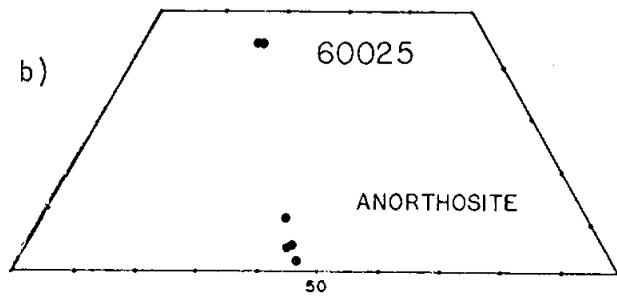
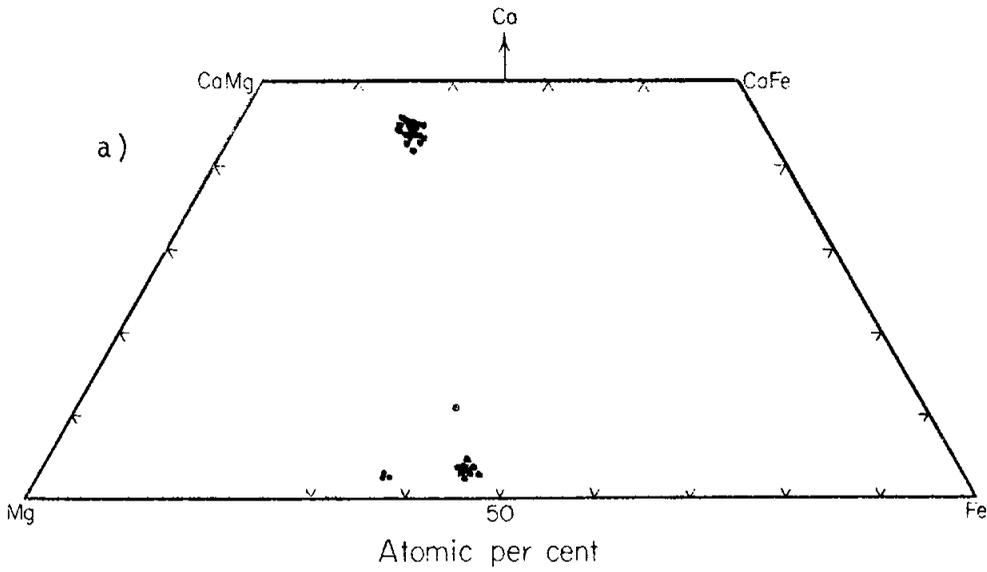


FIGURE 3. Pyroxenes.

a) from Hodges and Kushiro (1973).
 b) from Walker et al. (1973).

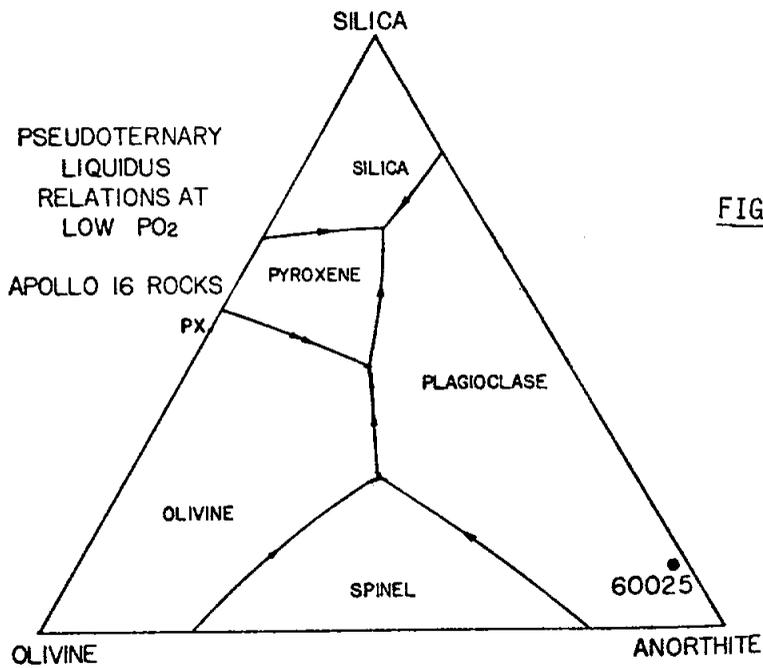


FIGURE 4. from Walker et al. (1973)

EXPERIMENTAL PETROLOGY: Ford *et al.* (1974) determined that plagioclase is the liquidus phase of a rock with the composition of 60025. The anhydrous liquidus occurs at temperatures $> 1370^{\circ}\text{C}$. Moderate water vapor pressure lowers the liquidus temperature to below 1200°C . The anhydrous solidus is $\sim 1200^{\circ}\text{C}$.

CHEMISTRY: Chemical studies of 60025 are listed in Table 1 and a summary chemistry in Table 2. The splits analyzed were almost pure plagioclase (Table 2, Fig. 4); apparently none of the mafic rich portions were sampled for chemistry.

Rare earths are low with the large positive Eu anomaly typical of lunar anorthosites (Fig. 5). The REE pattern of 60025 parallels that of 15415 and 60015 but with absolute concentrations nearly twice as high. Zr and Hf and the Zr/Hf ratio are typical of lunar anorthosites and are among the lowest measured in any lunar material (Ehmann *et al.*, 1975; Garg and Ehmann, 1976).

60025 is also low in siderophiles indicating a lack of meteoritic contamination. Its very high volatile to involatile ratios (e.g. Tl/Cs and Tl/U) however suggest that a fumarolic component is present (Krähenbühl *et al.*, 1973). Sulfur is also enriched in 60025 relative to the other light gases (Table 2), its Fe content (Fig. 3 of Kerridge *et al.*, 1975a) and other pristine anorthosites (e.g. 15415, 60015, 67075).

Flory *et al.* (1973) determined total amounts of hydrocarbons and other light gases and their release patterns upon heating. 60025 was the only rock analyzed by these authors to yield detectable methane, apparently produced by the hydrolysis of reactive, solar wind-deposited carbon.

Sato (1976) determined the oxygen fugacity of 60025 by the solid-electrolyte oxygen cell method and found it to have among the lowest f_{O_2} ever measured in lunar material. A self-reduction at high temperatures occurred during the first heating cycle. Reported values are given in Table 3.

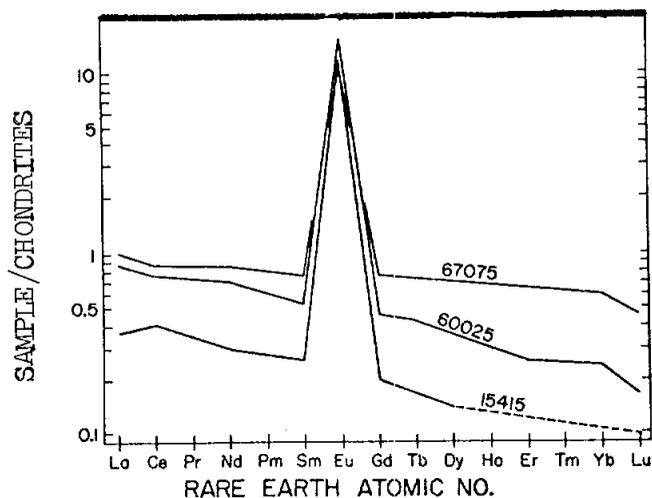


FIGURE 5. Rare earths; from Haskin *et al.* (1973).

TABLE 1. Chemical studies of 60025 anorthosite

Reference	Split #	Elements analyzed
Janghorbani <i>et al.</i> (1973)	,72	majors
Rose <i>et al.</i> (1973)	,95	majors, trace
Haskin <i>et al.</i> (1973)	,45	majors, REEs, other trace
Laul and Schmitt (1973)	,73	majors, REEs, other trace
Nakamura <i>et al.</i> (1973)	,76	majors, REEs, Ba
Walker <i>et al.</i> (1973)	,90	majors*
Krähenbühl <i>et al.</i> (1973)	,84	meteoritic sids. and vols.
Ehmann and Chyi (1974)	,72	Zr, Hf
Ehmann <i>et al.</i> (1975)	,72	Zr, Hf, Sc, Co, Fe, Eu
Miller <i>et al.</i> (1974)	,72	Fe, Sc, Co, Eu
Cripe and Moore (1974)	,82	S
Moore <i>et al.</i> (1973)	,82	C
Moore and Lewis (1976)	,82	N
Schaeffer and Husain (1974)	,86	K, Ca
Nyquist <i>et al.</i> (1975)	,268	Rb, Sr
Papanastassiou and Wasserburg (1972b)	,65	Rb, Sr
Tera and Wasserburg (1972)	} ,65	U, Th, Pb
Tera <i>et al.</i> (1973)		
Nunes <i>et al.</i> (1974)	?,9003 (from ,26)	U, Th, Pb, Rb, Sr, K
Nunes <i>et al.</i> (1977)	,9003 (from ,26)	U, Th, Pb

*Microprobe, fused powder

TABLE 2. Summary chemistry of anorthosite 60025

SiO ₂	44.2
TiO ₂	0.1
Al ₂ O ₃	35.3
Cr ₂ O ₃	0.02
FeO	0.6
MnO	0.014
MgO	0.2
CaO	19.0
Na ₂ O	0.44
K ₂ O	0.03
P ₂ O ₅	0.003
Sr	218
La	0.3
Lu	0.005
Rb	0.02
Sc	0.05
Ni	~ 1
Co	0.07
Ir ppb	0.006
Au ppb	0.007
C	35
N	56
S	240
Zn	<2(?)
Cu	8.4(?)

Oxides in wt%; others in ppm except as noted.

TABLE 3. Oxygen fugacity of 60025 (Sato, 1976)

<u>T (°C)</u>	<u>-log f_{O₂} (atm)</u>
1000	16.9
1050	16.1
1100	15.4
1150	14.7
1200	14.1

STABLE ISOTOPES: Taylor and Epstein (1973) report δO^{18} and δSi^{30} values of +5.95 and -0.01 respectively for whole rock splits of 60025.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Rb-Sr data are summarized in Table 4. The very low measured $^{87}Sr/^{86}Sr$ extrapolates to very close to BABI at 4.0 and 4.6 b.y. Only whole rock data from the anorthosite are currently available although a mineral isochron could conceivably be obtained from the mafic-rich portions of the rock. Schonfeld (1976) constructed a Rb-Sr whole rock isochron from data on lunar anorthosites which gave an apparent age of 4.6 b.y. and an initial $^{87}Sr/^{86}Sr$ of 0.69905. 60025 lies on this isochron.

An Ar-Ar determination yielded a well defined plateau age of 4.19 ± 0.06 b.y. (Fig. 6) (Schaeffer and Husain, 1974). There was no increase in apparent age at high temperatures (Fig. 6) indicating no relict Ar in ancient plagioclase clasts (Schaeffer and Husain, 1974).

U-Th-Pb data show very low concentrations of all of these elements and essentially no initial radiogenic Pb (Tera and Wasserburg, 1972; Tera et al., 1973; Nunes et al., 1974, 1977). The analyses are highly discordant (Fig. 7). Lead isotopes are not easily leachable and are highly evolved yielding a $^{207}Pb/^{206}Pb$ single stage model age of 4.64 b.y. (Tera and Wasserburg, 1972). Nunes et al. (1974, 1977) report serious terrestrial contamination in their samples with sawn surfaces. Interior chips without sawn surfaces do not show such contamination (Tera and Wasserburg, 1972).

TABLE 4. Summary of Rb-Sr data for anorthosite 60025

<u>Rb/Sr</u>	<u>$^{87}Sr/^{86}Sr$ measured</u>	<u>$^{87}Sr/^{86}Sr$ at 4.6 b.y.</u>	<u>Reference</u>
1.16×10^{-4}	0.69896 ± 3	0.69894	Papanastassiou and Wasserburg (1972b)
9.44×10^{-5}	0.69908 ± 6	0.69906	Nunes et al. (1974)
1.34×10^{-4}	0.69905 ± 6	0.69902	Nyquist et al. (1975)
1.22×10^{-4}	0.69913 ± 3	0.69910	Nyquist et al. (1979)

Not corrected for interlaboratory bias

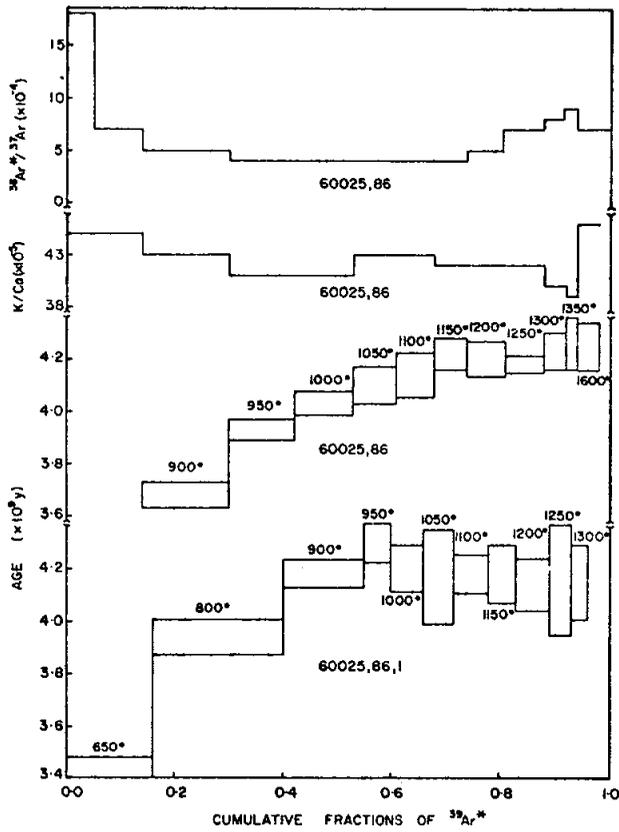


FIGURE 6. Ar release; from Schaeffer and Husain (1974).

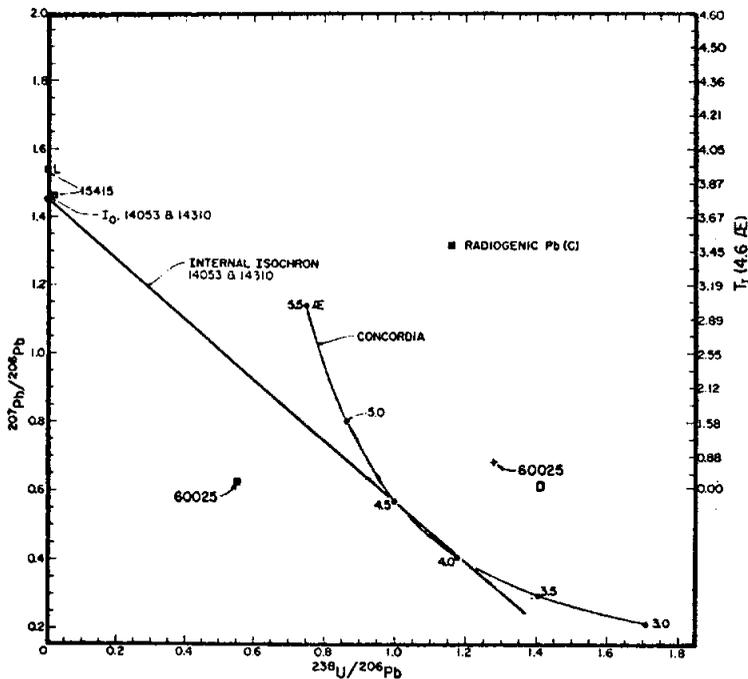


FIGURE 7. U-Pb evolution diagram; from Tera and Wasserburg (1972).

RARE GASES/EXPOSURE AGES: Lightner and Marti (1974a) and Leich and Niemeyer (1975) provide Xe, Kr and Ar isotope data. Significant amounts of trapped Xe not of solar or cosmic origin were found. It is however isotopically indistinguishable from terrestrial Xe and is believed to represent terrestrial contamination because experiments by Niemeyer and Leich (1976) showed that unexpectedly high temperatures ($> 1000^{\circ}\text{C}$) were required to remove known terrestrial contamination.

Marti (pers. comm., 1975, referenced in Drozd et al., 1977) calculated a single stage ^{81}Kr -Kr exposure age of 1.9 m.y., consistent with an excavation by the South Ray cratering event. Fruchter et al. (1977) and Kohl et al. (1977) report Mn and Al isotope data that confirm this 2 m.y. exposure age.

Schaeffer and Husain (1974) report Ar isotopic data and calculate ^{38}Ar - ^{39}Ar exposure ages which average 8.6 m.y., considerably higher than the ^{81}Kr -Kr age which Leich and Niemeyer (1975) consider more reliable.

PHYSICAL PROPERTIES: Limited magnetic information is provided by Cisowski et al. (1976) who found that 60025 possesses high saturation isothermal remanent magnetization (IRMs) comparable to soil breccias and well above that of other cataclastic anorthosites (see their Fig. 6).

Katsube and Collet (1973a,b) and Gold et al. (1976b) report electrical characteristics of the anorthosite (Fig. 8).

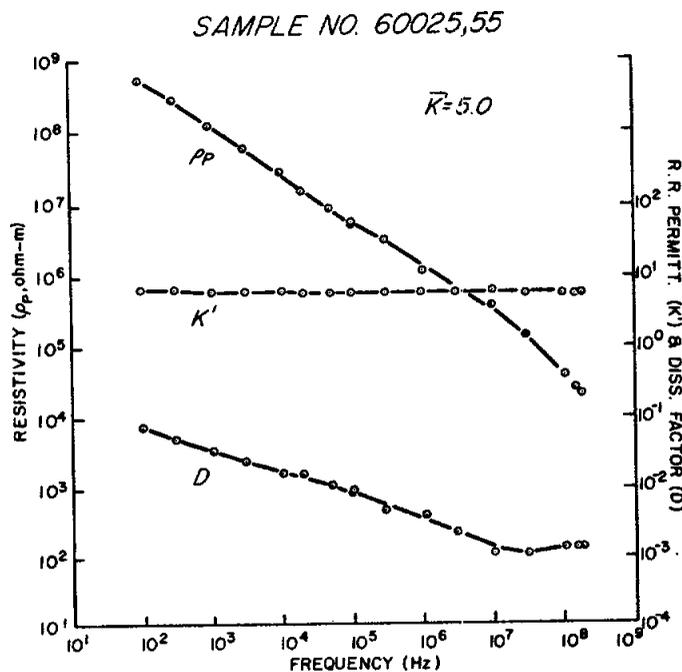


FIGURE 8. Electrical properties; from Katsube and Collett (1973b).

Sondergeld *et al.* (1979) measured compressional wave velocities on three perpendicular surfaces of a slab of the anorthosite. Measured velocities were all < 1 km/sec and deviated up to 29% from the mean value of the three directions (0.66 km/sec). Neither variation in temperature (up to 90° C) nor vacuum (down to 10^{-6} μ m Hg) had any detectable effect on the velocities. These data agree well with seismic wave data from the lunar surface at the Apollo 16 site.

Jeanloz and Ahrens (1978) determined shock wave, equation of state data for the anorthosite over the pressure range 400-1000 kbar (Fig. 9). Porosity in the rock (average $\sim 18\%$) induces smaller peak pressures and greater temperatures than experienced by non-porous rocks subjected to similar shock conditions. Jeanloz and Ahrens (1979) extended the shock wave experiments to higher and lower pressures (1160 and 270 kbar).

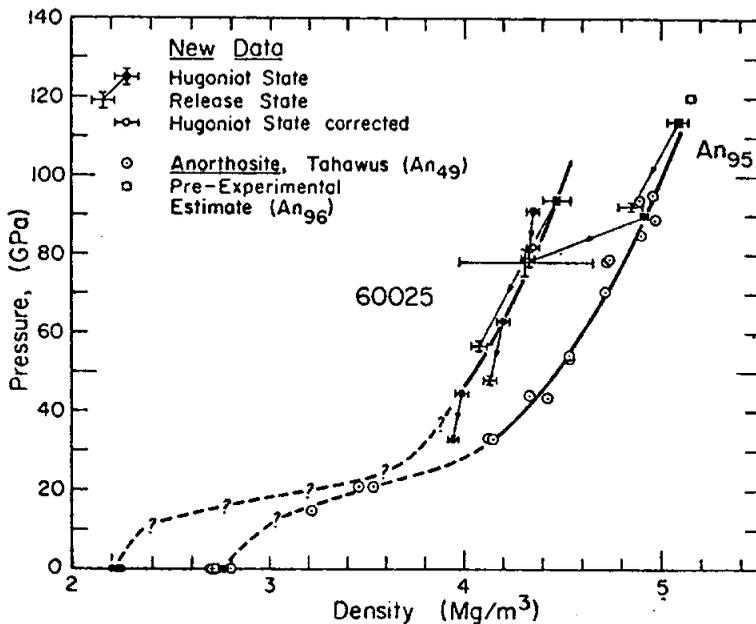


FIGURE 9. Hugoniot equation of state data; from Jeanloz and Ahrens (1978).

Microcracks were studied by Simmons *et al.* (1975) who found two sets of shock induced cracks, possibly indicating separate shock events.

Hapke *et al.* (1978) provide ultraviolet reflectance data.

PROCESSING AND SUBDIVISIONS: In 1972, 60025 was sawn into three main pieces (Fig. 10). The slab and the E butt end were extensively subdivided and allocated. The mafic-rich thin sections described by LSPET (1973) and Warren and Wasson (1978) are from an undocumented chip (60025,9) which is now a potted butt. Processing notes in the data pack indicates that mafic-rich clumps may be present on the N surface.

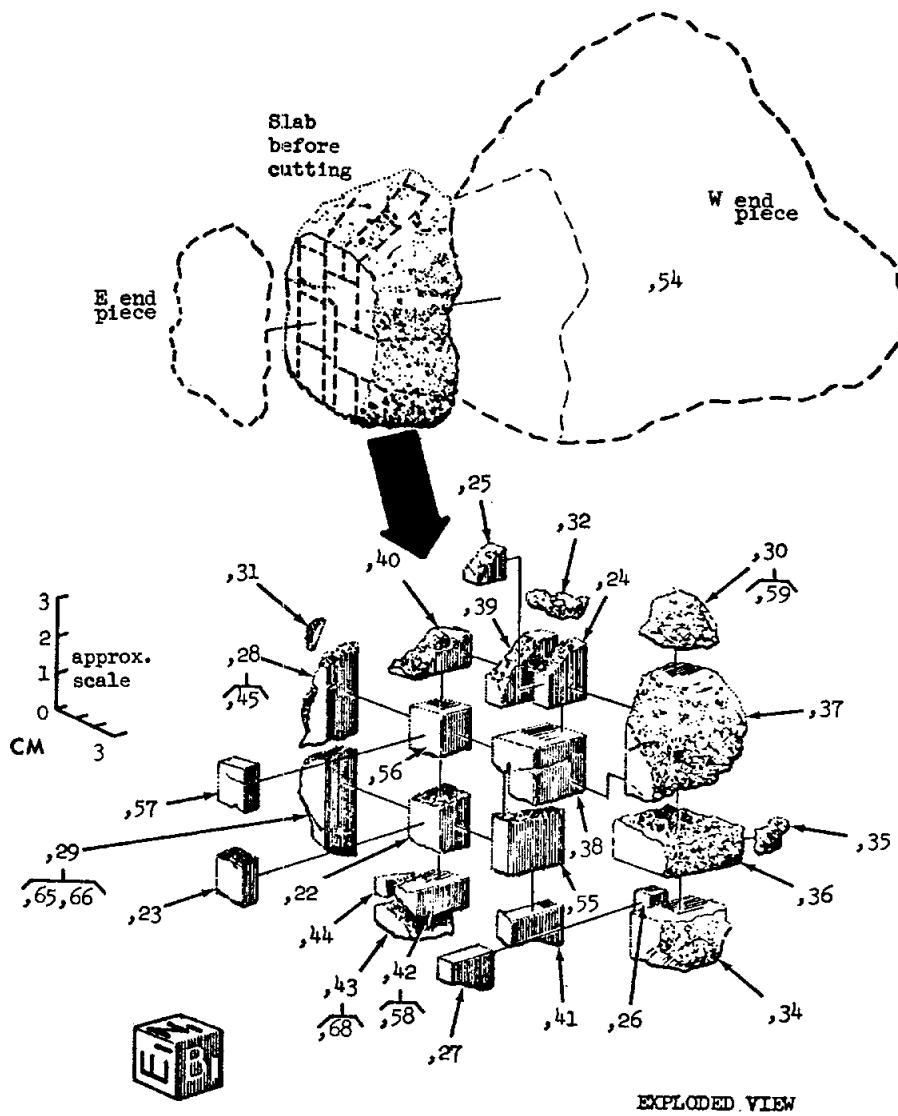


FIGURE 10. Cutting diagram.

INTRODUCTION: 60035 is a coherent, whitish breccia (Fig. 1) consisting mainly of a variety of feldspathic impactites with granoblastic and poikiloblastic textures (Fig. 2). Macroscopically the breccia is homogeneous and cut by a few veins of dark glass. It is partly coated with black glass which apparently once entirely coated the rock.

The sample was collected about 190 m south-southwest of the Lunar Module where it was partly buried. Its orientation is known and zap pits are common on the "lunar up" surface, rare to absent on others. 60035 was originally set aside as a posterity sample and only recently made available for study.

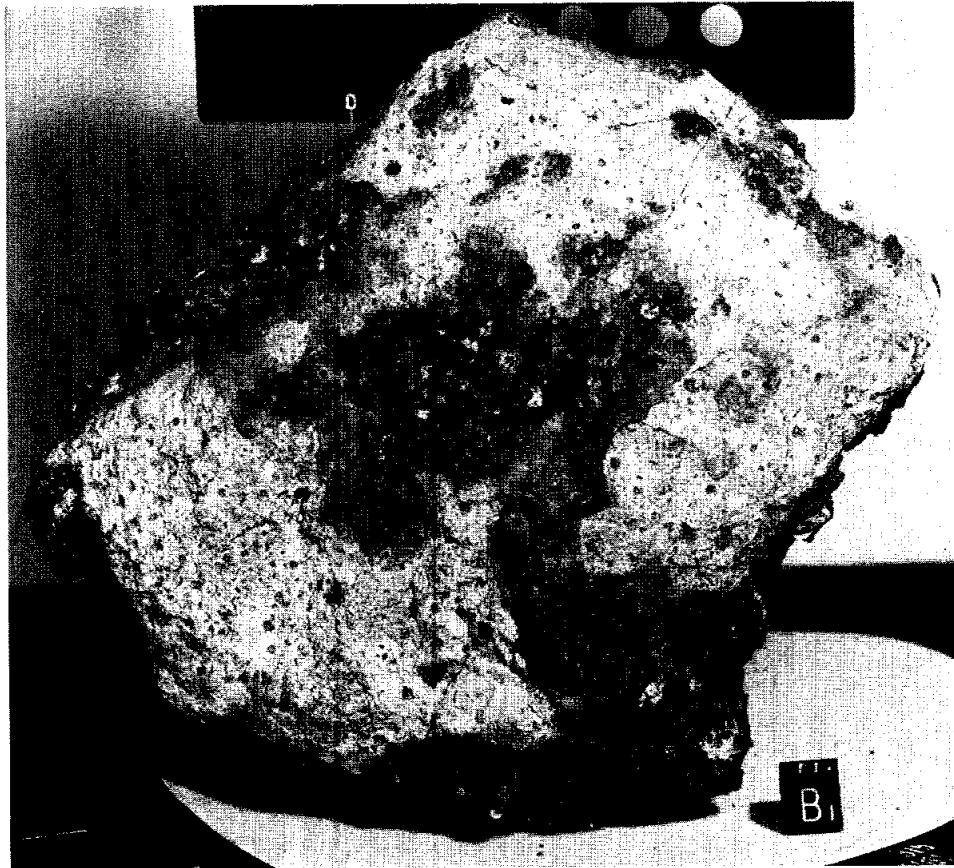


FIGURE 1. Cube is 1 cm. S-72-38300.

PETROLOGY: R. Warner et al. (1980) provide petrographic information. Thin sections from widely separated portions of the rock consist of a variety of crystalline anorthositic, troctolitic, and noritic lithologies that grade in size from clasts to a finer-grained matrix.

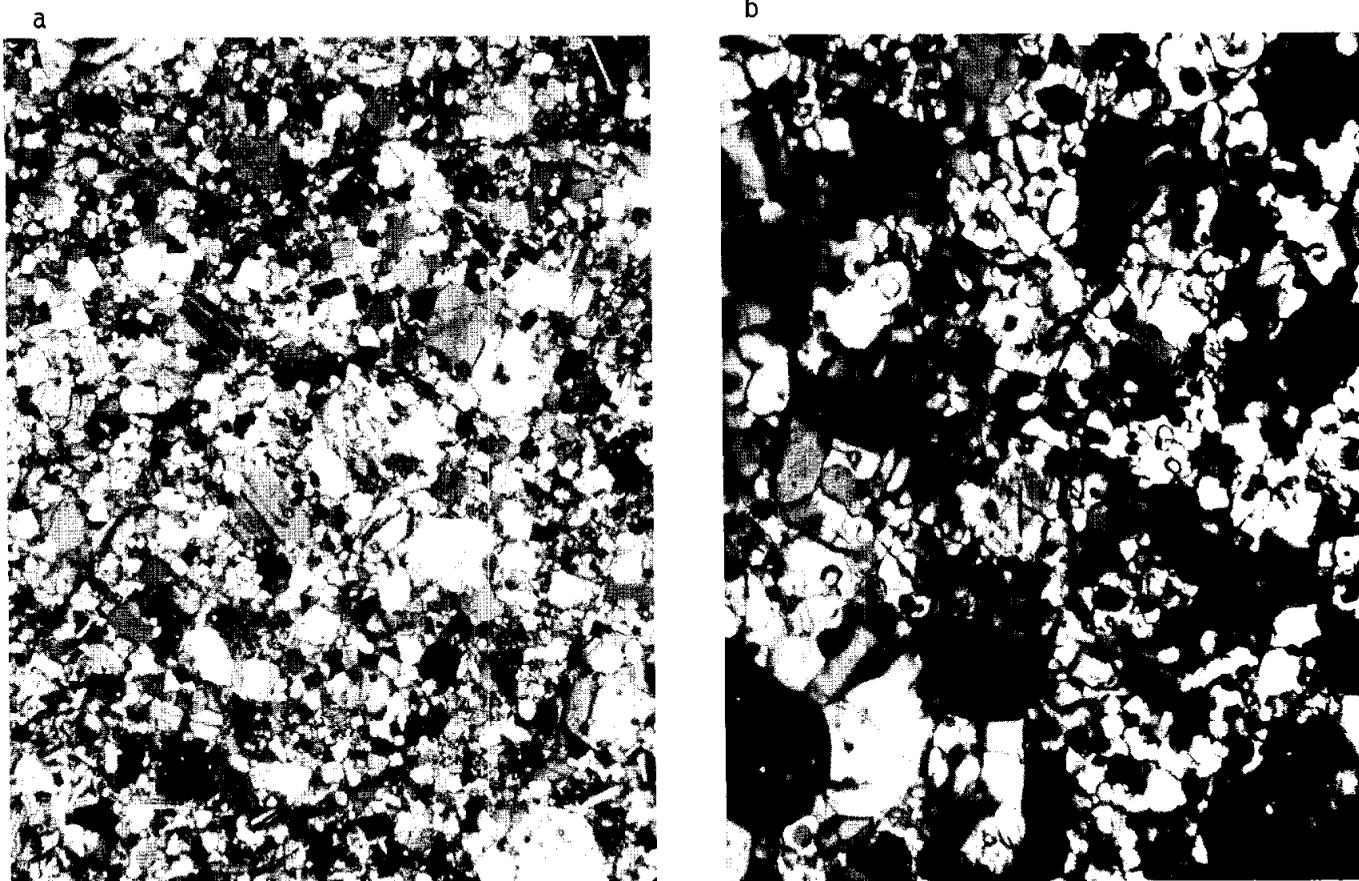


FIGURE 2. 60035,18. a) granoblastic,xpl. width 2mm. b) poikiloblastic,xpl. width 1mm.

The most common lithic type recognized by R. Warner *et al.* (1980) is poikiloblastic anorthositic norite (Fig. 2). Low-Ca pyroxene oikocrysts enclose small rounded to subequant grains of plagioclase. At least two distinct populations of pyroxene compositions were found: one more Fe-rich than the other (Fig. 3). More calcic plagioclases (An_{97-98}) are associated with the Fe-rich group. Minor amounts of olivine are present.

Granoblastic anorthositic troctolite clasts (70-80% plagioclase) are also common (Fig. 2). The grain size within these clasts is variable (0.05-0.25 mm). Larger plagioclase grains typically show shock effects such as cataclasis or undulose extinction. Olivine is Fo_{76-82} .

One large (4x8 mm) clast grades from fine-grained (0.05-0.25 mm) granular troctolite (~50% olivine, 50% plagioclase) through a coarser (up to 0.8 mm) zone with >60% plagioclase to another fine-grained (0.05 mm) area with low-Ca pyroxene more abundant than olivine. The mafics in this clast are considerably more magnesian (olivine ~ Fo_{88} ; low-Ca pyroxene Wo_3En_{86}) than other mafics in this rock.

Other lithic types include cataclastic anorthosite, basaltic impact melt with lathy plagioclase, and mineral clasts of plagioclase, rare olivine, spinel and a variety of opaque phases including chromite, ilmenite, troilite and metal. Most

metal grains analyzed by R. Warner *et al.* (1980) have ~6% Ni and 0.8% Co (Fig. 4). Metal in the magnesian granular troctolite is exceptional: 36-51% Ni and 1.2-1.9% Co.

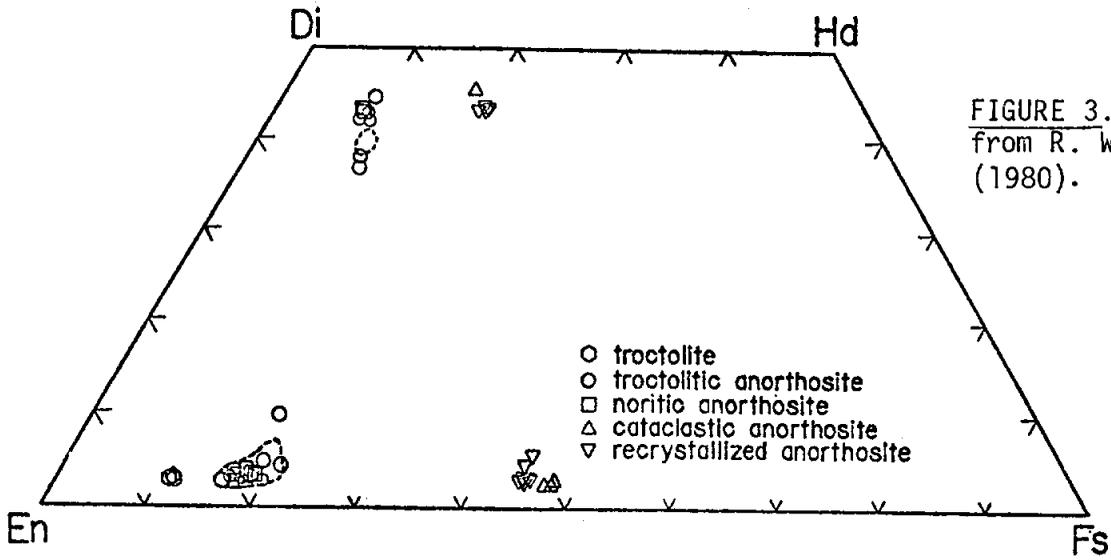


FIGURE 3. Pyroxenes; from R. Warner *et al.* (1980).

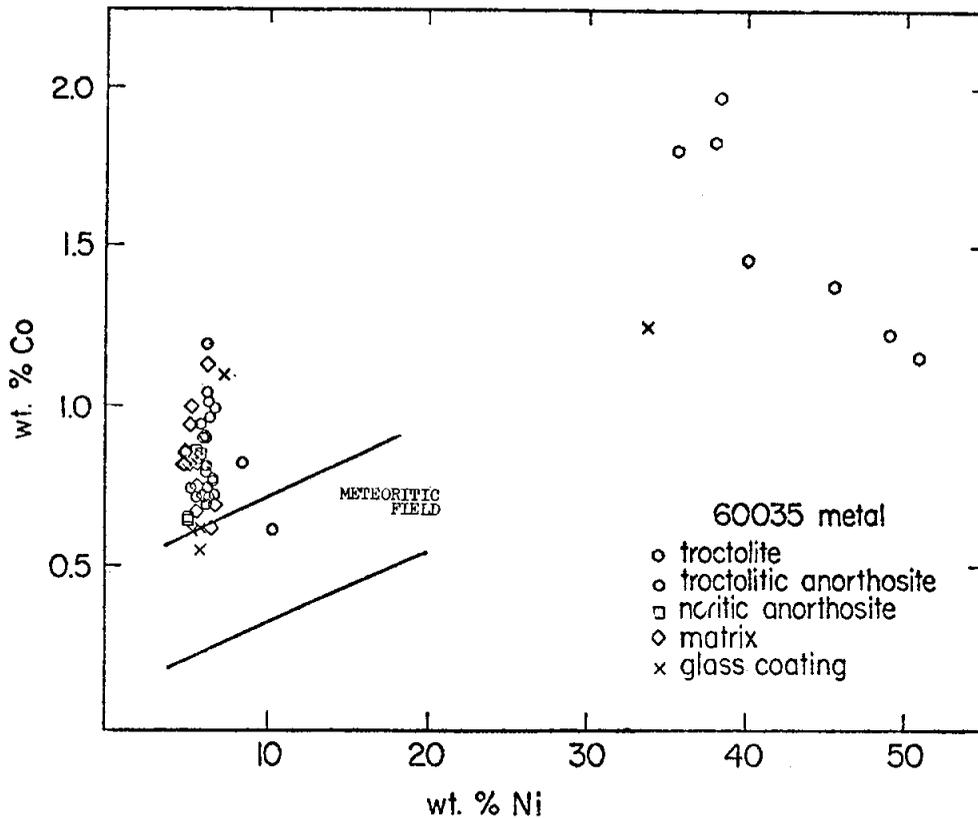


FIGURE 4. Metals; from R. Warner *et al.* (1980).

CHEMISTRY: The only chemical analysis of 60035 is an average defocused electron beam analysis (DBA) of the glass coat presented in R. Warner *et al.* (1980), reproduced in Table 1.

TABLE 1

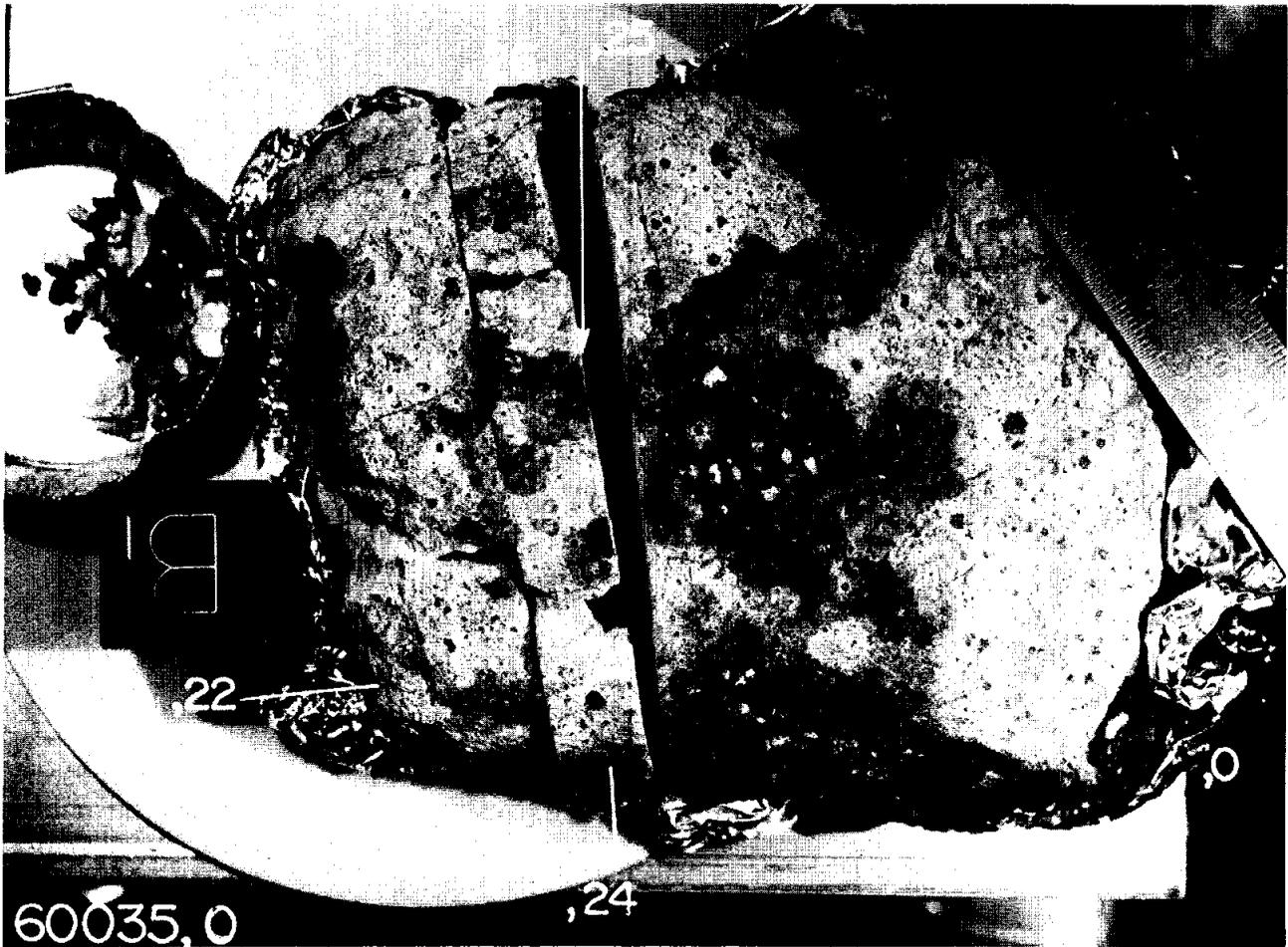
Average DBA of 60035 glass coat

SiO ₂	44.3
TiO ₂	0.29
Al ₂ O ₃	29.4
Cr ₂ O ₃	0.12
FeO	5.1
MnO	0.04
MgO	5.7
CaO	15.8
Na ₂ O	0.25
K ₂ O	0.06
P ₂ O ₅	0.01

Oxides in wt%

PROCESSING AND SUBDIVISIONS: 60035 was initially set aside as a posterity sample, and has only recently been made available for study. Three small unlocated chips were used to make the first thin sections (,4 ,5 ,6) and then three chips (,8 ,10 ,13) from different areas of the rock were taken to make thin sections ,16 and ,17; ,18 and ,19; and ,20 and ,21 respectively. Subsequently a slab was cut (Fig. 5). The slab broke into several pieces, and the sawing produced many small chips. Some of these have been allocated to Schmitt for chemical analyses.

FIGURE 5. Post sawing. Scale in cm. S-80 -35183.



INTRODUCTION: 60055 is a homogeneous, friable, cataclastic anorthosite which is chemically pristine. Original surface features have been obscured due to its friable, dusty nature (Fig. 1). This rock was collected about 170 m south-southwest of the Lunar Module. The sample was disturbed prior to photographing, hence burial and orientation data were lost.

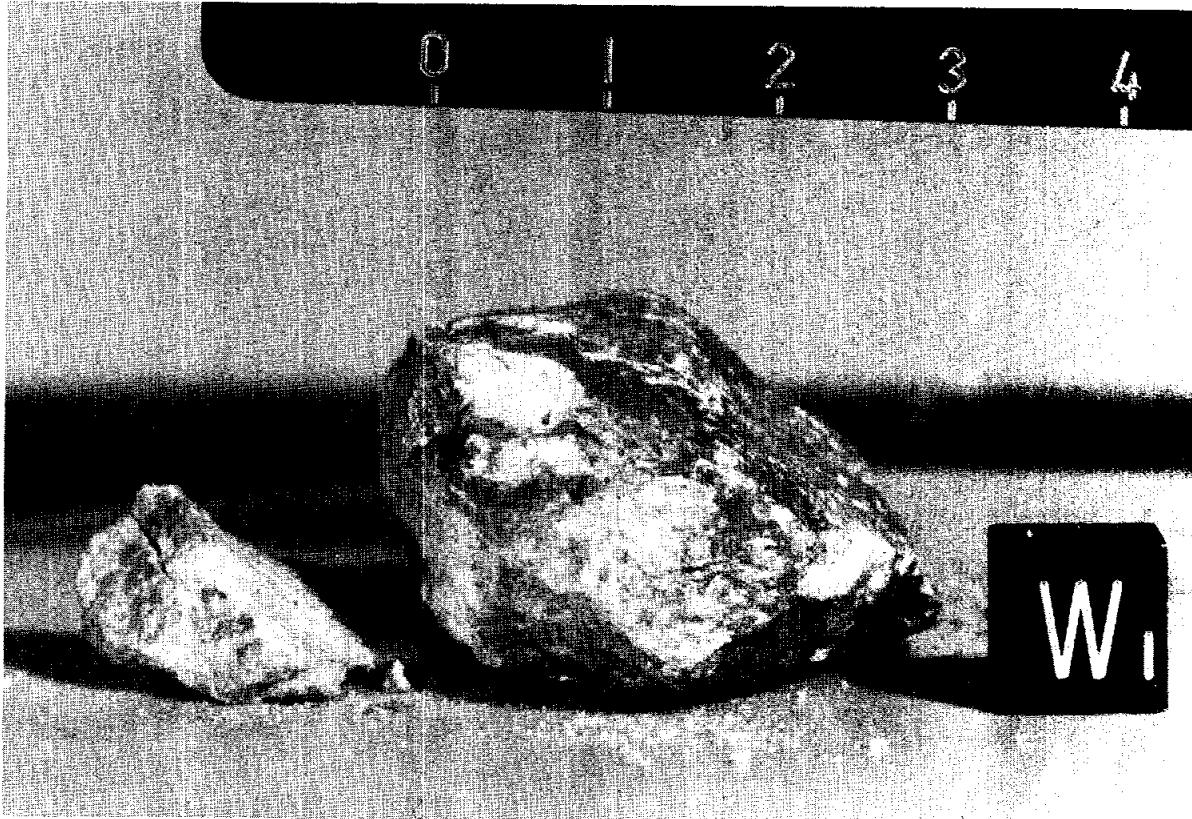


FIGURE 1. Scale in cm. S-72-41416.

PETROLOGY: Warren and Wasson (1978) provide petrographic information. They describe a granular, unannealed anorthosite with 98% plagioclase (An_{95-96}) and 2% high-Ca pyroxene ($Wo_{42-44}En_{42}$). A single grain of exsolved low-Ca pyroxene (Wo_2En_{61}) is also mentioned. Original grain size was >2 mm.

Our own thin section observations confirm that the rock is a porous, cataclastic anorthosite (Fig. 2) with traces of a silica mineral, rare grains of ilmenite with exsolved rutile lamellae, and at least one other, more-poorly-reflecting opaque phase. Rare relict grain boundaries between mafics and plagioclase are present.

CHEMISTRY: Warren and Wasson (1978) report major and trace element data. Their analysis confirms the highly anorthosite nature of the rock and demonstrates that the rock is free of meteoritic siderophiles and low in incompatible elements (Table 1).

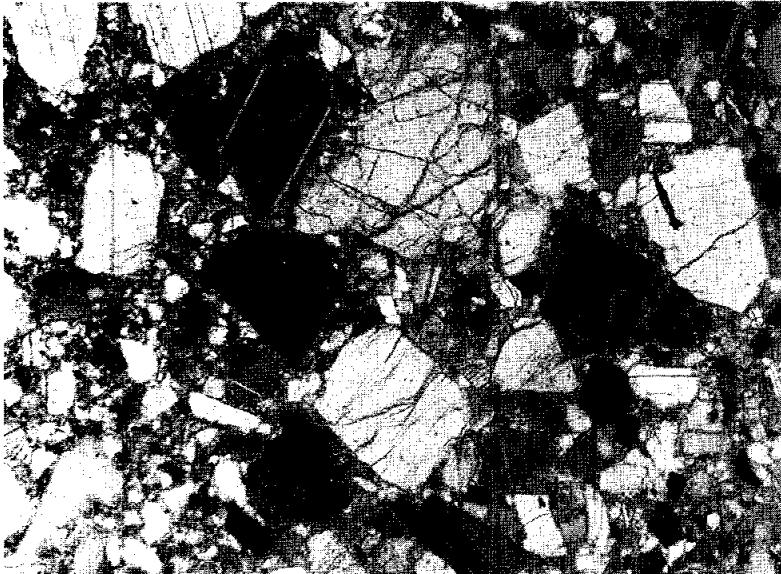


FIGURE 2. 60055,4.
general view, partly
xpl. width 2.3mm.

TABLE 1. Summary chemistry of anorthosite 60055

SiO ₂	44.3
TiO ₂	
Al ₂ O ₃	34.0
Cr ₂ O ₃	0.005
FeO	0.34
MnO	0.096
MgO	0.33
CaO	19.04
Na ₂ O	0.335
K ₂ O	0.010
P ₂ O ₅	
Sr	
La	0.13
Lu	0.0038
Rb	
Sc	0.55
Ni	1.9
Co	0.84
Ir ppb	0.013
Au ppb	0.014
C	
N	
S	
Zn	0.60
Cu	

Oxides in wt%; others in ppm except as noted.

INTRODUCTION: 60056 is a friable, white rock (Fig. 1) that is probably a cataclastic anorthosite but may be a fragmental, polymict breccia. A thin coat of dark glass is present on some pieces. Apparently it was removed from its documented bag as a single piece but broke into many small fragments and fines during initial processing. 60056 was collected about 170 m southwest of the Lunar Module. Zap pits are absent.

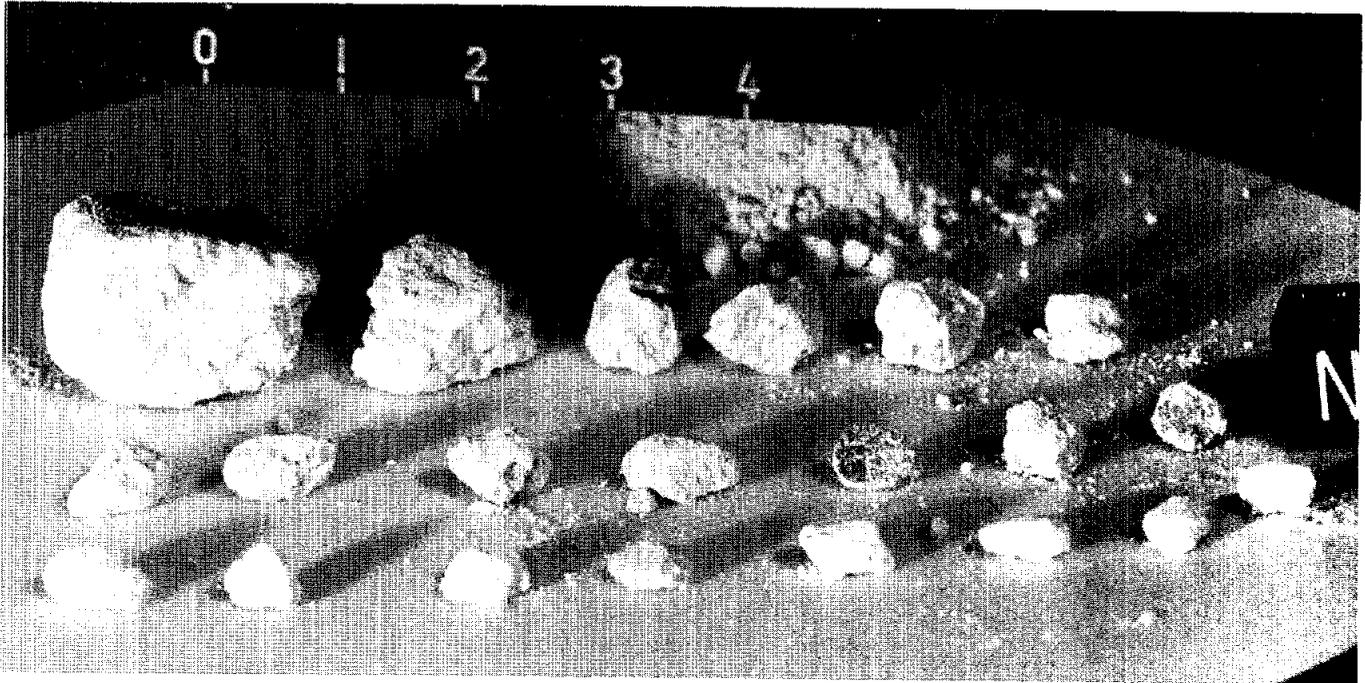


FIGURE 1. Scale in cm. S-72-41420.

INTRODUCTION: 60057 is a friable, white rock (Fig. 1) that is probably a cataclastic anorthosite. Some patina is present but zap pits are absent. It was collected ~170 m southwest of the Lunar Module.

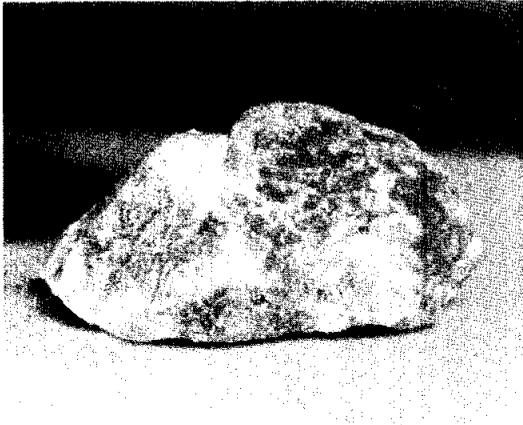


FIGURE 1. Sample is about 2 cm. long. S-72-41309.

INTRODUCTION: 60058 is a friable, light gray rock (Fig. 1) that is probably either a polymict or dilithologic clastic breccia. Most of the rock is a white, friable matrix that supports a few (~10% of the rock?) dark clasts. It was collected ~170 m southwest of the Lunar Module. Zap pits are absent.

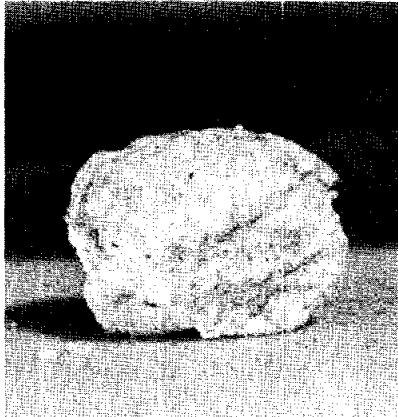


FIGURE 1. Sample is about 1.5 cm. long. S-72-41309.

INTRODUCTION: 60059 is a friable, white rock (Fig. 1) that is probably a cataclastic anorthosite. It was collected ~170 m southwest of the Lunar Module. Zap pits are absent.

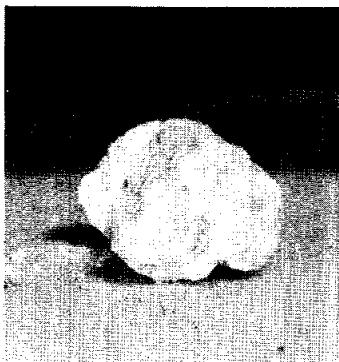


FIGURE 1. Sample is about 1 cm.
long. S-72-41309.

INTRODUCTION: 60075 is a very friable clastic breccia; it was removed from its documented bag as 13 small pieces. These pieces have been subsequently broken and powdered even more during processing and handling (Fig. 1). A few zap pits on the largest fragment were reported in the original catalog description but the extremely dusty and friable nature of the rock has now obscured all original surfaces. The rock was collected about 170 m south-southwest of the Lunar Module. It was disturbed prior to photographing, hence burial and orientation data were lost.



FIGURE 1. Part of 60075. Small scale units are mm. S-75-33675

PETROLOGY: Library thin sections are of a highly porous and fragmental breccia composed of abundant small (<2 mm) clasts in a fine-grained clastic matrix (Fig. 2). Lithic clasts include granoblastic anorthosites, troctolites, and norites, cataclastic anorthosite, spinel-bearing basaltic impact melt and vitric matrix breccia. Plagioclase, pyroxene and olivine clasts are also present as well as metal, troilite, oxide and devitrified brown glass fragments. Pyroxene and plagioclase clasts occasionally contain parallel rods and stringers of exsolved opaques.

TABLE 1

Summary Chemistry of 60075

SiO ₂	45.47
TiO ₂	0.20
Al ₂ O ₃	32.55
Cr ₂ O ₃	0.03
FeO	1.73
MnO	0.02
MgO	1.87
CaO	17.63
Na ₂ O	0.67
K ₂ O	0.05
P ₂ O ₅	0.02
Sr	174
La	<10
Lu	
Rb	1.0
Sc	5.1
Ni	50
Co	7.5
Ir ppb	
Au ppb	
C	4
N	66
S	630
Zn	<4
Cu	3.4

Oxides in wt %; others in ppm
except as noted.

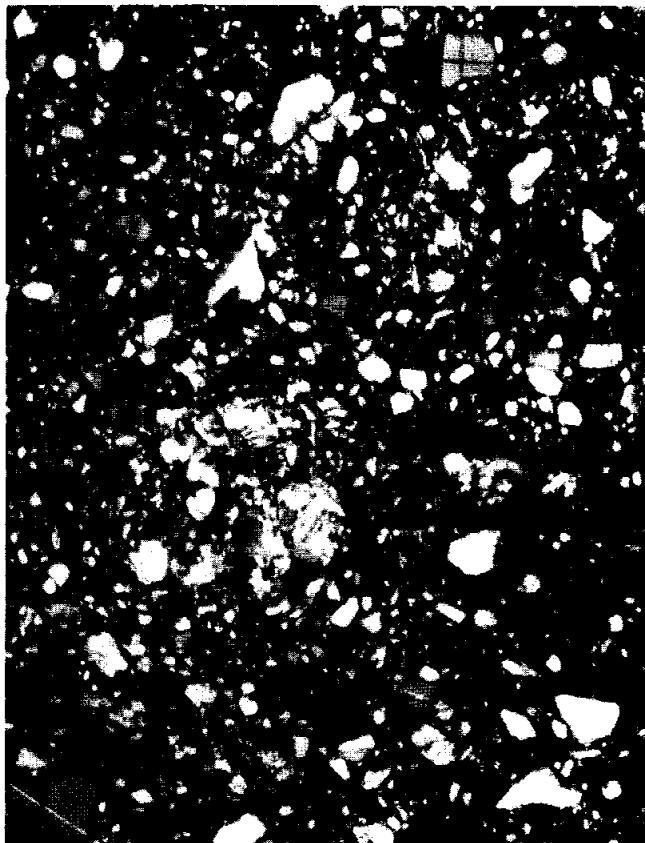


FIGURE 2. 60075,34. general view,
xpl. width 2mm.

CHEMISTRY: Rose *et al.* (1975), Cripe and Moore (1975) and Moore and Lewis (1976) provide major and trace element data for the bulk rock (Table 1). Its reported composition is very aluminous and quite unlike that of the local soil. Despite the abundant metal seen in thin section, the split analyzed by Rose *et al.* (1975) was low in Ni and Co. Incompatible elements are also low indicating a very small KREEP component.

PROCESSING AND SUBDIVISIONS: All of the allocated splits came from a single 21 g fragment (60075,4) which was one of the original 13 pieces of the rock. During processing 60075,4 broke into a 2 cm fragment, two 1 cm fragments and many smaller chips and fines. Processing notes indicate that the portions analyzed for chemistry were typical fragments and fines that included both dark and light clasts.

INTRODUCTION: 60095 is a fractured spheroid of yellow-green to light brown glass (Fig. 1). Internal vesicles are numerous. Cooling cracks and zap pits are present but rare on all surfaces. The sample was collected about 175 m southwest of the Lunar Module at the heat flow hole site.

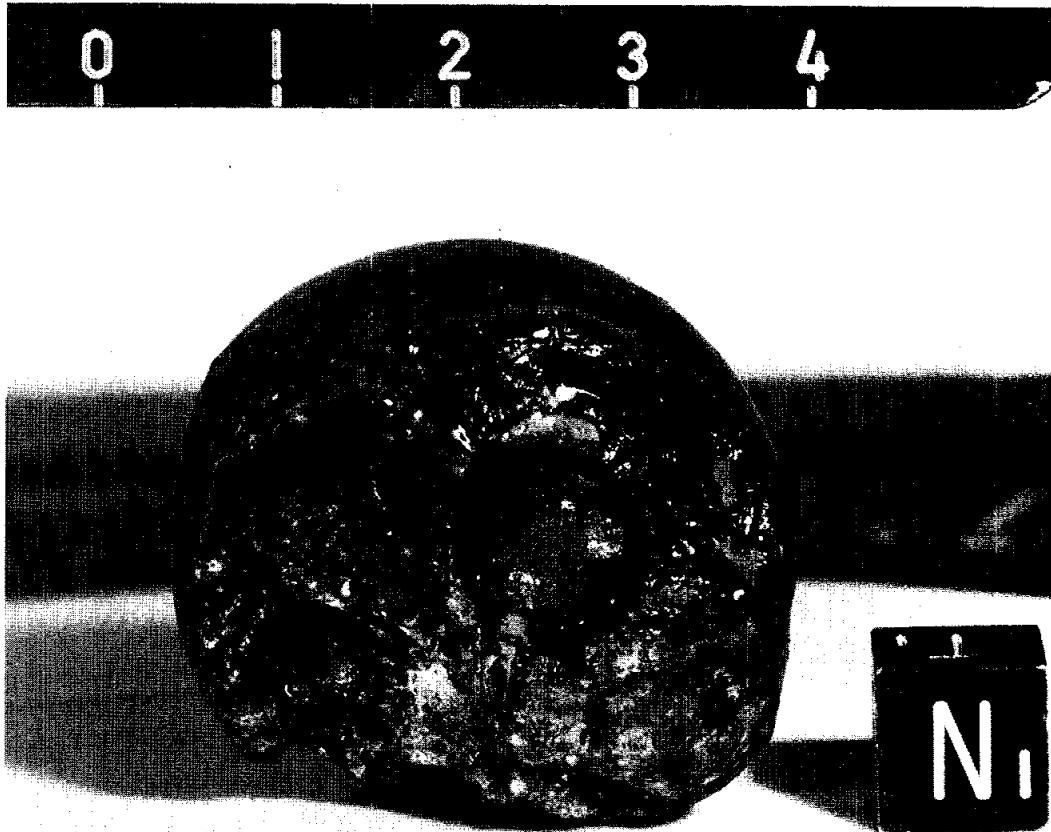


FIGURE 1. Scale in cm. S-77-39424

PETROLOGY: Schaal et al. (1979) and Mehta and Goldstein (1979) provide petrographic information. The sample is nearly holohyaline. A few partially digested and recrystallized clasts of plagioclase act as nucleation sites for areas of devitrification and quench-crystal growth (Fig. 2). Rounded blebs of metal with associated troilite and schreibersite are abundant, ranging in size from $\sim 50 \mu\text{m}$ down to a few Angstroms. Submicron metal particles are peppered through the glass, sometimes aligned in flow planes. Mehta and Goldstein (1979) provide detailed information on the metal in this rock.



FIGURE 2. 60095,30. general view, ppl. width 2mm.

TABLE 1
Summary chemistry of 60095

SiO ₂	44.87
TiO ₂	0.51
Al ₂ O ₃	25.48
Cr ₂ O ₃	0.14
FeO	5.75
MnO	0.07
MgO	8.11
CaO	14.52
Na ₂ O	0.28
K ₂ O	0.09
P ₂ O ₅	
Sr	
La	
Lu	
Rb	1.67
Sc	
Ni	560
Co	
Ir ppb	25.4
Au ppb	7.11
C	
N	
S	
Zn	1.55
Cu	

Oxides in wt%; others in ppm except as noted.

CHEMISTRY: Schaal (unpublished) analyzed for major elements by defocussed electron beam (DBA) and Ganapathy *et al.* (1974) report siderophile and volatile abundances. In terms of major elements 60095 is equivalent to local Apollo 16 soil (Table 1). Siderophiles are very high. Hertogen *et al.* (1977) assigned this meteoritic component to group 5H, probably derived from the South Ray Crater projectile. Ganapathy *et al.* (1974) discuss other possibilities for the presence of this meteoritic group.

MICROCRATERS AND SURFACES: Neukum *et al.* (1973), and Brownlee *et al.* (1975) studied the microcraters on this sample (Figs. 3, 4 and 5). The surface has had a complex exposure history and is in production. Blanford *et al.* (1974) briefly mention glass droplets on the surface.

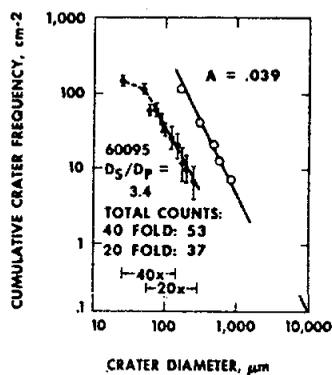


FIGURE 3. Microcraters; from Neukum *et al.* (1973).

FIGURE 4. Microcraters; from Brownlee *et al.* (1975).

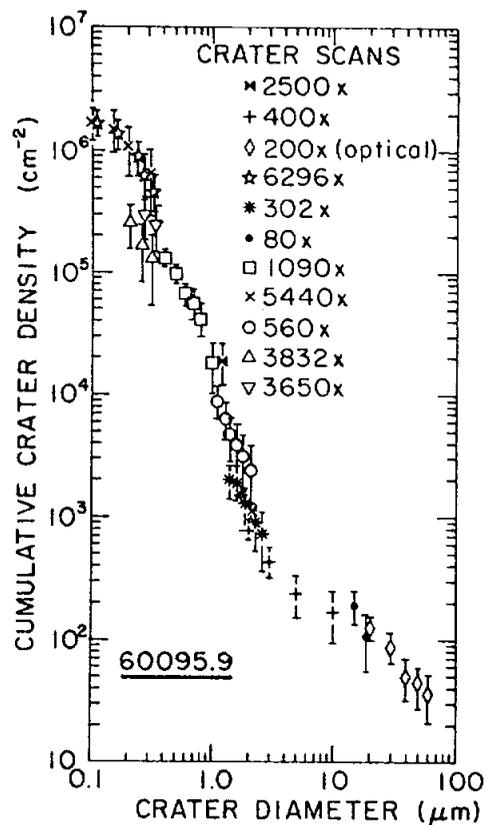
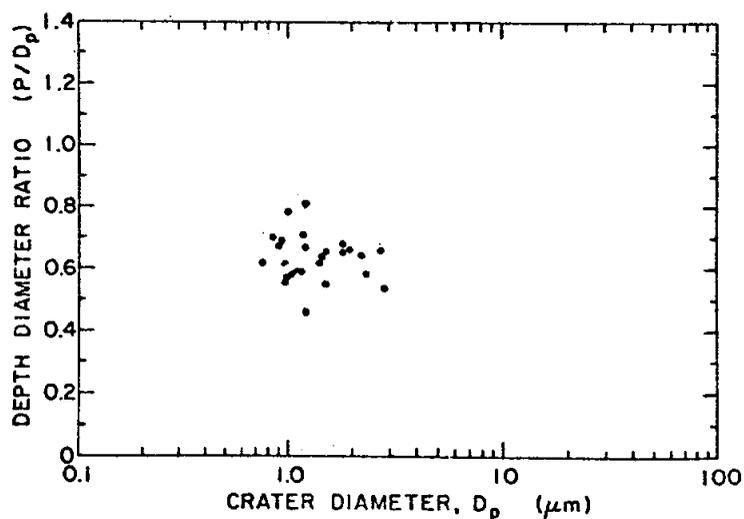


FIGURE 5. Microcraters; from Brownlee *et al.* (1975).

PHYSICAL PROPERTIES: Hopper *et al.* (1974), Uhlmann *et al.* (1974) and Klein and Uhlmann (1976) provide data relating to the glass forming process and discuss the kinetics of the transformation (Figs. 6,7,8, and 9). Theoretical considerations assuming a nucleation barrier of 50 kT predict that a sphere the size of 60095 should not be glassy. A somewhat higher nucleation barrier (60-65 kT) and very few heterogeneous nuclei are required to bring prediction in line with observation. The critical cooling rate of an object with the composition of 60095 is 70 °C/sec; anhydrous liquidus temperature is 1270° C.

PROCESSING AND SUBDIVISIONS: In 1973, 60095 was cut into two pieces, the smaller being subdivided for allocations. The larger piece ($\sim 2/3$ of the sample) preserved the entire hemisphere with an intact exterior surface.

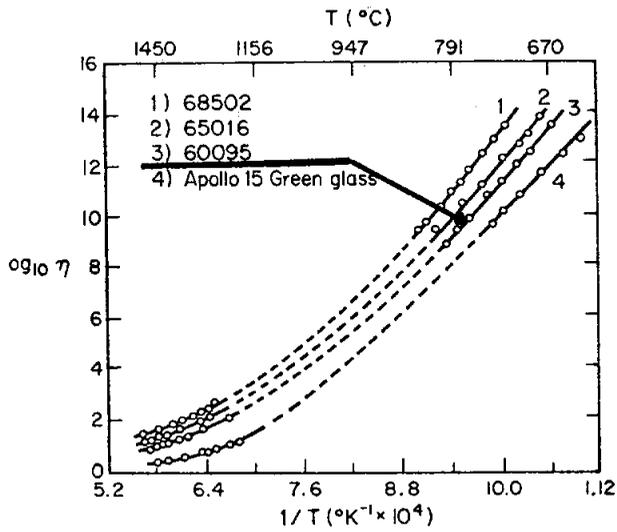


FIGURE 6. Viscosity v. temperature; from Uhlmann *et al.* (1974).

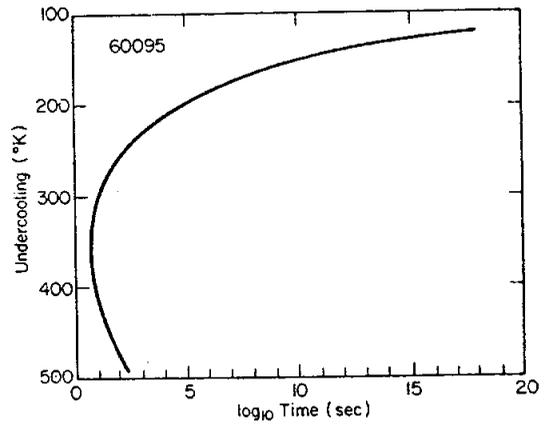


FIGURE 7. Time-temperature-transformation curve; from Uhlmann *et al.* (1974).

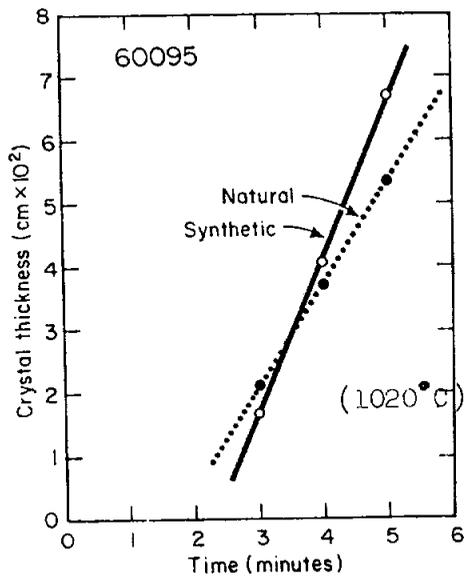


FIGURE 8. Crystal thickness v. time, from Klein and Uhlmann (1975).

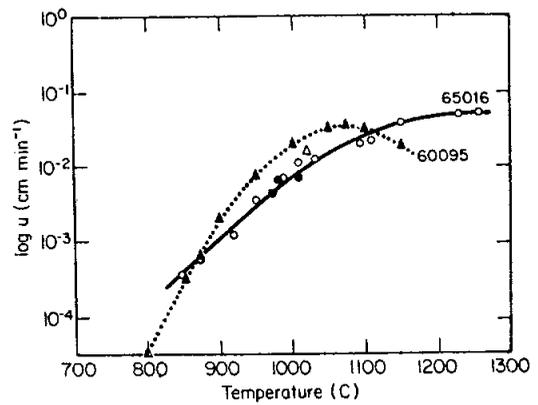


FIGURE 9. Crystal growth rate v. temperature, from Klein and Uhlmann (1975).

INTRODUCTION: 60115 is a tough, angular sample with many fractures (Fig. 1). It is dominantly glassy but complex. The glassy matrix is variable in color and vesicularity, and glass veins cut it. Plagioclase and light gray porphyritic clasts are prominent as well as dark, glassy clasts. Clasts boundaries are commonly indistinct.

60115 was collected approximately 60 m southwest of the Lunar Module where it was slightly buried. Its orientation is known. Very few zap pits are present.

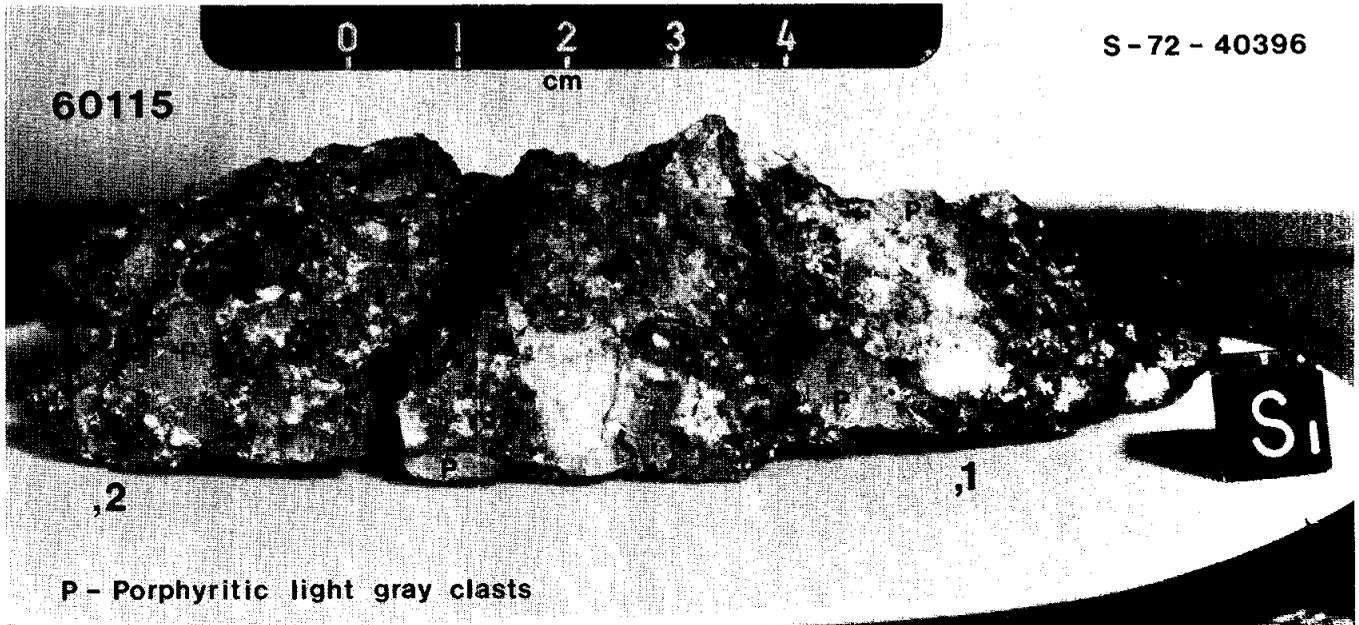


FIGURE 1.

PETROLOGY: Thin sections dominantly show angular fragments of dark aphanitic impact melt engulfed in a colorless shock-melted anorthosite (Fig. 2). Relics of shocked anorthosite, grading into the swirly glass, are abundant. The glass penetrates the dark clasts (Fig. 2). In a few places the dark clasts are strung out and melted, causing the host anorthositic glass to have a brown color. The dark aphanitic impact melts contain few clasts, but have metal grains.

The porphyritic clasts contain small (<500 μm) elongate mafic mineral phenocrysts and some plagioclases set in a groundmass of spherulitic plagioclase laths, mafic minerals, and glass (Fig. 2). Metal is present.

CHEMISTRY: Clark and Keith (1973) show that the bulk rock is low in K (0.054%), Th (1.46 ppm) and U (0.35 ppm) from γ -ray counting. Data on radionuclides (^{26}Al , etc.) are also given, but it cannot be decided whether the surface is saturated in ^{26}Al or not (Yokoyama *et al.*, 1974).



FIGURE 2.

- a) 60115,8. shock-melted anorthosite and aphanitic clasts, ppl. width 2mm.
 b) 60115,8. relict shocked anorthosite, xpl. width 2mm.
 c) 60115,14. plagioclase porphyritic clast, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: 60115 has been split along a natural fracture into two main pieces, ,1 and ,2, and a few small pieces, but has not been extensively subdivided.

INTRODUCTION: 60135 is an oblate ellipsoidal rock with a core of shocked anorthosite partly coated with a smooth glass (Fig.1). The sample was collected from a level area 100 m southwest of the Lunar Module. It may have been perched and its orientation is not definitely known. Zap pits are present but areas on both the anorthosite and the glass are free of zap pits.

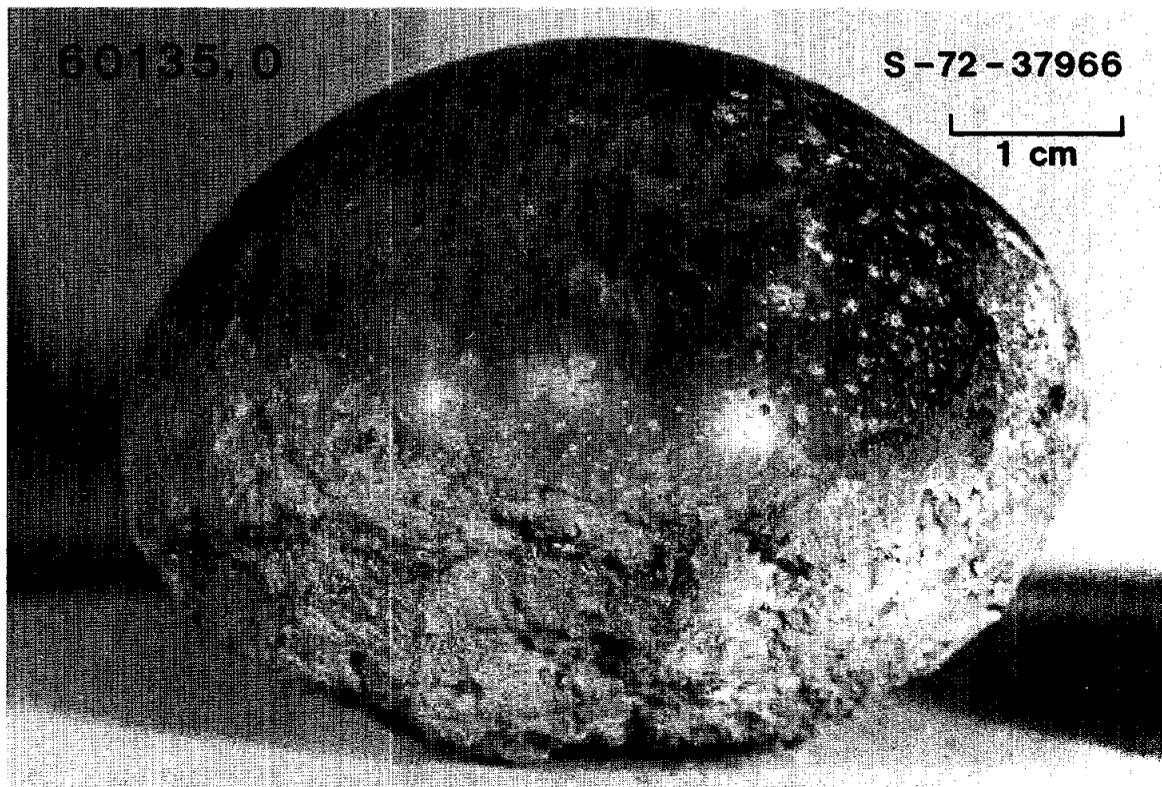


FIGURE 1.

PETROLOGY: A thin section of the anorthosite at the glass contact consists of three 3x3 mm patches of fine-grained shock mosaics of plagioclase (Fig.2) which probably represent original grains. A 500 μ m deformed mafic grain (olivine?) occurs at their mutual junction. Brown vesicular, columnar devitrified glasses invade the anorthosite and surround the mafic grain. Macroscopically the plagioclase is variably white, milky, cloudy and vitreous.

The vesicular coat varies from glass at the exterior, through spherulitic and bow-tie structures of plagioclase and mafic minerals to intergrown ragged plagioclase laths with interstitial glass in the interior (Fig.2). These laths can be seen macroscopically. The bulk is 90% or more of plagioclase. The glass coat makes small apophyses into the anorthosite but without extensive veining.



FIGURE 2.
a) 60135,6. anorthosite, shocked, with mafic grain at junction, xpl. width 2mm.
b) 60135,5. spherulitic coat, xpl. width 1mm.
c) 60135,6. vesicular, basaltic-spherulitic coat, xpl. width 2mm.

CHEMISTRY: Eldridge et al. (1973) measured K, U, Th, and cosmogenic radionuclides in the rock. The abundances of the incompatible elements are extremely low (K_2O 0.017%, Th 0.27 ppm, U 0.068 ppm).

EXPOSURE AGE: The ^{26}Al and ^{22}Na abundances (Eldridge et al., 1973) indicate saturation values, hence an exposure long with respect to the half-life of ^{26}Al .

MICROCRATERS: Size characteristics and cumulative size distributions of the crater population (Fig.3) on the glass surface of 60135 are presented by Neukum et al. (1973). This surface is a production surface and rock has a simple (i.e., un-tumbled) surface history.

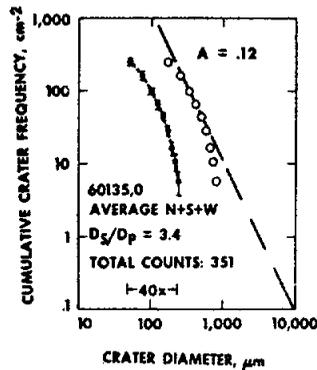


FIGURE 3. Microcraters; from Neukum et al. (1973).

PROCESSING AND SUBDIVISIONS: The rock is undivided except for chips taken for thin sections of the anorthosite and the coat.

INTRODUCTION: 60215 is a coherent, cataclastic anorthosite with very low porosity. A dark, vesicular glass coats ~15% of the rock's surface (Fig. 1). The bulk of the rock is probably a monomict breccia although the presence of basaltic impact melt clasts indicates at least some mixing. On the basis of very low Ni and Co concentrations the anorthosite has not been contaminated by meteoritic siderophiles.

Zap pits and patina are abundant on the lunar-up side. The opposite surface is devoid of pits, indicating a simple exposure history. The sample was collected about 115 m southwest of the Lunar Module.

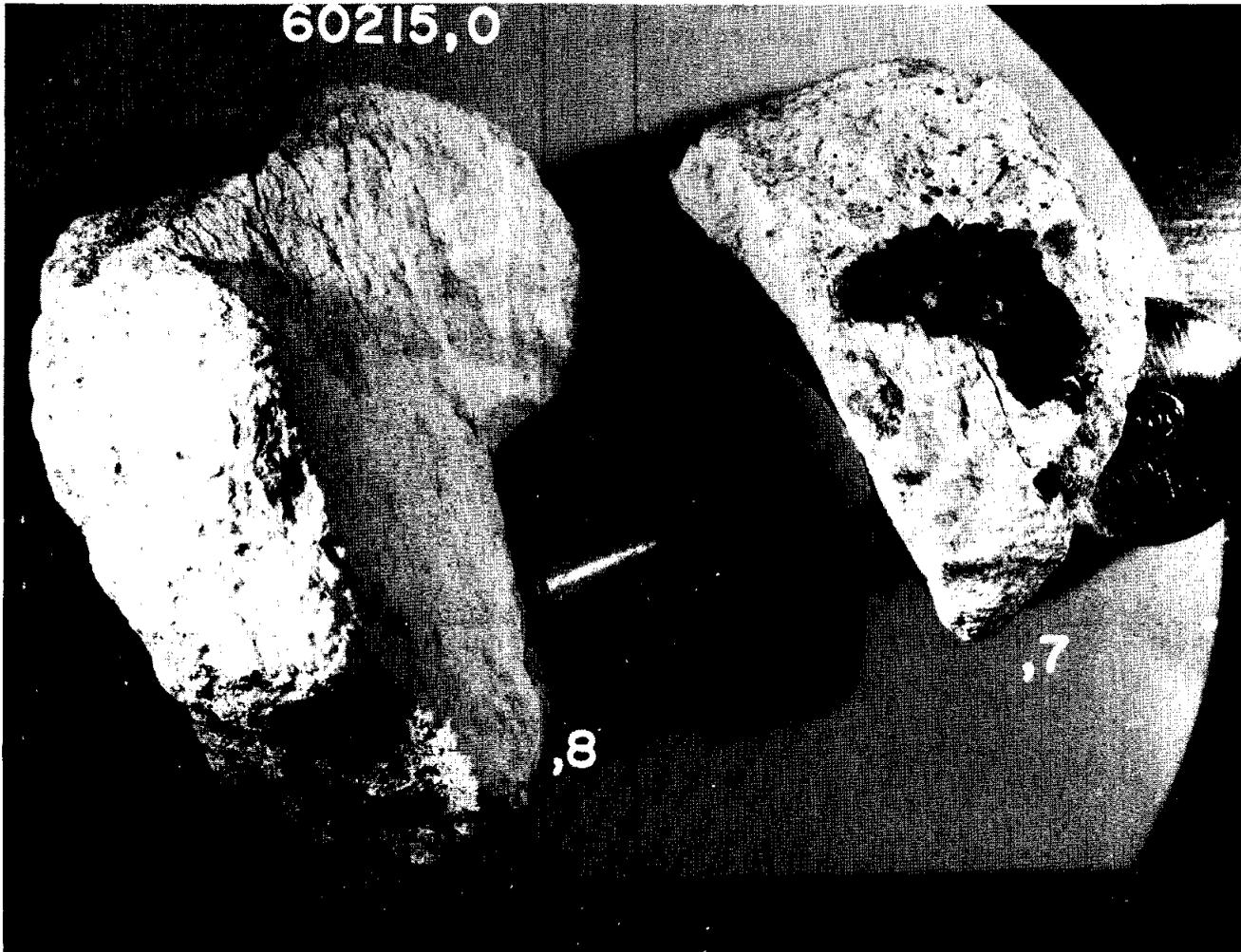
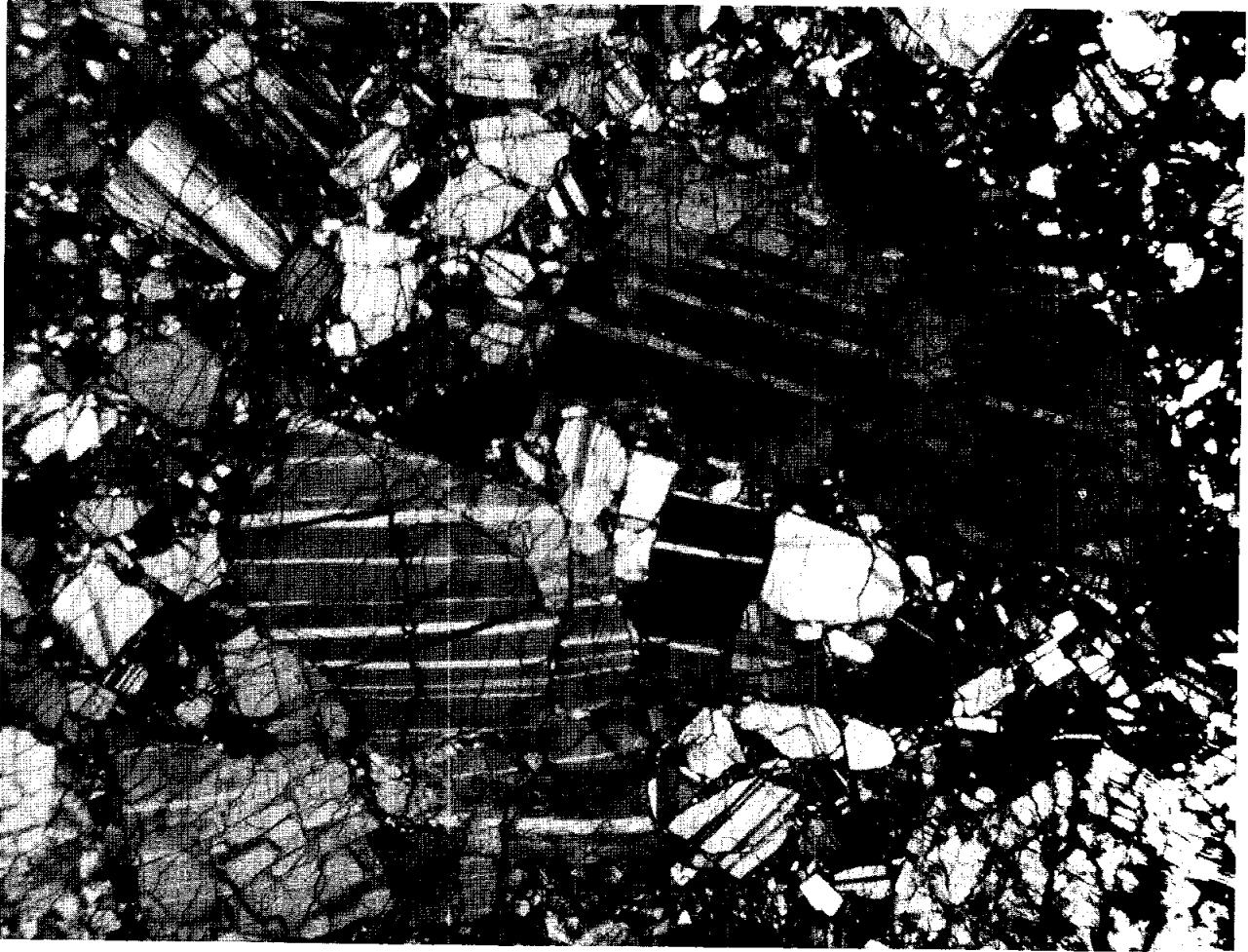


FIGURE 1. Scale in cm. S-74-32059.

PETROLOGY: Meyer and McCallister (1973), Dixon and Papike (1975), Ishii *et al.* (1976) and the Apollo 16 Lunar Sample Information Catalog (1972) provide petrographic information. Seriate plagioclase mineral clasts (An_{96}) up to 4 mm long make up 97% of the rock (Fig. 2). Small amounts of maskelynite are present and some grains have been recrystallized to a fibrous or microgranular texture. Accessory minerals include orthopyroxene ($En_{62-68}Wo_{1-2}$; Fig. 3), augite ($En_{44}Wo_{44}$), rare olivine (Fo_{78}), metal, troilite and ilmenite. Pyroxenes occur as discrete grains without exsolution lamellae (Meyer and McCallister, 1973; Dixon and Papike, 1975).

a

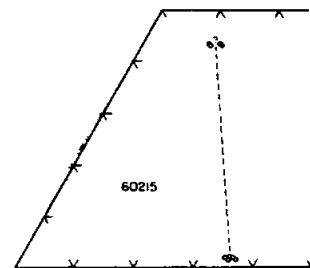


b



FIGURE 2. a) 60215 anorthosite, xpl. width about 3mm. S-72-43966. b) 60215, 14. basaltic clasts, partly xpl. width 1mm.

FIGURE 3. Pyroxenes; from Dixon and Papike (1975).



Lithic clasts are predominantly anorthositic, compositionally identical to the mineral clasts. One large anorthosite clast contains a nest of disaggregated orthopyroxene significantly more calcic than the mineral clasts ($En_{63}Wo_5$) and a single grain of Cr-spinel (Meyer and McCallister, 1973). Fragments of basaltic impact melt (troctolitic basalt; Meyer and McCallister, 1973) account for up to 3% of one thin section (,13). These clasts are small (<0.8 mm) and angular, and have subophitic to intersertal textures (Fig. 2). Plagioclase in these fragments is An_{94} and olivine is Fo_{80-90} . Minor phases include interstitial glass and sulfides.

CHEMISTRY: Rose et al. (1975) (split ,30 erroneously published as ,33), Cripe and Moore (1975) and Moore and Lewis (1976) report chemical data for the anorthosite. Meyer and McCallister (1973) provide defocussed electron beam analyses (DBA) of two "troctolitic basalt" clasts. The anorthosite is nearly pure plagioclase with $Al_2O_3 > 35\%$ (Table 1). The low Ni and Co contents indicate a lack of meteoritic contamination. Total sulfur is among the lowest ever measured in a lunar rock. The compositions of the two troctolitic basalt clasts are different (Table 1).

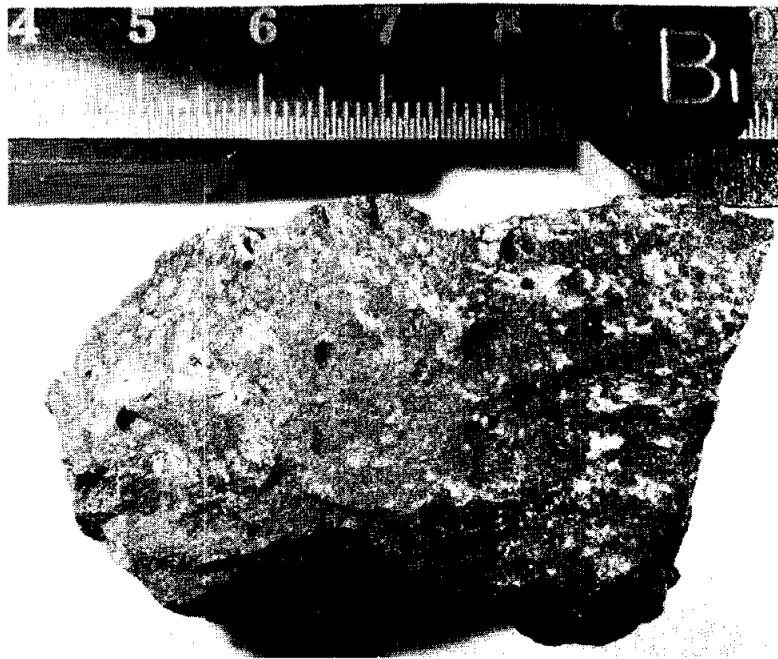
TABLE 1. Summary chemistry of 60215 lithic types

	<u>Bulk anorthosite</u>	<u>Troctolitic basalt clasts (DBA)</u>	
SiO ₂	44.50	47.8	44.7
TiO ₂	0.0	0.15	0.83
Al ₂ O ₃	35.53	24.3	21.2
Cr ₂ O ₃	0.05	0.16	<0.16
FeO	0.15	5.1	8.32
MnO	0.01	0.18	0.13
MgO	0.14	5.62	14.1
CaO	19.34	15.5	10.6
Na ₂ O	0.40	0.45	0.63
K ₂ O	0.02	0.01	0.22
P ₂ O ₅	0.0		
Sr	121		
La	<10		
Lu			
Rb	<1		
Sc	<2		
Ni	1.8	Oxides in wt%; others in ppm except as noted.	
Co	<2		
Ir ppb			
Au ppb			
C	17		
N	105		
S	<6		
Zn	<4		
Cu	1.8		

PROCESSING AND SUBDIVISIONS: In 1972, 60215 was cut into two main pieces (Fig. 1). Allocations were made from chips taken from both of these pieces. Several interior and exterior chips of both the anorthosite and the glass coat exist.

INTRODUCTION: 60235 is a vesicular, medium gray basaltic impact melt (Fig. 1). The coherent rock has a soft, white, earthy coating, distinct from soil, in places. It was collected about 30 m south or southwest of the Lunar Module and it was photographed prior to collection. A few zap pits are present on all surfaces.

FIGURE 1. Scale in mm.



PETROLOGY: A thin section cut for this study shows that 60235 is a plagioclase-rich impact melt. It consists of plagioclase laths 200-300 μm long (Fig. 2) which are frequently hollow and have square cross-sections. Interstitial minerals are mainly pyroxene, with some mesostasis glass with opaque minerals and cristobalite. Clastic material consists of plagioclases and plagioclase-rich breccias.



FIGURE 2. 60235,2. general view, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: A single representative chip (,1) was used to make thin section ,5.

INTRODUCTION: 60255 is a tough, dark, glassy matrix breccia with abundant and varied clasts. A lineation of the clasts is apparent on sawn surfaces (Fig.1). In many respects 60255 is very similar to local soils but with a fairly large and stable magnetic component. Splash glass coats part of the N and E surfaces.

This rock was probably collected 30-40 m southwest of the Lunar Module and was partially buried at the time of collection. The lunar orientation is known. Zap pits are rare to absent on all surfaces.

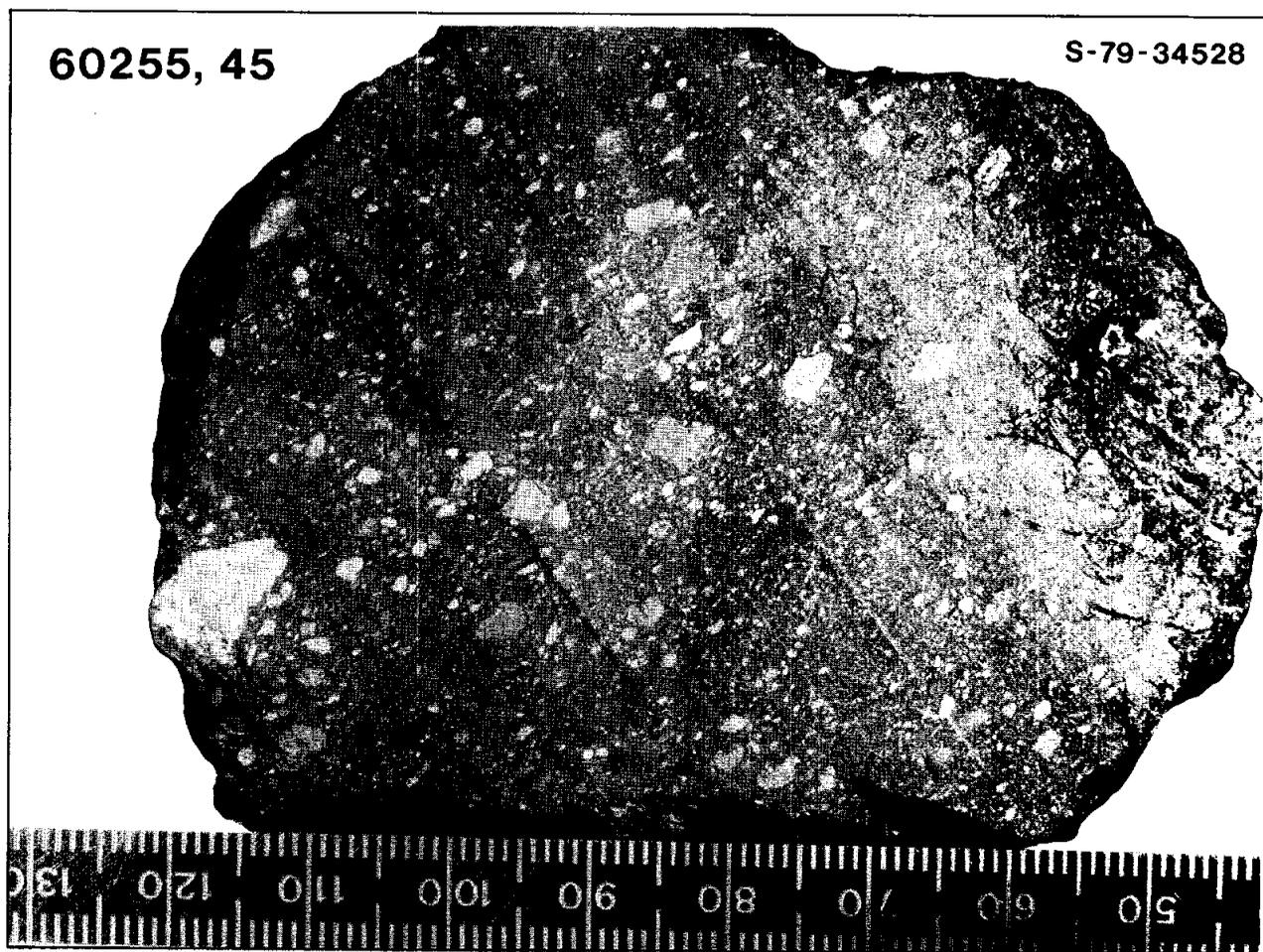


FIGURE 1. Saw cut face. Small scale division is mm.

PETROLOGY: Petrographic descriptions are given by Schaeffer and Hollister (1975), James *et al.* (1975), Schaeffer (1974) and the Apollo 16 Lunar Sample Information Catalog (1972). Many different lithic, mineral and glass clasts are welded together by a cryptocrystalline to glassy matrix. All of the clasts show minute fractures and internal deformation indicative of mild shock.

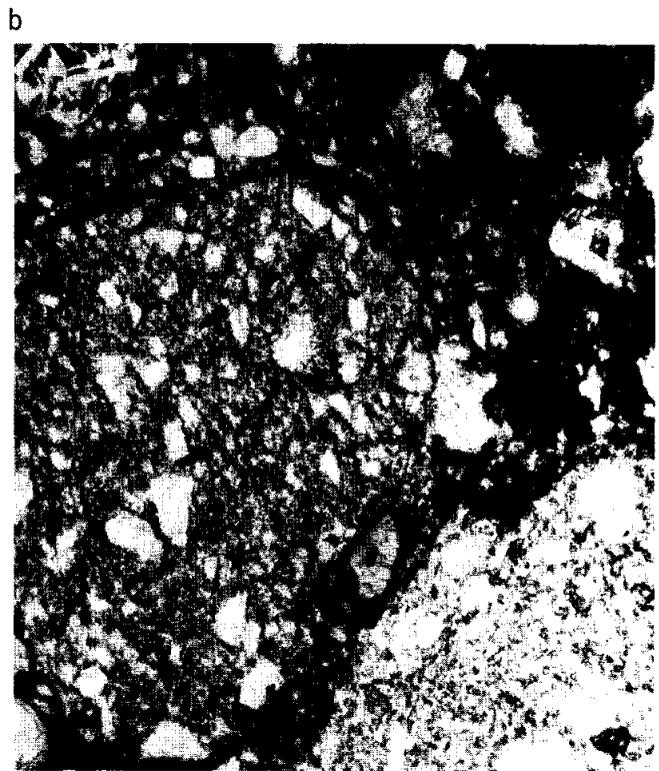
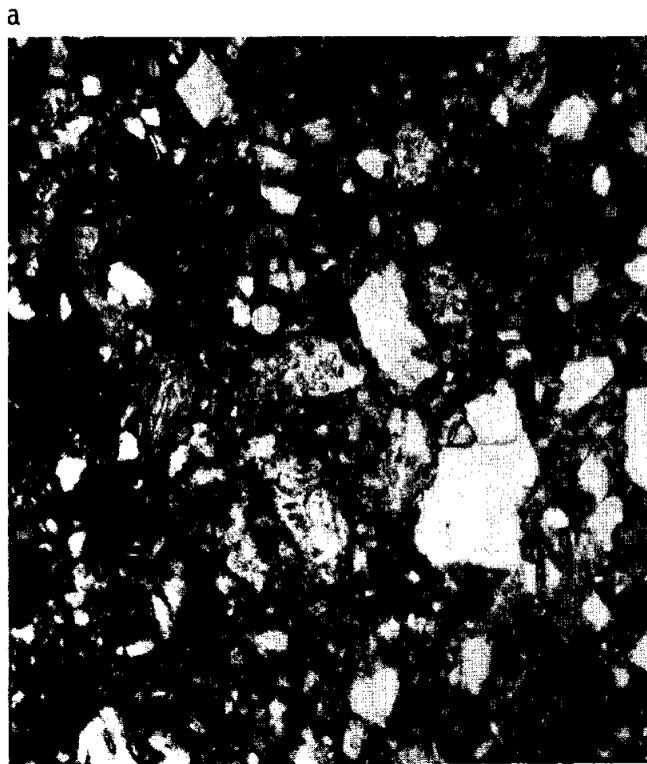


FIGURE 2. a) 60255,81. general view, ppl. width 2mm.

b) 60255,81. clasts, ppl. width 2mm.

c) 60255,81. basaltic melt clast, xpl. width 2mm.

c) 60255,75. vitrophyre (center), ppl. width 0.5mm.

Granoblastic and basaltic textured fragments are the most abundant of the lithic clasts (Fig.2). One of the basaltic textured impact melt clasts has homogeneous olivine (Fo₇₄), two zoned pyroxenes (augite and pigeonite) and plagioclase which is largely homogeneous (An₉₇) but with marked zoning (down to An₆₉) near contacts with mesostasis (Schaeffer and Hollister, 1975; Schaeffer, 1974).

A coarse-grained "gabbroic textured" clast (Fig. 2) with ~90% plagioclase and 10% poikilitic and exsolved pyroxene and olivine is sampled by several serial thin sections (,71-,76 and ,77-,82). The pyroxenes in this clast are ~Wo₃₋₈En₇₀₋₆₅ and Wo₃₀₋₃₅En₅₀₋₄₅, olivine is Fo₇₄ and plagioclase is An₉₂₋₉₅ (Schaeffer and Hollister, 1975; Schaeffer, 1974; Steele, unpublished). Fe-metal, troilite and ilmenite are accessory phases; mesostasis is absent.

Rare olivine vitrophyres are present in some sections (Fig. 2). No analyses are yet available. Clear, orange, yellow and brown glass beads and fragments are scattered throughout the rock. Some are partially crystalline. The presence of clean glass precludes any significant thermal event after the formation of this rock.

CHEMISTRY: Scoon (1974) reports major element data, Boynton et al. (1975) determined major and lithophile elements, Wasson et al. (1975) provide siderophile and volatile element analyses and Clark and Keith (1973) give K,U,Th and cosmic-ray induced nuclides determined by gamma-ray spectroscopy.

All of these data indicate that 60255 is compositionally indistinguishable from the local mature soils. Major elements indicate an anorthositic norite composition (Table 1) and REEs in the rock fall within the range of the REEs in the local mature soils (Fig.3). 60255 is also enriched in siderophiles and volatiles with absolute abundances and interelement ratios equivalent to those of the local soils.

TABLE 1. Summary chemistry of 60255

SiO ₂	45.2	Sr	
TiO ₂	0.69	La	12.6
Al ₂ O ₃	26.1	Lu	0.70
Cr ₂ O ₃	0.11	Rb	
FeO	6.0	Sc	10.7
MnO	0.07	Ni	391
MgO	6.4	Co	35
CaO	16.3	Ir ppb	12.2
Na ₂ O	0.49	Au ppb	5.6
K ₂ O	0.13	C	
P ₂ O ₅	0.12	N	
		S	
		Zn	21.0
		Cu	

oxides in wt.%; others in ppm
except as noted.

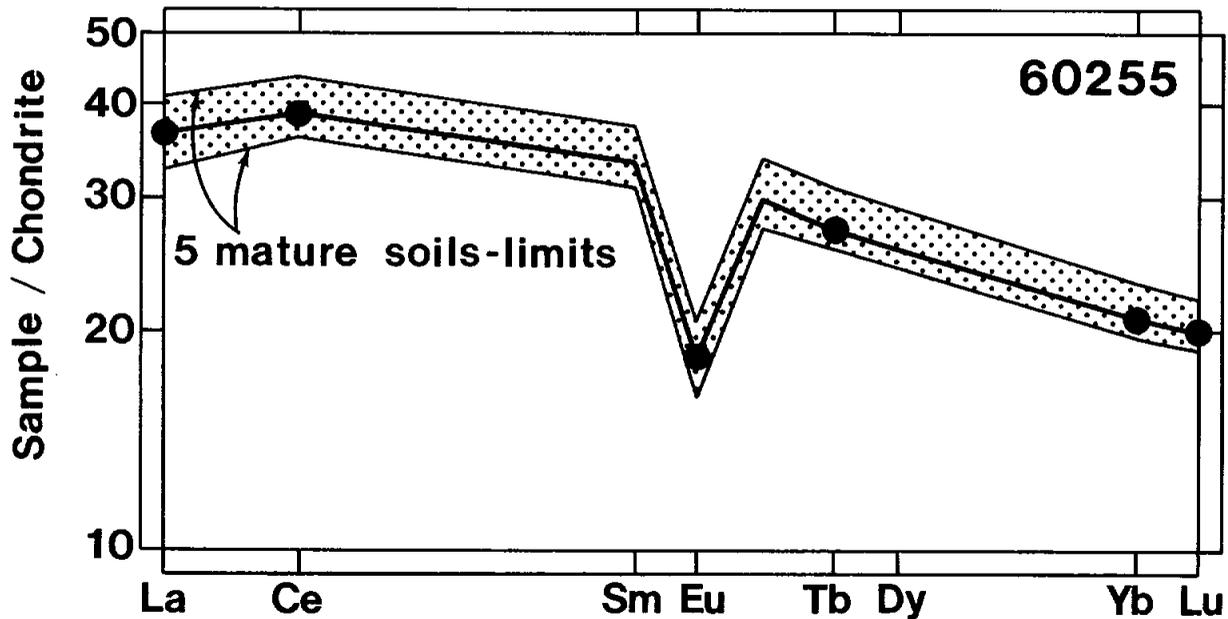


FIGURE 3. Rare earths; from Boynton *et al.* (1975).

RARE GAS/EXPOSURE AGE: Clark and Keith (1973) provide data on cosmic-ray induced nuclides as determined by gamma-ray spectroscopy. Yokoyama *et al.* (1974) discuss ^{22}Na - ^{26}Al chronology and conclude that 60255 is saturated in ^{26}Al . Bernatowicz *et al.* (1978) report Xe and Kr isotopic data. 60255 is rich in trapped solar wind and a cosmogenic component but may or may not contain excess fission Xe.

MICROCRATERS AND TRACKS: MacDougall *et al.* (1973) observe solar flare tracks only in plagioclase grains and infer that the rock experienced a thermal event which erased the tracks from some but not all components. Estimated annealing temperature was 700-800°C. Uranium is concentrated in fine-grained areas but is heterogeneously distributed throughout the rock (MacDougall *et al.*, 1973).

PHYSICAL PROPERTIES: Magnetic characteristics of 60255 were studied by Nagata *et al.* (1973) and Pearce *et al.* (1973) using standard alternating field (AF) and thermal demagnetization techniques. A fairly large component of NRM (11×10^{-6} emu/g) is present that is quite stable with respect to intensity and direction of AF-demagnetization between 100-400 Oe, rms (Fig. 4). This component is considered by Nagata *et al.* (1973) to be a genuine natural remanent magnetization acquired on the lunar surface.

Ferromagnetic metal accounts for 0.47 wt% of the rock and occurs as about equal amounts of pure iron and kamacite with ~ 6 wt% Ni (Nagata *et al.*, 1973). Fine-grained metal (30-150 Å) in 60255 averages 41 Å as determined by magnetic granulometry (Schwerer and Nagata, 1976). Mossbauer-determined distributions of iron among the various mineral phases are reported by Schwerer *et al.* (1973) and Huffman *et al.* (1974).

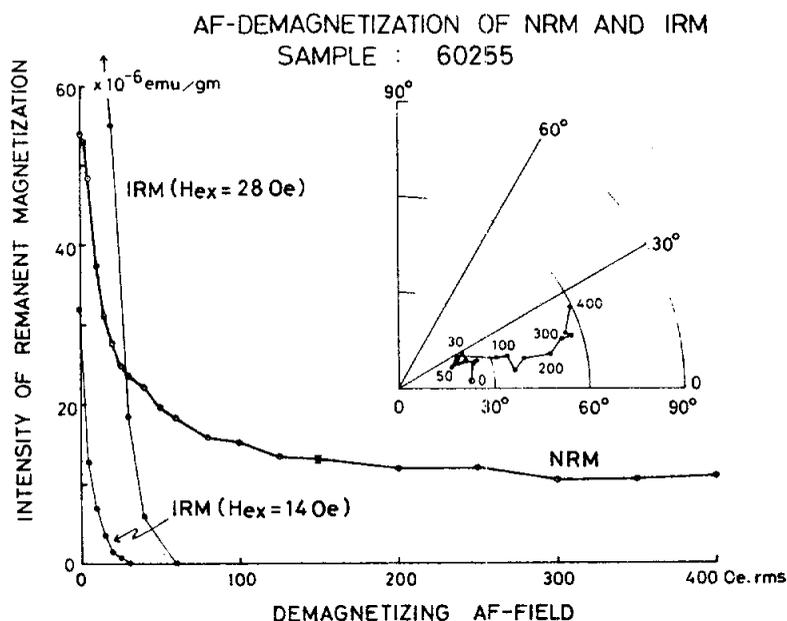


FIGURE 4. AF-demagnetization; from Nagata *et al.* (1973).

PROCESSING AND SUBDIVISIONS: In 1972, 60255 was slabbed and the slab subdivided (Fig.5). Allocations were made from the slab and from other chips. Thin sections from ,23 and ,30 (adjacent pieces from the slab) contain the basaltic and "gabbroic" clasts described in PETROLOGY. The largest single piece of 60255 remaining is ,45 (672.9 g).

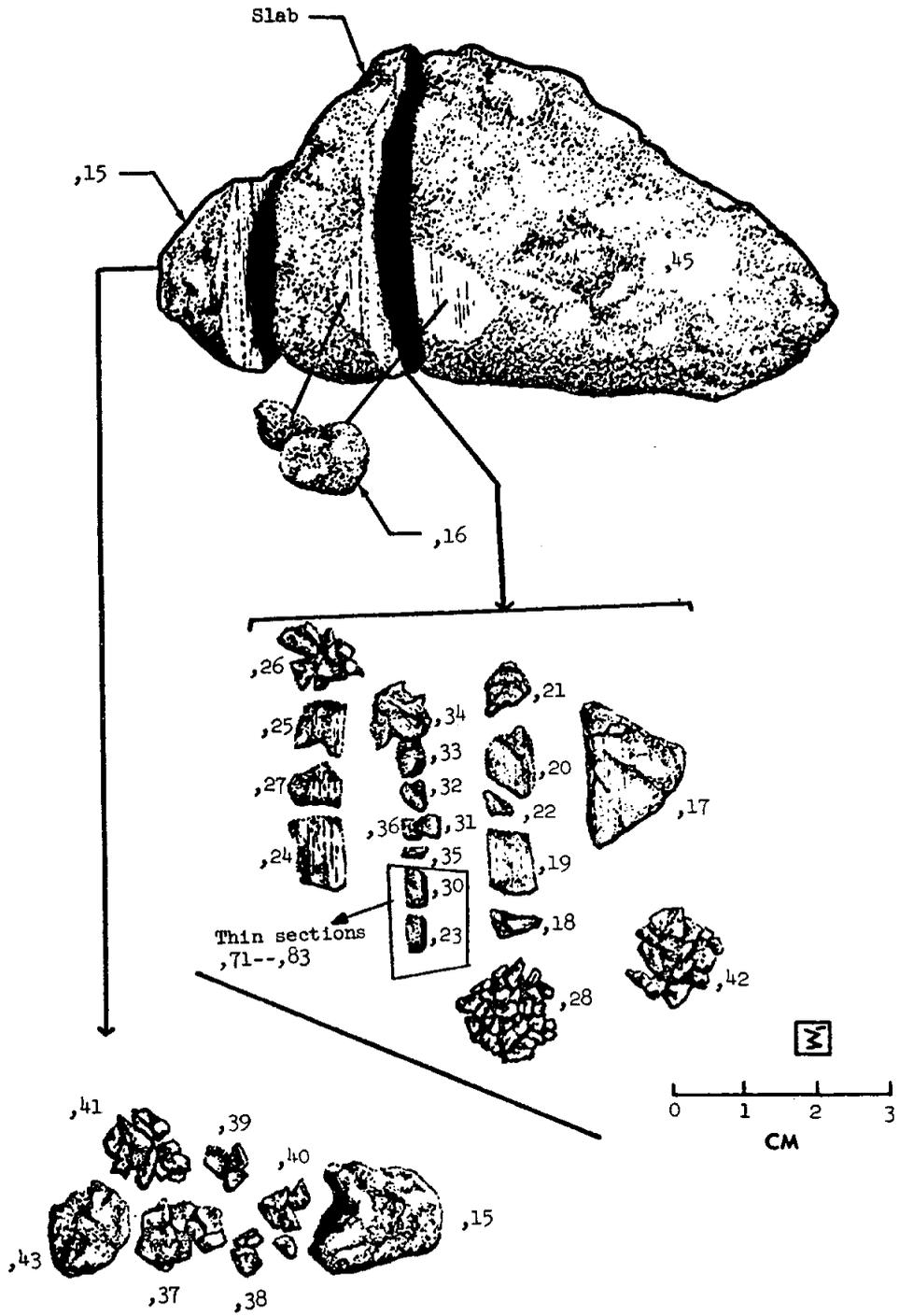
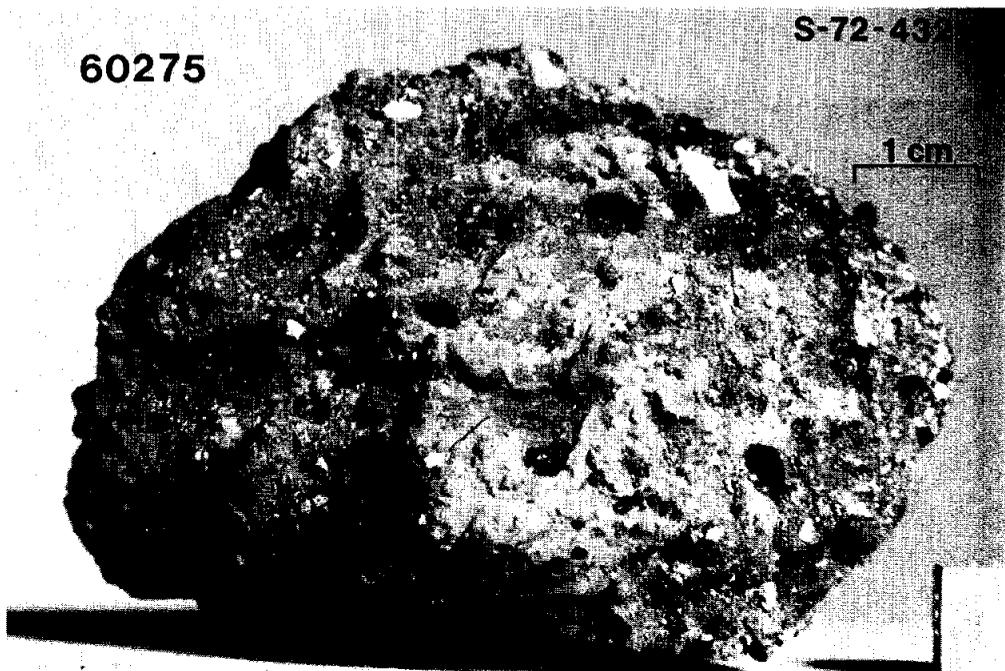


FIGURE 5. Cutting diagram.

INTRODUCTION: 60275 is a polymict, dark-colored breccia coated with a vesicular glass (Fig. 1). The breccia matrix is glassy and mineral, lithic, glass, and devitrified glass fragments are common.

60275 was collected adjacent to the Lunar Module, where it was perched. Its orientation is known. It has a few zap pits on one surface.

a



b

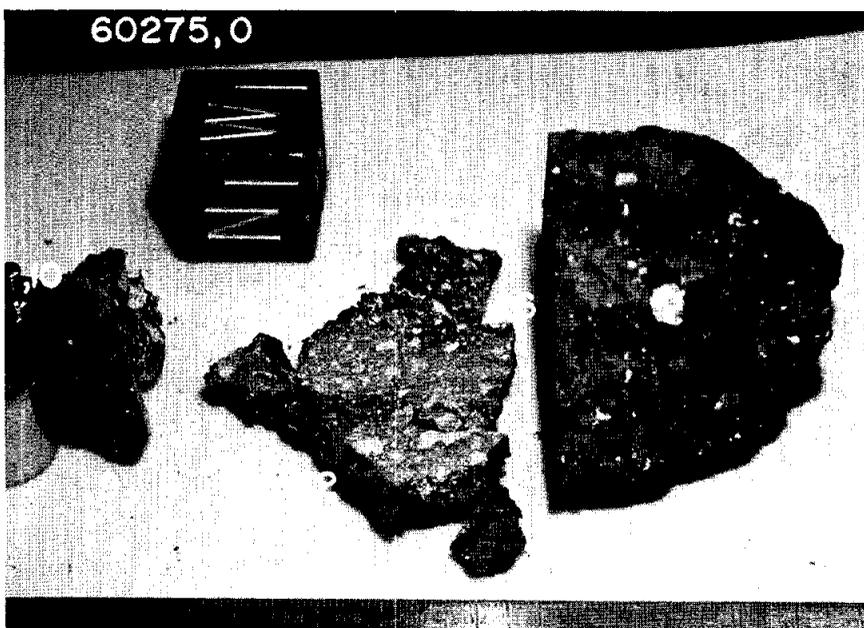
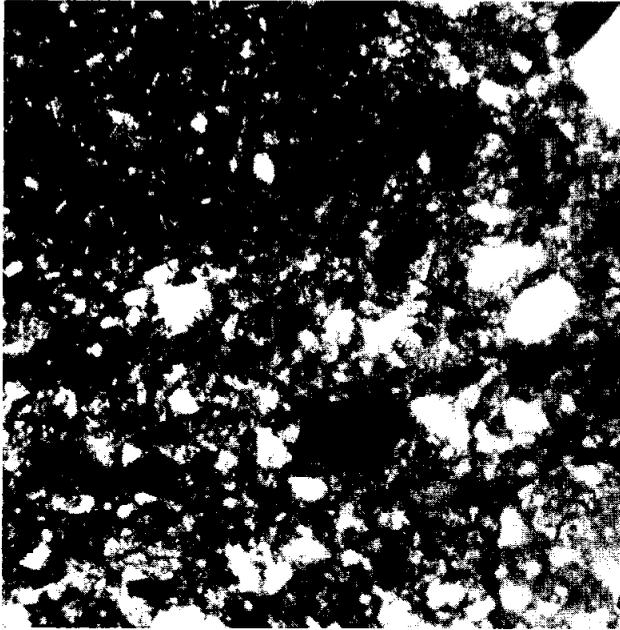


FIGURE 1.

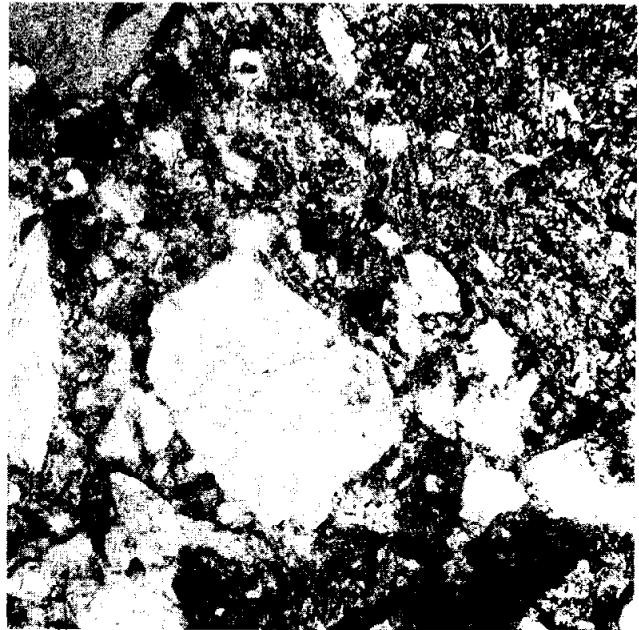
b) is S-75-20527, cube is 2cm.

PETROLOGY: 60275 consists of a variety of clasts apparently bonded with brownish glass (Fig. 2). The lithic clast population includes poikilitic and basaltic-textured impact melts, cataclastic anorthosites, and feldspathic granulites. Glass and brown devitrified glass fragments are also common. The sample may be a regolith breccia but it lacks glass beads and agglutinates. Hansen et al. (1979b and unpublished) report microprobe data for plagioclases and mafic minerals in granoblastic clasts in thin section ,47. One clast has plagioclase An_{95-96} , pyroxene averaging $\sim En_{71}Wo_4$, and olivine Fo_{57} . Two other analyzed clasts have similar plagioclases.

a



b



c



FIGURE 2.

- a) 60275,51. general view, ppl. width 2mm.
- b) 60275,13. melt clasts, ppl. width 2mm.
- c) 60275,51. glass, ppl. width 2mm.

CHEMISTRY: Christian et al. (1976) report major and some trace element analyses for a chip ,34, summarized in Table 1. Clark and Keith (1973) analyzed K, U, and Th in the bulk rock using gamma-ray spectroscopy; their K abundance is significantly lower than that of Christian et al. (1976). The analysis of Christian et al. (1976) is similar to local soil analyses.

TABLE 1. Summary chemistry of 60275

(from Christian et al., 1976)

SiO ₂	44.9	Sr	150
TiO ₂	0.62	La	14
Al ₂ O ₃	25.4	Lu	
Cr ₂ O ₃	0.10	Rb	3.2
FeO	5.8	Sc	9.8
MnO	0.06	Ni	250
MgO	7.6	Co	18
CaO	14.6	Ir ppb	
Na ₂ O	0.46	Au ppb	
K ₂ O	0.22	C	
P ₂ O ₅	0.26	N	
		S	
Oxides in wt%; others in		Zn	10
ppm except as noted		Cu	5.4

RARE GASES AND EXPOSURE AGE: Bernatowicz et al. (1978) provide Xe and Kr isotopic data and conclude that 60275 contains significant amounts of solar wind components. It also has excess fission xenon. Clark and Keith (1973) report cosmic ray induced radionuclide data and the sample is saturated in ²⁶Al (Yokoyama et al., 1974).

PROCESSING AND SUBDIVISIONS: 60275 has been sawn and substantially split. The main post-sawing splits are shown in Figures 1 and 3. Earlier chips of the rock (,1 and ,2) were made into thin sections and clear glass fragments (,3) were made into grain mounts. ,12 (Fig. 3) was also made into a potted butt for thin sections.

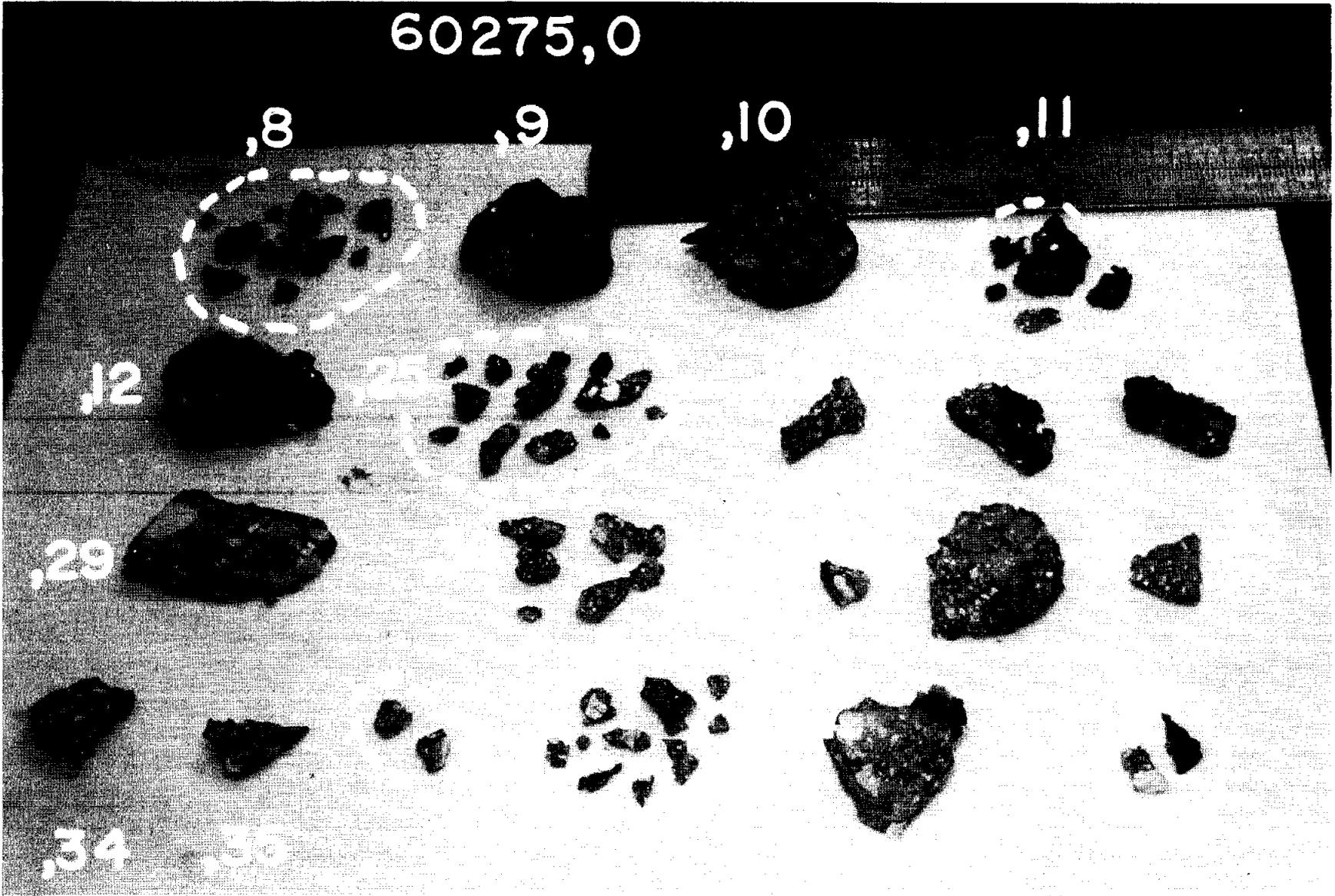


FIGURE 3. Rule is 15 cm. long. S-75-20524.

INTRODUCTION: 60315 is a greenish-gray, very coherent poikilitic impact melt (Fig. 1) that is enriched in incompatible elements compared with most other Apollo 16 rocks. Its texture and major element chemistry is typical of Apollo 16 poikilitic rocks. Macroscopically the silicate phases are homogeneously distributed but the grain size is somewhat variable. The sample was collected 5 m north of the Lunar Module, where it was only slightly buried. Its orientation is known, and the exposed lunar surface has many zap pits, with few on other surfaces.



FIGURE 1. Scale in cm. S-72-41572B

PETROLOGY: Bence et al. (1973), Simonds et al. (1973), Hodges and Kushiro (1973) and Walker et al. (1973) provide detailed petrographic descriptions of 60315. All note the anhedral orthopyroxene ($Wo_4 En_{80}$) oikocrysts up to 3 mm long which enclose abundant laths and clasts of plagioclase, rare olivines (Fo_{74-77}) and opaques (Fig. 2). Plagioclase clasts often have very calcic cores (An_{95-97}) and narrow, more sodic rims (down to An_{89}). Augite, olivine, ilmenite and armalcolite discontinuously rim some oikocrysts. Simonds et al. (1973) give a mode of 55% plagioclase + mesostasis, 34% orthopyroxene, 4% augite, 1% olivine and 1% opaques. Mineral compositions are shown in Figure 3. Similar data are presented by Vaniman and Papike (1981).

Areas interstitial to the oikocrysts have textures ranging from granular to subophitic and account for $\sim 10\%$ of the rock. Most of the interstices are enriched in K, Na, Si, S, P and opaque minerals. Rounded vesicles are common. Bence et al. (1973) report one interstitial region with euhedral plagioclase crystals in a troilite matrix. In many places the oikocrysts grade into a fine-grained clastic matrix of plagioclase (An_{71-80}), olivine (Fo_{71-80}), pyroxene, opaques and lithic fragments. Plagioclase grains often show textural signs of reequilibration with the matrix. The small (~ 0.5 mm) subophitic patches consist of interlocking plagioclase laths (An_{90-95}) with interstitial olivine (Fo_{71-73}), zoned augite ($Wo_{35-41} En_{53-48}$), orthopyroxene ($Wo_3 En_{82}$) and minor K-feldspar, ilmenite, armalcolite, phosphates, silica, metal and troilite.

Hewins and Goldstein (1975b), Ridley and Adams (1976) and Hodges and Kushiro (1973) calculated equilibration temperatures based on pyroxene, olivine and metal phase geothermometers. The silicate phases equilibrated at $\sim 1000-1200^\circ C$ whereas the metallic phases record a temperature of $\sim 600^\circ C$. Metal compositions (Fig. 4) are

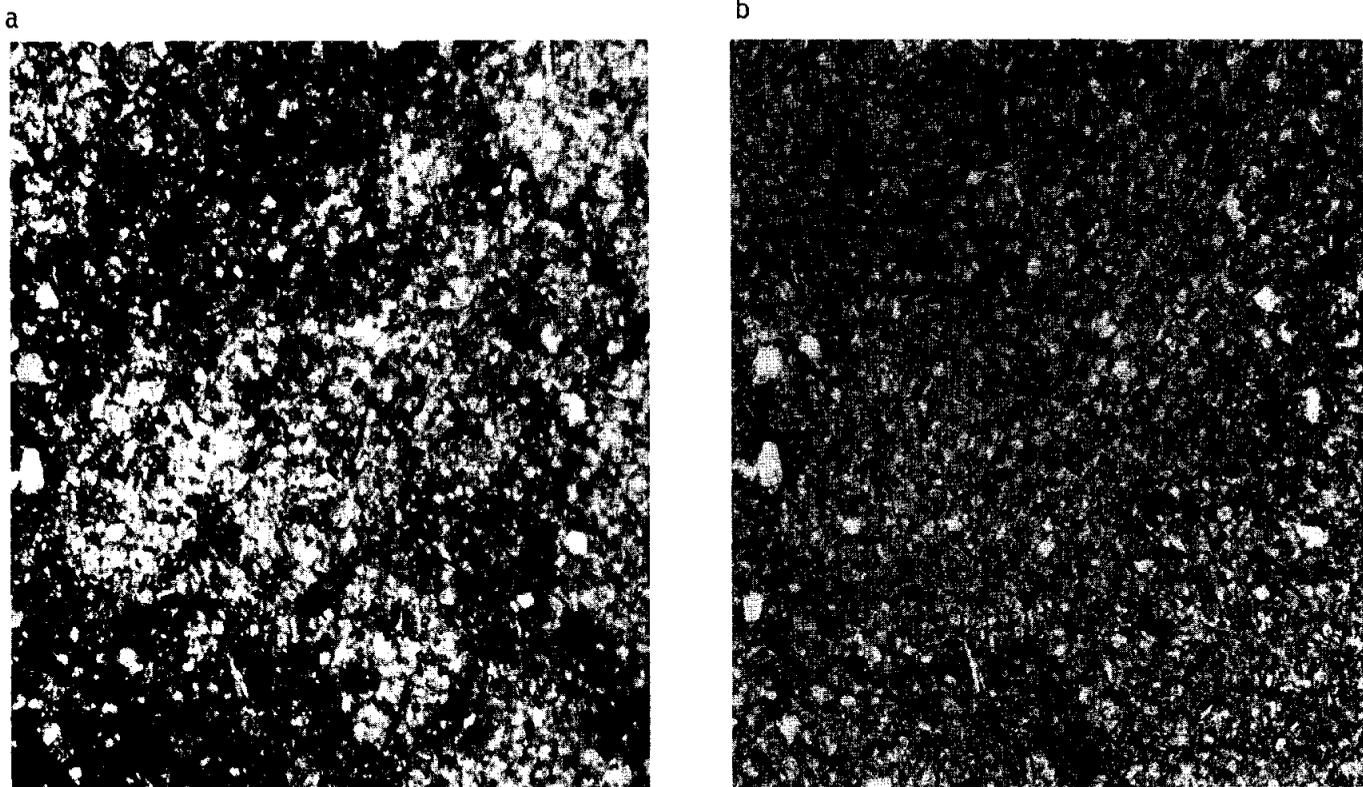


FIGURE 2. 60315,15. Same view, width 2mm. a) xpl. b) ppl.

given by L. Taylor et al. (1973a), Reed and Taylor (1974) and Misra and Taylor (1975). Meyer (1979) determined trace elements in plagioclase in 60315 using the ion microprobe.

EXPERIMENTAL PETROLOGY: Ford et al. (1974) experimentally determined the phase relations of 60315. Spinel is the equilibrium liquidus phase (1300°C) followed by olivine (1276°C) and plagioclase (1256°C). Pyroxene was not produced even at their lowest temperature (1200°C). This is consistent with textural evidence which indicates that olivine and plagioclase preceded pyroxene.

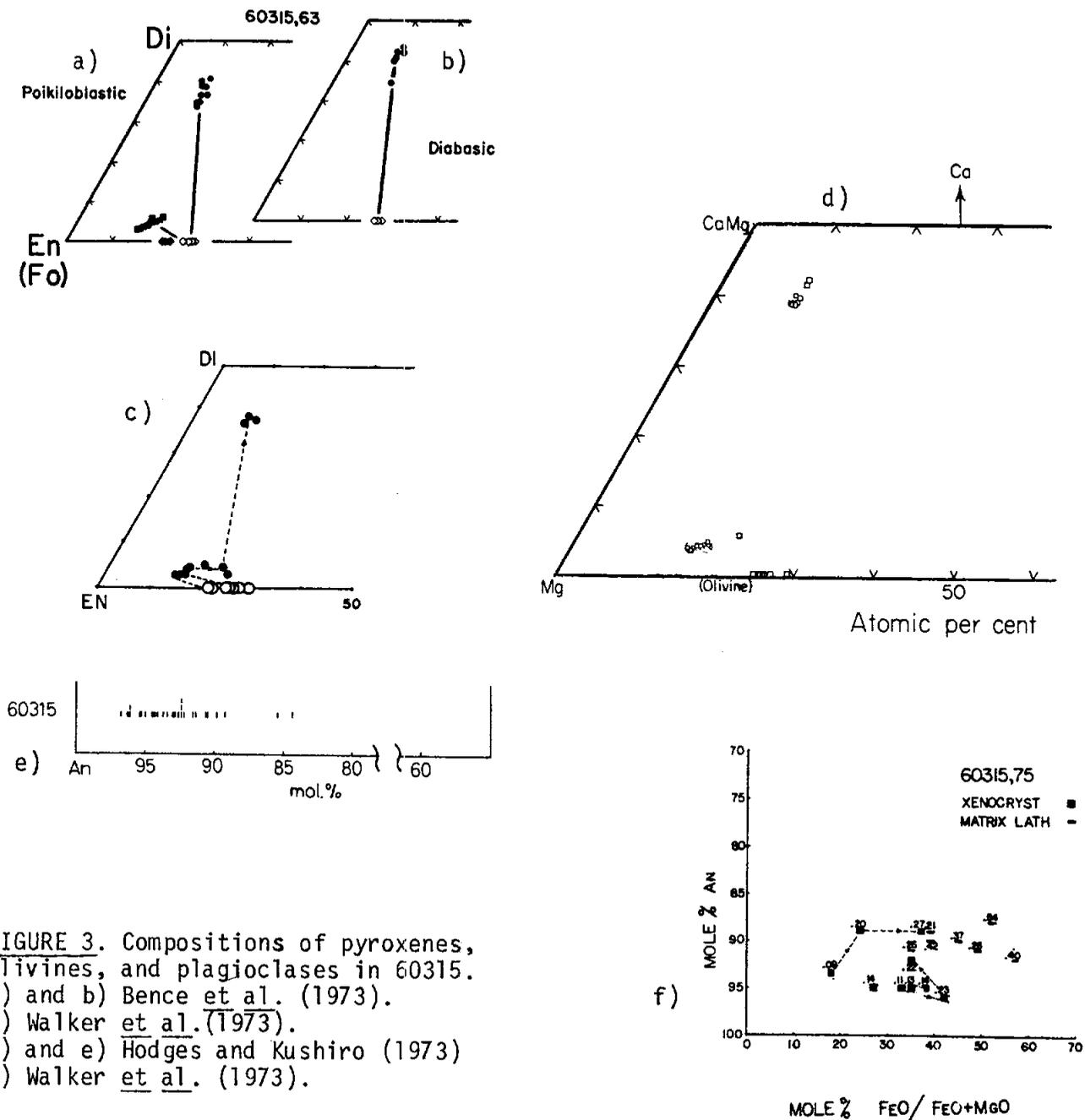


FIGURE 3. Compositions of pyroxenes, olivines, and plagioclases in 60315. a) and b) Bence et al. (1973). c) Walker et al. (1973). d) and e) Hodges and Kushiro (1973) f) Walker et al. (1973).

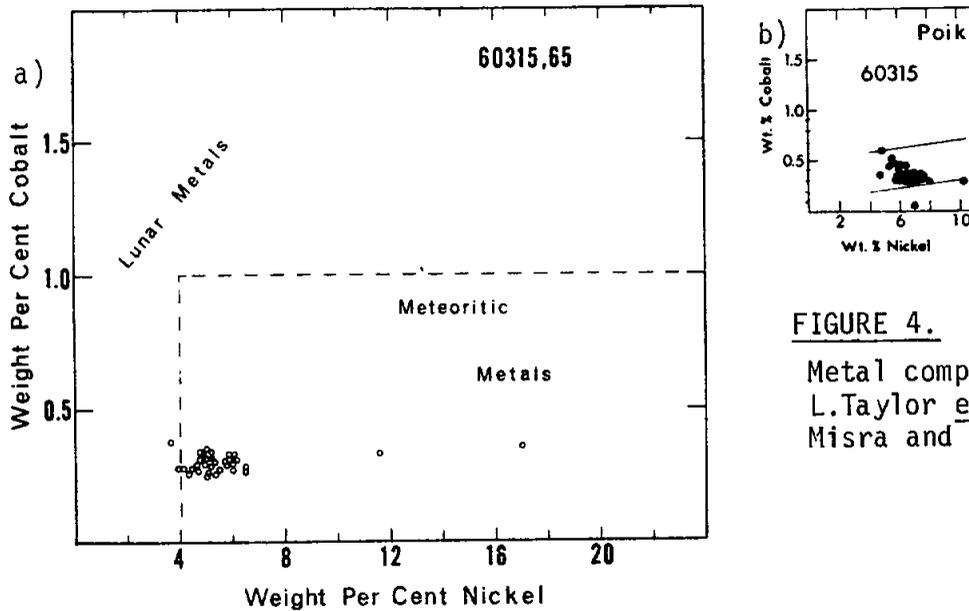


FIGURE 4.

Metal compositions; a) from L. Taylor *et al.* (1973a). b) from Misra and Taylor (1975).

CHEMISTRY: Chemical studies of 60315 are listed in Table 1 and a summary chemistry in Table 2. Rare earth element abundances and patterns are shown in Figure 5.

The major element chemistry of 60315 is very similar to Apollo 15 "Fra Mauro basalt" glasses, and it lies very near the olivine-plagioclase cotectic of the OL-AN-SI system (Fig. 6). Rare earth element abundances are among the highest measured in any Apollo 16 sample (see also 62235 and 65015) and have a KREEP pattern (Table 3 and Fig. 5). 60315 is not simply remelted local soil: it is much lower in Al_2O_3 and higher in rare earth elements. Siderophile abundances vary from split to split (e.g. reported Ni values range from 191-1400 ppm) but all indicate substantial amounts of meteoritic material. Hertogen *et al.* (1977) considered the anomalously low Ir/Au ratio indicative of a distinct meteoritic component and assigned 60315 to a new meteoritic signature, Group 1LL. Volatiles also vary by two orders of magnitude between different splits (e.g. reported Zn ranges from 0.3-12 ppm).

Sato (1976) measured the oxygen fugacity of 60315 directly using the solid-electrolyte oxygen cell method. Fugacity values at a series of temperatures are given in Table 3. Nash and Haselton (1975) calculated the equilibrium silica activity of a melt with the composition of 60315. They conclude that Apollo 16 crystalline rocks 60315 and 68416 have higher initial silica activities than Apollo 17 high-Ti mare basalts.

TABLE 1. Chemical studies of 60315

Reference	Split #	Elements analyzed
Rose <u>et al.</u> (1973)	,88	majors, trace, incl. some REEs
Hubbard <u>et al.</u> (1973)	,3	majors, REEs, other trace
Hubbard <u>et al.</u> (1973)	,57	majors
Morrison <u>et al.</u> (1973)	,53	majors, REEs, other trace
LSPET (1973)	,3	majors, trace
S.R. Taylor <u>et al.</u> (1973)	,58	majors, REEs, other trace
Lau <u>et al.</u> (1974)	,157	majors, REEs, other trace
Wänke <u>et al.</u> (1976)	,87; ,103	majors, REEs, other trace
Wänke <u>et al.</u> (1977)	,87	V
Nyquist <u>et al.</u> (1973)	,3	Rb, Sr
Kirsten <u>et al.</u> (1973)	,19	K, Ca
Nunes <u>et al.</u> (1973)	,81	U, Th, Pb
Nunes (1975)	,81 ?	U, Th, Pb
Eldridge <u>et al.</u> (1973)	,0	U, Th, K
Moore <u>et al.</u> (1973)	,4	C
Ganapathy <u>et al.</u> (1974)	,79	meteoritic sids. and vols.
Flory <u>et al.</u> (1973)	,52	volatile organogenic compounds

TABLE 3. Oxygen Fugacity of 60315

T (°C)	-log f_{O_2} (atm)
1000	16.2
1050	15.4
1100	14.6
1150	13.9
1200	13.2

TABLE 2. Summary chemistry of 60315

SiO ₂	46.5
TiO ₂	1.31
Al ₂ O ₃	17.2
Cr ₂ O ₃	0.21
FeO	9.3
MnO	0.11
MgO	13.2
CaO	10.2
Na ₂ O	0.61
K ₂ O	0.40
P ₂ O ₅	0.48
Sr	155
La	49
Lu	2.1
Rb	9.7
Sc	15
Ni	~800
Co	~50
Ir ppb	~10
Au ppb	~17
C	~20 (?)
N	~20
S	1300
Zn	~5 (?)
Cu	11

Oxides in wt%; others in ppm except as noted.

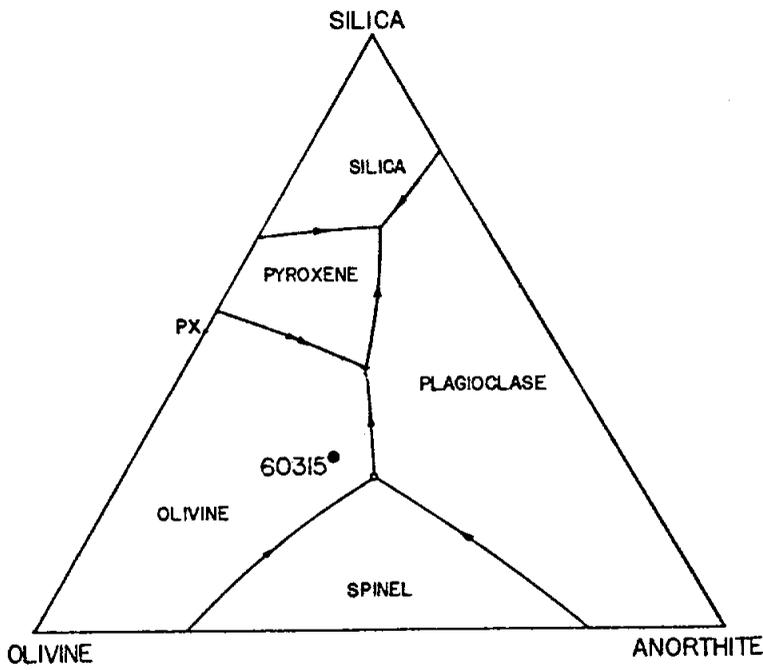


FIGURE 5. from Walker *et al.* (1973).

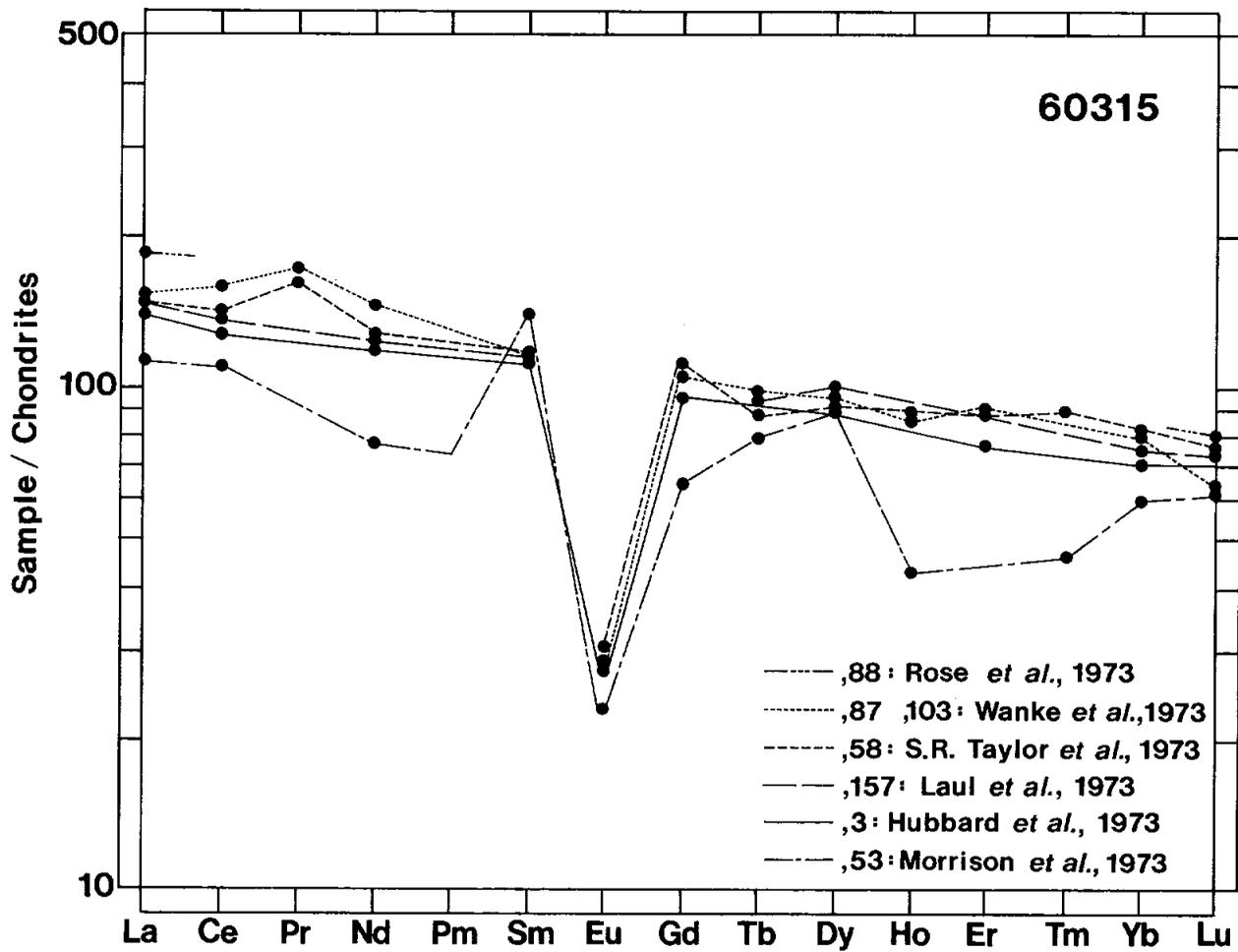


FIGURE 6. Rare earths.

GEOCHRONOLOGY AND RADIOGENIC ISOTOPES: Whole rock Rb-Sr data are presented by Nyquist *et al.* (1973). Model ages of $T_{BABI} = 4.41 \pm 0.06$ b.y. and $T_{LUNI} = 4.44 \pm 0.06$ b.y. were calculated. KREEP-rich rocks 60315, 62235, and 65015 define a whole rock Rb-Sr isochron of 4.42 ± 0.38 b.y. with initial $^{87}\text{Sr}/^{86}\text{Sr} = 0.6992 \pm 9$. Assuming a 3.9 b.y. age for these rocks yields an initial $^{87}\text{Sr}/^{86}\text{Sr} = 0.70040 \pm 15$ (Nyquist *et al.*, 1973).

Well defined ^{39}Ar - ^{40}Ar plateau ages of 4.03 ± 0.03 , 3.94 ± 0.05 and 3.91 ± 0.02 b.y. were obtained by Kirsten *et al.* (1973), Husain and Schaeffer (1973) and Schaeffer *et al.* (1976) respectively (Fig. 7). Schaeffer *et al.* (1976) also report a K-Ar age of 3.69 ± 0.01 b.y.

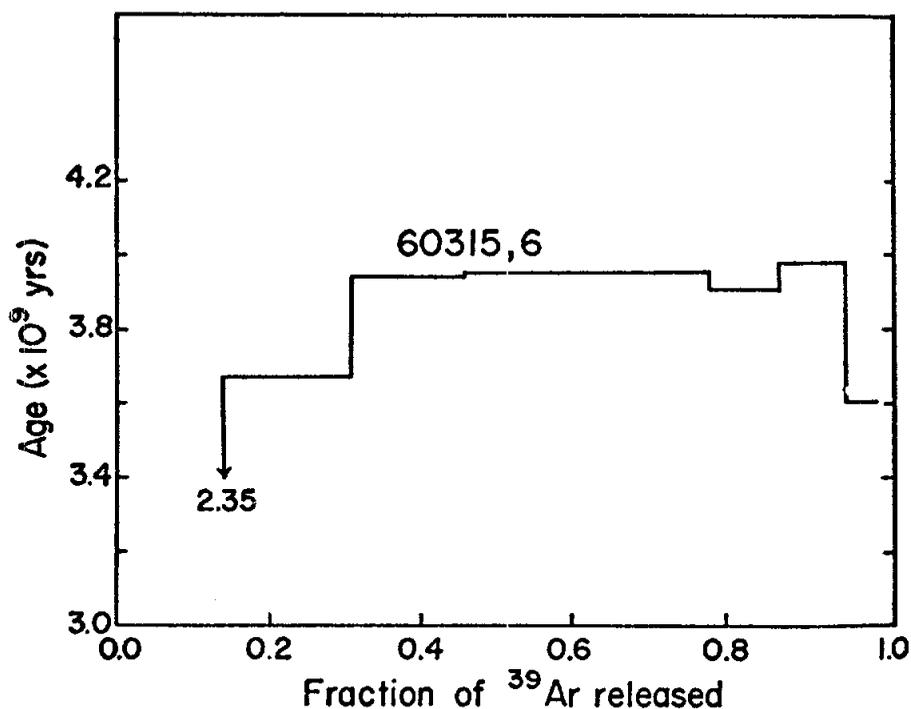


FIGURE 7a. Ar release; from Husain and Shaeffer (1973).

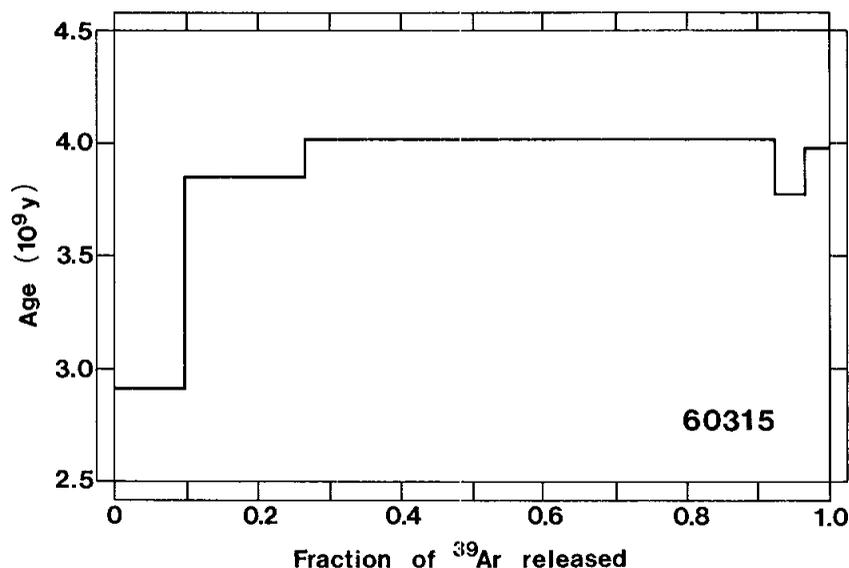


FIGURE 7b. Ar release; from Kirsten *et al.* (1973).

Nunes *et al.* (1973) and Nunes (1975) report U-Th-Pb data. 60315 is very enriched in *in situ* radiogenic lead ($^{206}\text{Pb}/^{204}\text{Pb}$, >10,000). Nearly all of the original lead was probably expelled during a period of intense heating. A Pb-Pb internal isochron yields an age of 3.99 ± 0.01 b.y. (Fig. 8). The bulk rock is concordant at 3.93 b.y. (Nunes, 1975) rather than slightly discordant at 3.99 b.y. as originally reported by Nunes *et al.* (1973).

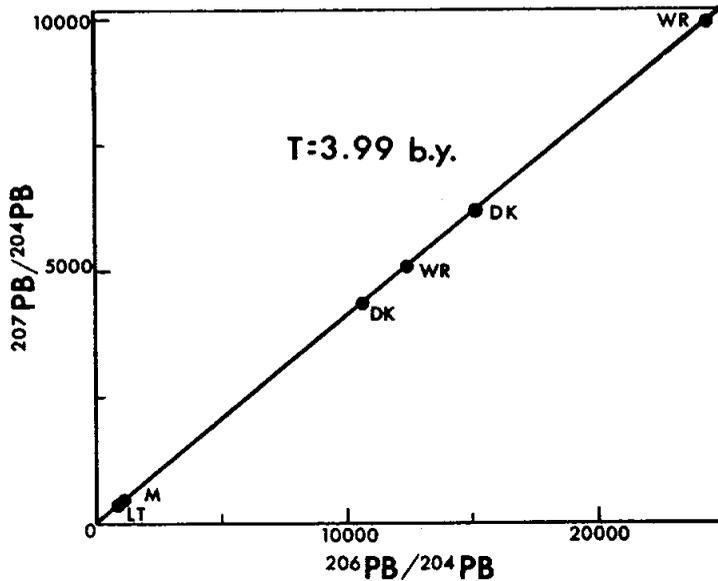


FIGURE 8. Pb-Pb isochron; from Nunes *et al.* (1973).

RARE GAS/EXPOSURE AGE: Kirsten *et al.* (1973) report a ^{38}Ar age of 4.5 ± 1 m.y. Schaeffer *et al.* (1976) determined a maximum ^{38}Ar age of 11 m.y. with a more probable age of 5 ± 3 m.y. Keith and Clark (1974) calculate a ^{26}Al maximum exposure age of 2.3 m.y. Eldridge *et al.* (1973) provide abundance data on cosmogenic radionuclides determined by γ -ray spectroscopy and Keith *et al.* (1975) discuss the saturated activities of specific short-lived, cosmogenic radionuclides.

MICROCRATERS AND TRACKS: Neukum *et al.* (1973), Fechtig *et al.* (1974) and Nagel *et al.* (1975) provide data on microcraters on 60315. The rock has had a simple exposure history and the surfaces are in production. Nagel *et al.* (1975) report small metallic spherules enriched in Fe, Ni and S suspended within some of the crater glass linings.

PHYSICAL PROPERTIES: Brecher *et al.* (1973), Nagata *et al.* (1973) and Schwerer and Nagata (1976) provide magnetic data and discussion (Figs. 9 and 10). Coarse multidomain grains predominate over a superparamagnetic fraction. About 40% of the metallic iron component in this rock is kamacite with $\sim 5\%$ Ni. A very small component of NRM and IRM is stable against AF-demagnetization (Fig. 10). Measured magnetic parameters of 60315 vary from chip to chip by over an order of magnitude (see e.g. Brecher *et al.*, 1973) possibly relating to the inhomogeneous distribution of metallic phases.

Mossbauer analyses are given by Brecher et al. (1973), Huffman et al. (1974) and Huffman and Dunmyre (1975) (Fig. 11). Tsay and Bauman (1977) studied para-magnetic iron using the electron spin resonance (ESR) method. These spectra and the magnetic data referenced above indicate up to ~ 4.5 wt% metallic iron in 60315.

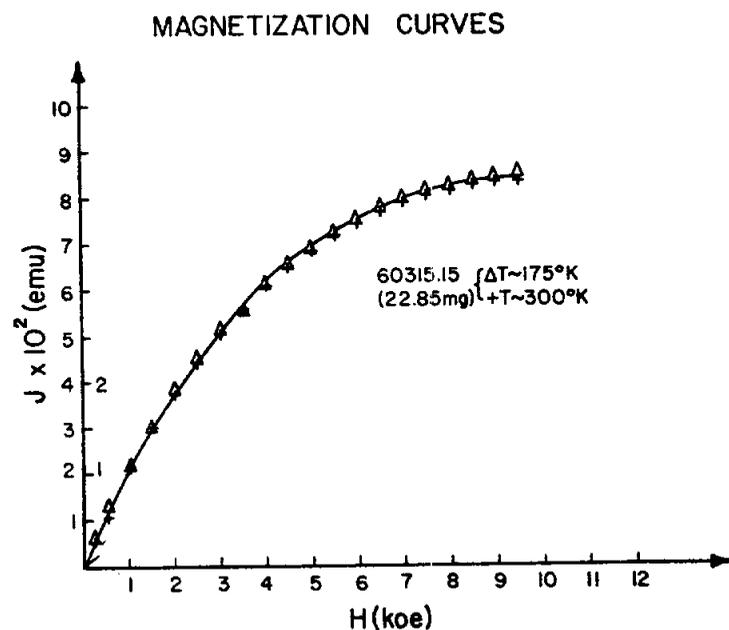
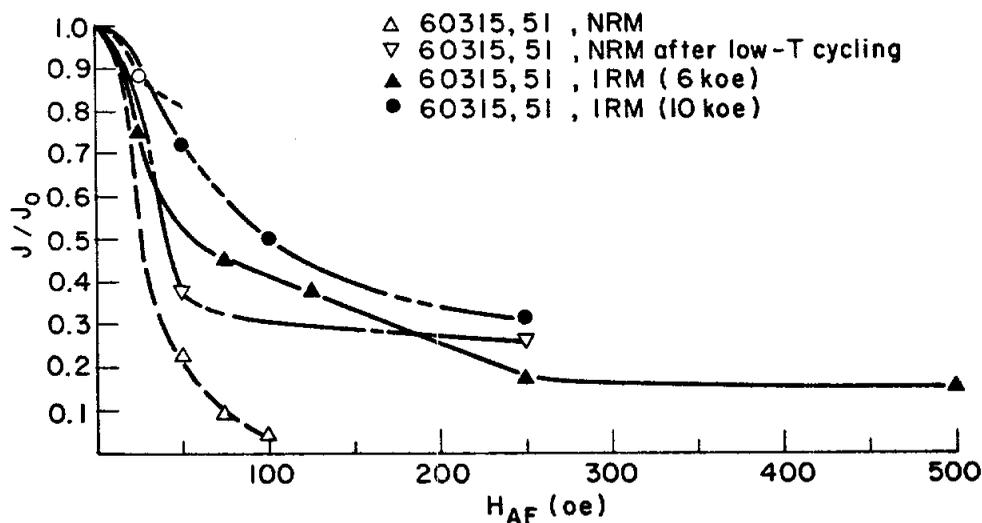


FIGURE 9. Magnetization; from Brecher et al. (1973).



Normalized AF Demagnetization

FIGURE 10. AF-demagnetization; from Brecher et al. (1973).

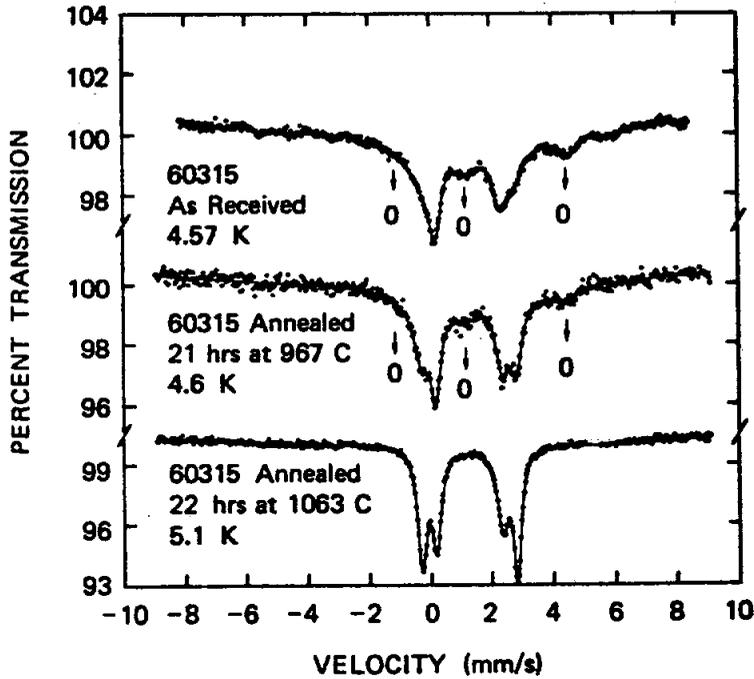


FIGURE 11. Liquid-helium spectra; from Huffman and Dunmyre (1975).

Elastic wave velocities at pressures up to 10 kb were measured by Mizutani and Newbigging (1973) (Fig. 12). These data closely match the seismic velocity profiles from 5-25 km depth in the moon.

Chung and Westphal (1973) note the unusual electrical properties of 60315. The dielectric constant, dielectric losses and conductivity are all high (Figs. 13 and 14) possibly owing to the high concentration of metallic iron in the rock.

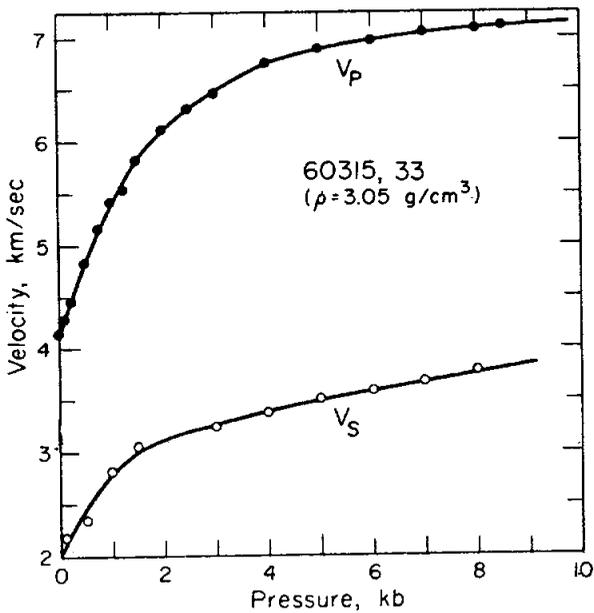


FIGURE 12. Elastic wave velocities; from Mizutani and Newbigging (1973).

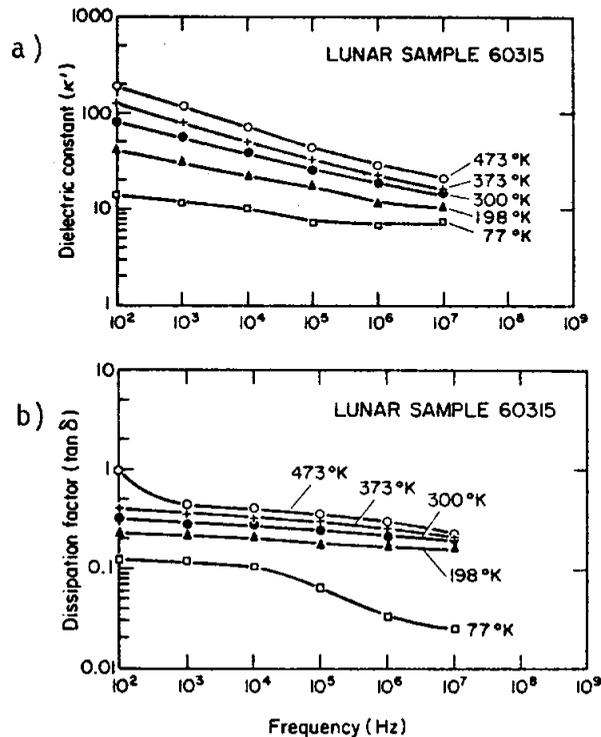


FIGURE 13. from Chung and Westphal (1973). a) dielectric constant b) dielectric losses.

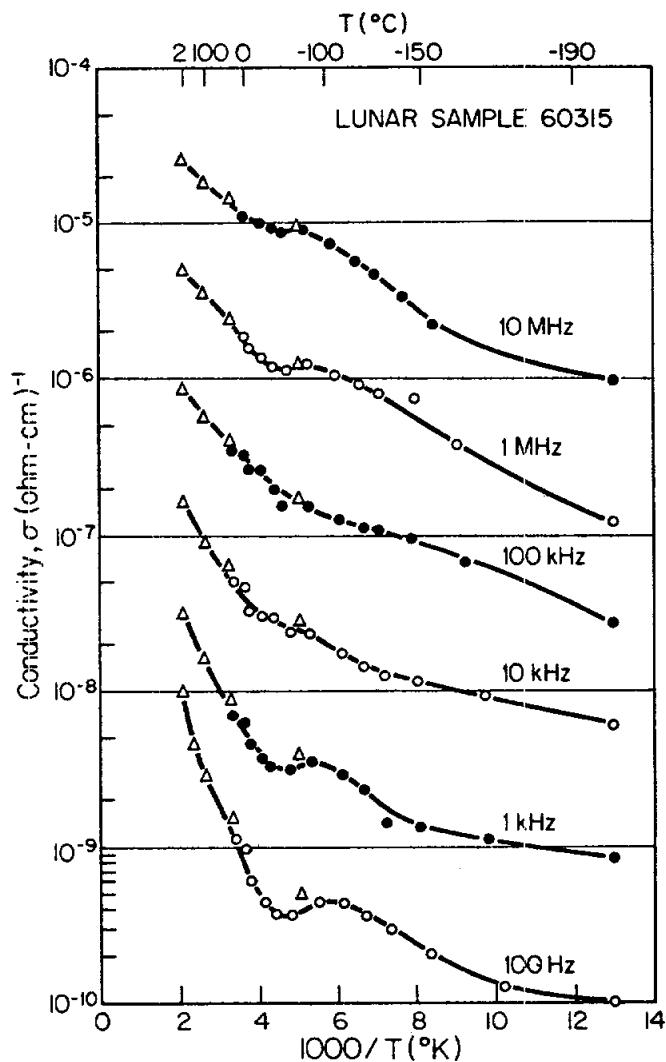


FIGURE 14. Electrical conductivity; from Chung and Westphal (1973).

Charette and Adams (1977) provide visible and near-infrared reflectance data .

PROCESSING AND SUBDIVISIONS: This rock has been extensively subdivided and widely allocated. In 1972, it was cut into four pieces, including a slab (Figs. 15,16). Allocations were primarily from the slab, from ,18 (entirely subdivided as ,47- ,59 and ,79- ,97) and from chips of ,0. The largest single piece remaining (,0 in Fig. 16) weighs 594.3 g and has been renumbered ,46. Serial thin sections were made from slab pieces ,20 and ,26. Thin sections also sample other portions of the rock. Many interior and exterior splits exist.

FIGURE 15.
Cutting diagram.

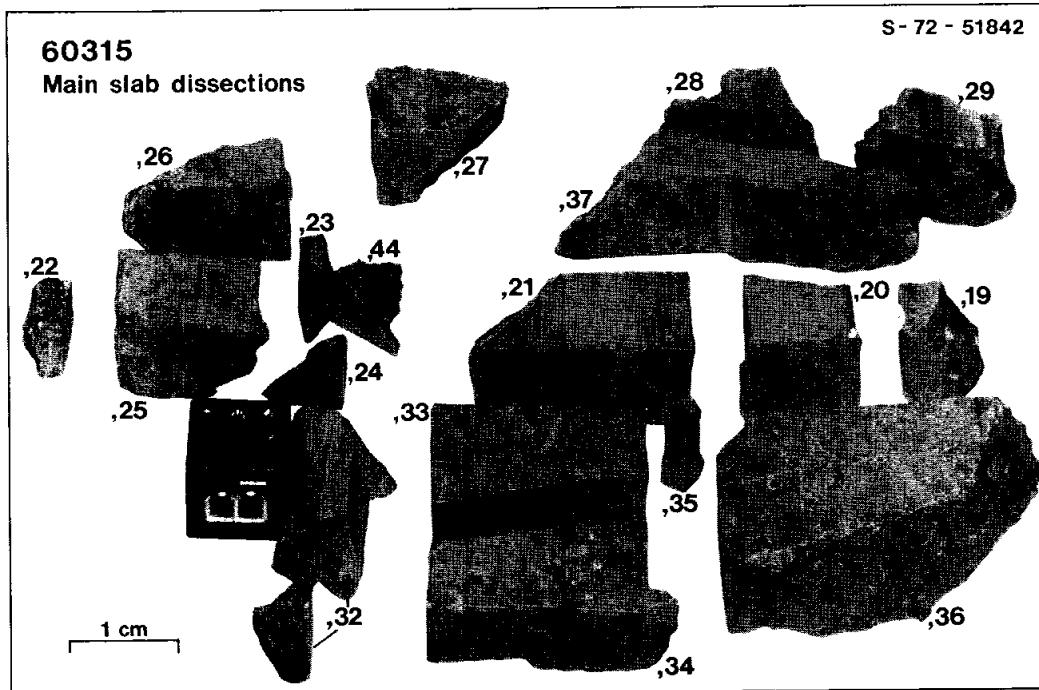
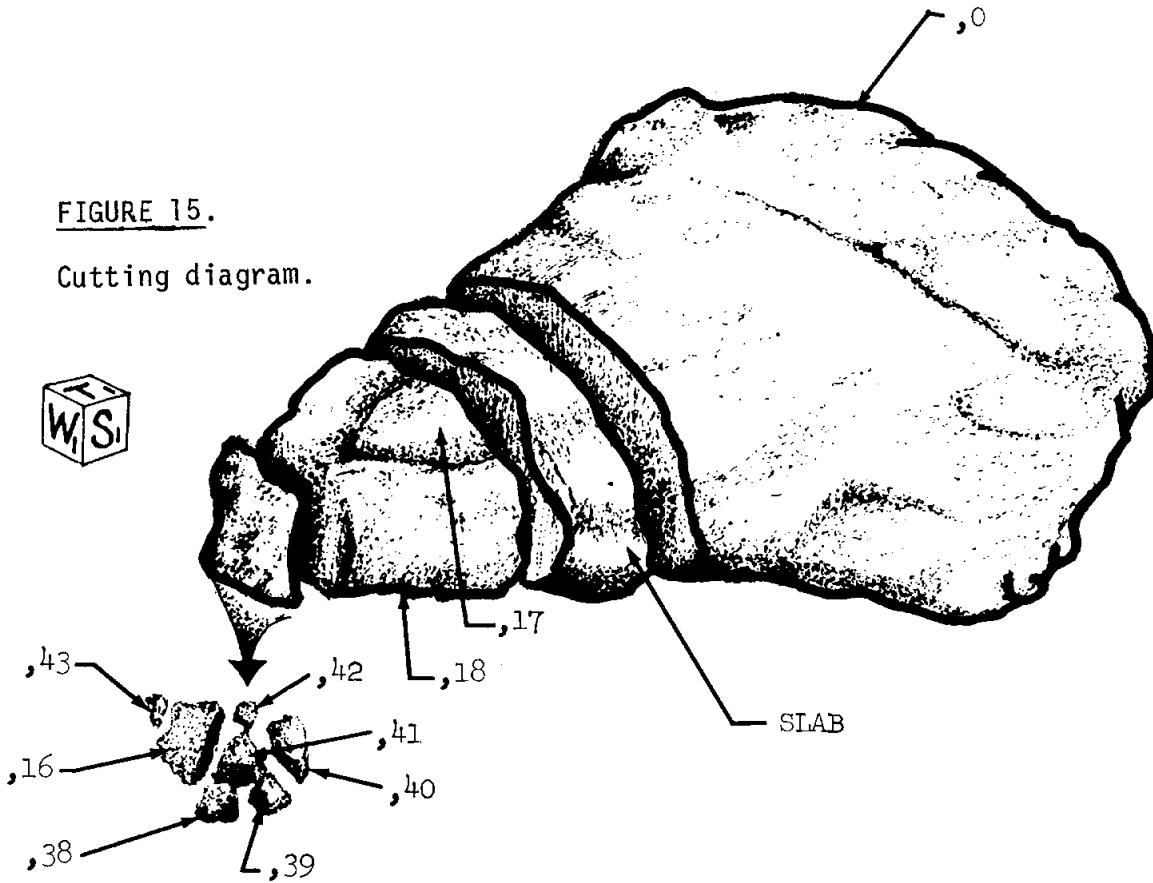


FIGURE 16.

INTRODUCTION: 60335 is a tough, medium gray, basaltic impact melt with a pronounced vug population (Fig. 1). The rock as a whole is homogeneous although the grain size changes abruptly and color varies irregularly from dark to light areas. Metal spherules (up to 5 mm) are abundant.

60335 was collected about 70 m east-northeast of the Lunar Module, where it was 1/3-1/2 buried with a moderately well-developed fillet. Its orientation is known; zap pits are present on all surfaces but one, although the densities vary considerably from surface to surface.

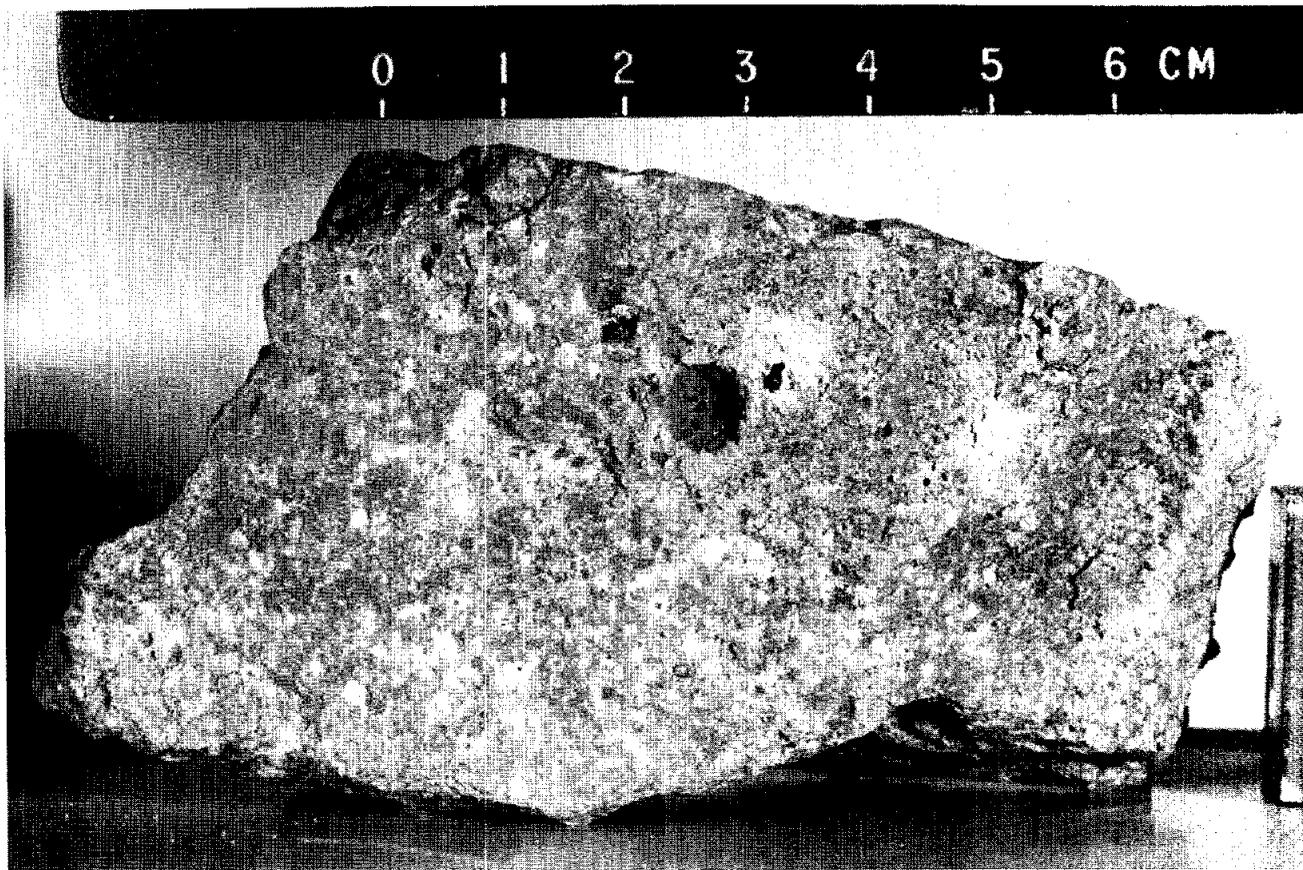


FIGURE 1. S-72-38289

PETROLOGY: Walker *et al.* (1973), Brown *et al.* (1973), Nord *et al.* (1973) and Vaniman and Papike (1981) provide petrographic information. Nord *et al.* (1973) studied pyroxene exsolution using high-voltage transmission electron microscopy. Misra and Taylor (1975) report metal and schreibersite compositions.

60335 is a basaltic impact melt rock that exhibits a variety of melt textures (Fig. 2). Most commonly, normally zoned, subhedral plagioclase phenocrysts (An₉₅₋₈₆) and shocked, anhedral plagioclase xenocrysts (An₉₇₋₉₅, up to 4 mm) grade into a finer grained matrix of equant to lathy plagioclase partially enclosed by olivine (Fo₈₅₋₇₉, single crystals up to 10 mm). In other areas a Si-K-rich glassy mesostasis fills the interstices. Overgrowths of ortho-

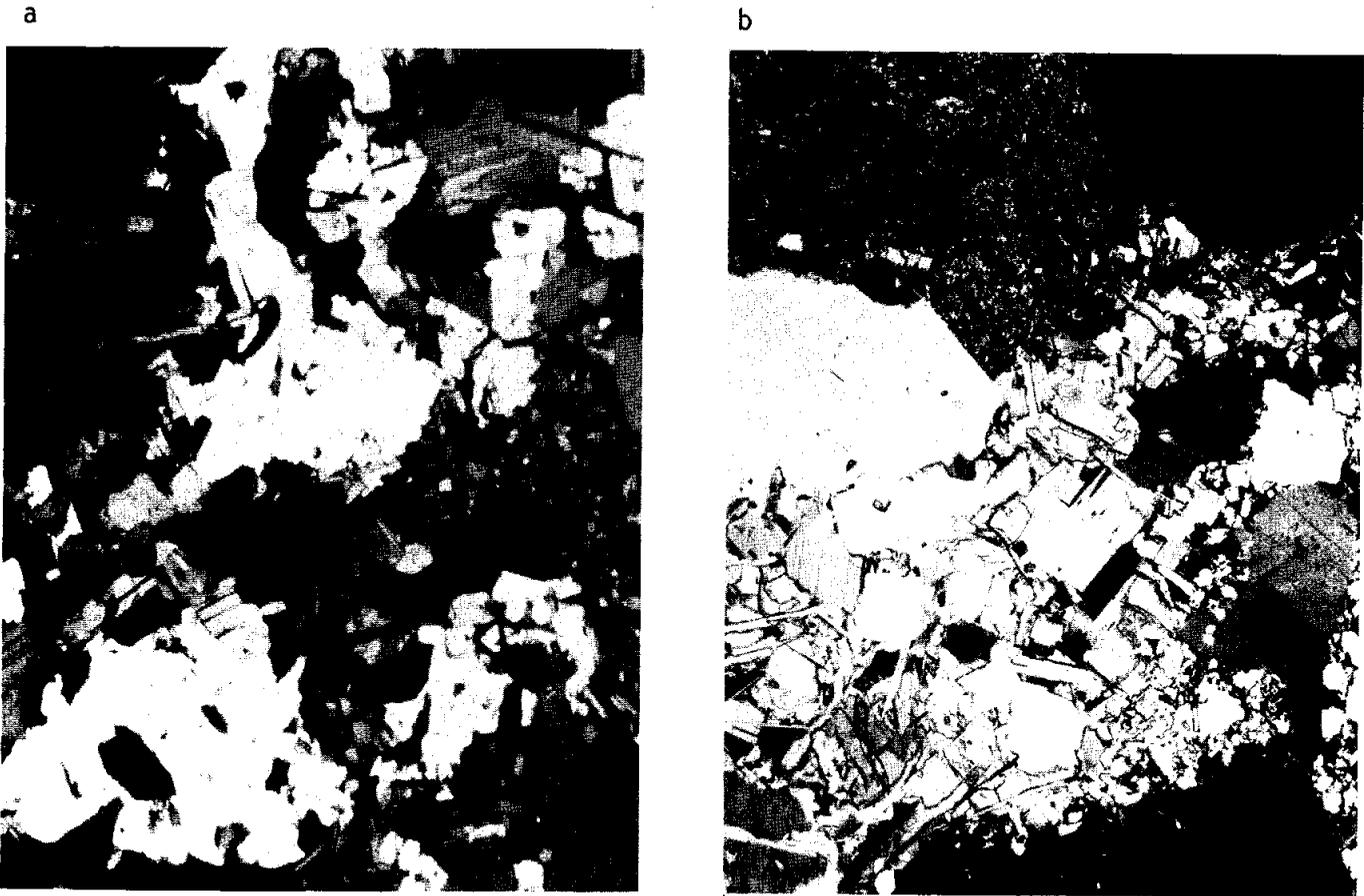


FIGURE 2. a) 60335,61. general basaltic, xpl. width 2mm. b) poikilitic area (top left) and vesicle (top right) in general basaltic area, xpl. width 1mm.

pyroxene ($Wo_5 En_{76}$), pigeonite ($Wo_9 En_{68}$) and augite occasionally rim the olivines and many of the plagioclase phenocrysts display a clear rim over a shocked core. Pigeonite occasionally shows augite exsolution lamellae. A mode of the matrix given by Walker *et al.* (1973) is reproduced as Table 1. Minor phases include silica, phosphates, Zr-armalcolite, ilmenite, ulvöspinel, metal and schreibersite. Mineral compositions are given in Figures 3 and 4.

Less common melt textures in this rock include radiating clusters of plagioclase, often cored by an incompletely digested clast and poikilitic patches in which 0.5 mm olivine encloses many small clasts and crystallites of plagioclase (Fig.2). Although Walker *et al.* (1973) and the Apollo 16 Lunar Sample Information Catalog (1972) interpret certain poikilitic areas as lithic clasts, an extensive survey of library thin sections convinces us that these patches crystallized from the same melt that produced the bulk of the rock. Evidence for this interpretation includes the arcuate boundaries of the patches against vesicles (Fig. 2), the tendency of the poikilitic patches to completely fill irregularly shaped areas and the fact that some of the poikilitic olivines are single crystals with olivines that are definitely a part of the ophitic matrix.

Lithic clasts include granoblastic anorthosite (2 mm) and granoblastic troctolite (5 mm) with accessory ilmenite and metal. Most of the lithic clasts are shocked with a well defined reaction rim of fine-grained, unshocked plagioclase.

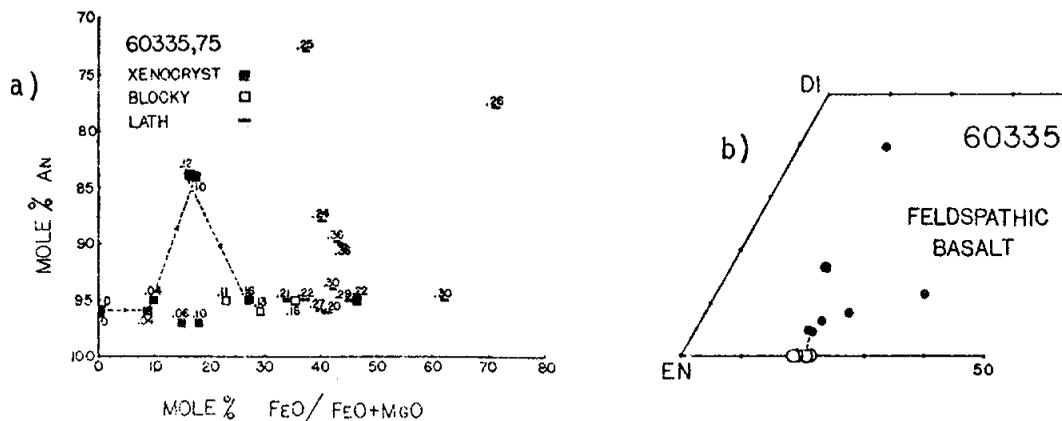


FIGURE 3. Mineral compositions;
 a) plagioclases, from Walker et al. (1973)
 b) pyroxenes, from Walker et al. (1973).
 c) pyroxenes, from Vaniman and Papike (1981).

TABLE 1

Mode of 60335 from Walker et al. (1973)

Plagioclase	64%
Olivine	16%
Clinopyroxene	10%
Opauques	2%
Glassy mesostasis	8%
Orthopyroxene	tr

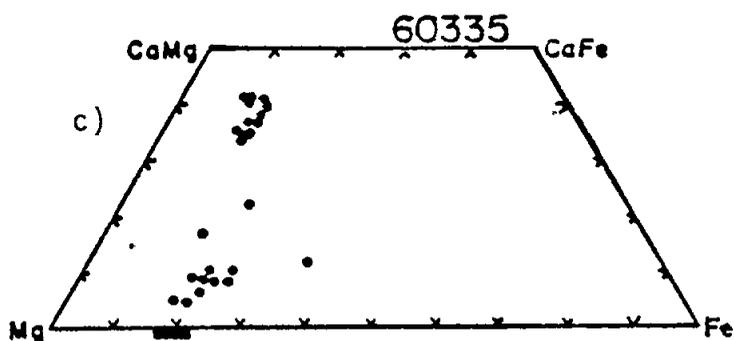
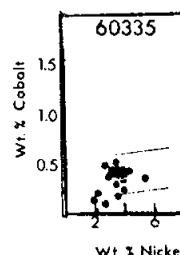


FIGURE 4.
 Metals; from
 Misra and
 Taylor (1975).



EXPERIMENTAL PETROLOGY: Muan et al. (1974) and Ford et al. (1974) report experimentally determined equilibrium phase relations. At low pressure plagioclase is the liquidus phase of 60335, followed by spinel, then olivine. Liquidus temperature is $>1370^{\circ}\text{C}$. Spinel becomes unstable between $1200-1216^{\circ}\text{C}$. At 1 kb pressure with 10% water, spinel is the liquidus phase at temperatures $>1250^{\circ}\text{C}$ (Ford et al., 1974).

L.A. Taylor et al. (1976) performed subsolidus heating experiments to observe changes in metal grain morphology and chemistry. The most conspicuous textural change observed was the development of euhedral metal crystals at the edges of the annealed fragments. Observed changes in metal compositions are summarized in Figure 5.

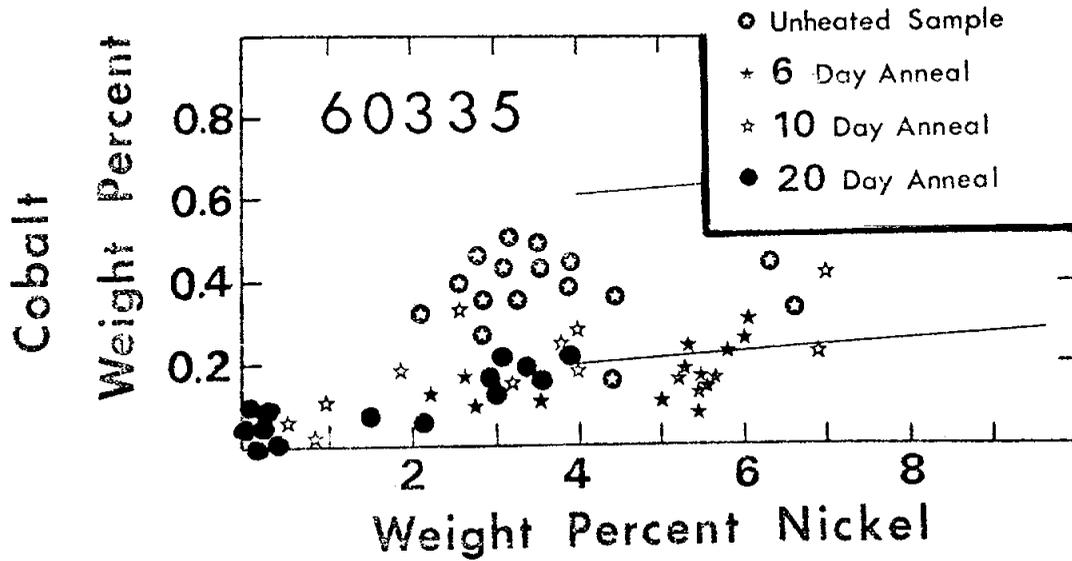


FIGURE 5. Subsolidus metal changes; from L. Taylor *et al.* (1976).

CHEMISTRY: Major and trace element data are given by Haskin *et al.* (1973), Rose *et al.* (1973), Miller *et al.* (1974), Fruchter *et al.* (1974) (of 34 erroneously reported as 4), Wänke *et al.* (1976) and LSPET (1973). Hubbard *et al.* (1974) and Ehmman and Chyi (1974) report trace elements, Clark and Keith (1973) provide data on natural and cosmogenic radionuclides and Barnes *et al.* (1973) present trace element and isotopic abundances (see also STABLE ISOTOPES and GEOCHRONOLOGY below). Walker *et al.* (1973) report major elements determined by electron microprobe analyses of natural rock powder fused to a glass.

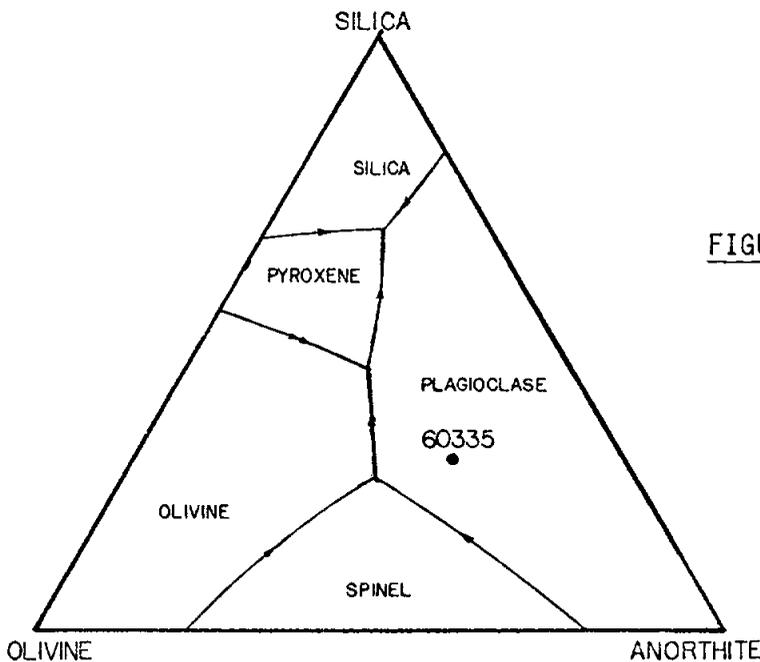


FIGURE 6. from Walker *et al.* (1973).

TABLE 2
Summary chemistry of 60335

SiO ₂	46.0
TiO ₂	0.61
Al ₂ O ₃	24.9
Cr ₂ O ₃	0.13
FeO	4.7
MnO	0.07
MgO	8.1
CaO	14.3
Na ₂ O	0.57
K ₂ O	0.25
P ₂ O ₅	0.21
Sr	150
La	21
Lu	0.84
Rb	6.8
Sc	8.1
Ni	340
Co	20
Ir ppb	17
Au ppb	16.8
C	
N	
S	
Zn	2
Cu	8

Oxides in wt%; others in ppm except as noted.

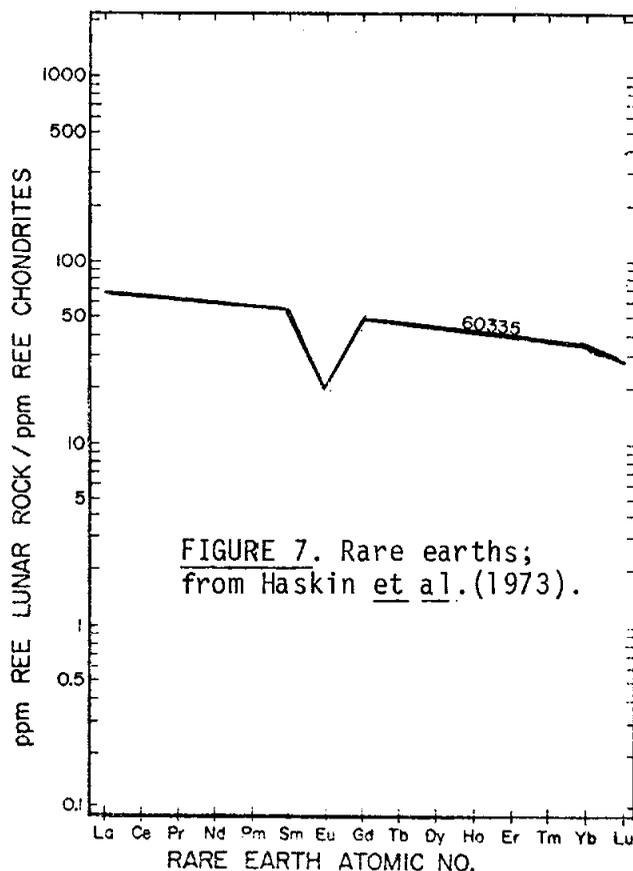


FIGURE 7. Rare earths; from Haskin et al. (1973).

TABLE 3
Average oxygen fugacity of 60335

<u>T (°C)</u>	<u>-log f_{O₂}(atm)</u>
1000	16.7
1060	15.6
1100	14.6
1150	13.7
1200	12.8

Chemically 60335 is a very homogeneous rock. Its major element composition is that of anorthositic norite (Table 2 and Fig. 6), very similar to the local mature soils. Rare earth elements (Fig. 7) are slightly higher in the rock (La ~ 65 x chondrites) than in the local soils (La ~ 45 x chondrites). The Zr/Hf is high, dominated by a KREEP component (Ehmann and Chyi, 1974). Siderophiles indicate a substantial meteoritic contribution (Table 2).

Sato (1976) measured the oxygen fugacity of 60335 directly using the solid-electrolyte oxygen cell method. The low values (Table 3) are consistent with the equilibration of metallic iron with the silicate and oxide phases. A slight self-reduction was noted during the first heating cycle.

STABLE ISOTOPES: Barnes et al. (1973) provide data on isotopes of Cr, Ni and K.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Whole rock Rb-Sr data are provided by Barnes et al. (1973) and Nyquist et al. (1974). A model age of 4.055 b.y. was calculated by Barnes et al. (1973) assuming $I = 0.6994$ (sic.). Model ages of $T_{\text{BABI}} = 4.19 \pm 0.06$ b.y. and $T_{\text{LUNI}} = 4.23 \pm 0.06$ b.y. were calculated by Nyquist et al. (1974).

Whole rock U-Th-Pb isotopic data are reported by Barnes et al. (1973). Four model ages ranging from 4.059 - 4.081 b.y. and averaging 4.070 b.y. were calculated. 60335 is concordant at 4.075 b.y.

Relative isotopic compositions of ^{39}K , ^{40}K and ^{41}K are given by Barnes et al. (1973).

RARE GAS/EXPOSURE AGE: Solar flare track data indicate that 60335 had a complex exposure history (Fig. 8) but allow an approximate burial (subdecimeter) age of 50 m.y. and a surface exposure age of ~ 0.5 m.y. to be calculated (Bhandari et al., 1976). Bhandari (1977) reports a ^{26}Al surface exposure age of < 0.2 m.y. ^{26}Al and other cosmic-ray induced radionuclide abundance data are provided by Clark and Keith (1973).

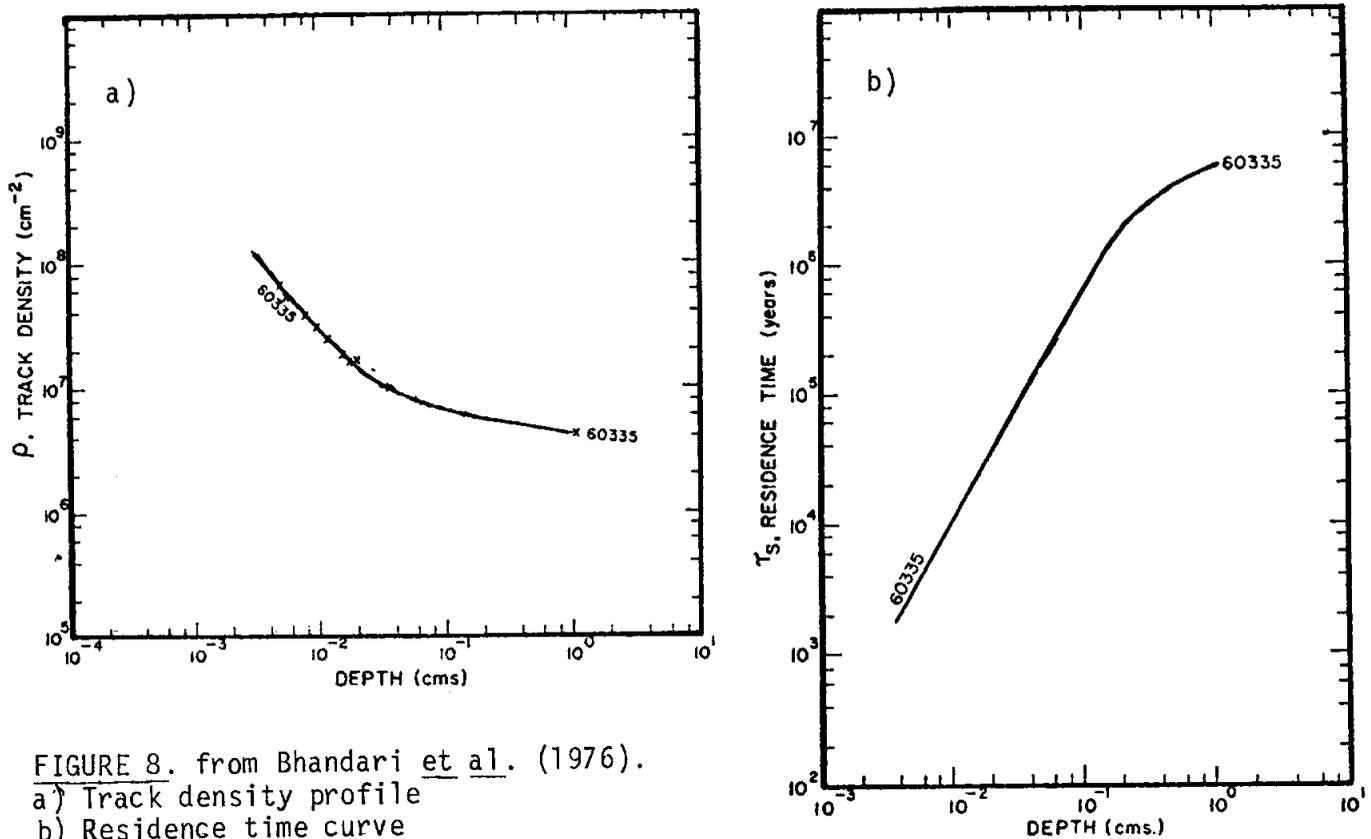


FIGURE 8. from Bhandari et al. (1976).

- a) Track density profile
b) Residence time curve

MICROCRATERS AND TRACKS: Morrison et al. (1973) and Neukum et al. (1973) provide size-frequency data on microcraters. Morrison et al. (1973) note the exceptionally low frequency of craters on 60335 and calculate a "best estimate" exposure age of 0.6-0.8 m.y.

PHYSICAL PROPERTIES: 60335 is the "LPM" rock, chosen to measure the in situ remanent magnetization of a lunar sample using the Lunar Portable Magnetometer. Measurements made with the LPM on the lunar surface and in the laboratory did not detect any rock magnetization (Dyal et al., 1972). Pearce et al. (1973) report the total remanence of 60335 as 5.4×10^{-6} emu/g, confirming that its intensity is well below the resolution of the LPM. Thus the amount of lunar-induced soft remanence in this sample could not be determined.

Intrinsic and remanent magnetic properties were measured on two chips of 60335 by Pearce et al. (1973) using room temperature hysteresis loops and AF-demagnetization techniques. Total metal content is 0.36 wt %, principally as multi-domain particles. The Curie temperature ($\theta=760^{\circ}\text{C}$) is characteristic of iron with a few percent Ni. A low Curie temperature ($\theta' = 350^{\circ}\text{C}$) phase, possibly high-Ni metal, was also detected. Electron microprobe studies did not detect such a high-Ni metal phase (Misra and Taylor, 1975). Chou and Pearce (1976) note that 60335 has Ni/metal slightly higher than the local soils and interpret this as indicating that very little metal in the rock was produced by subsolidus reduction.

AF-demagnetization of the two chips revealed significant differences between the chip that was stored in field-free space (,30) and the chip that was not (,18) (Fig. 9). Apparently the rock acquired a non-lunar viscous remanence that is stable against AF-demagnetization but not against field-free storage (Pearce et al., 1973).

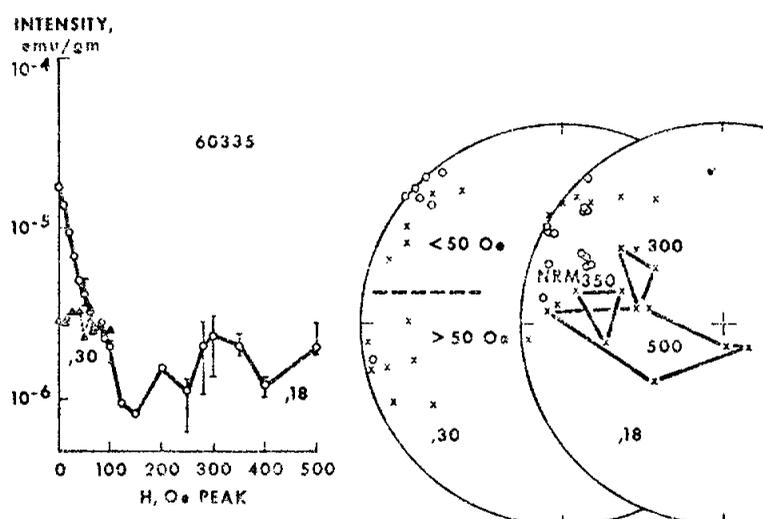


FIGURE 9. AF-demagnetization; from Pearce et al. (1973).

Velocity and linear strain data are provided by Warren *et al.* (1973) for hydrostatic and uniaxial loading conditions (Fig. 10). Bulk elastic properties calculated from the density, bulk modulus and shear modulus of the silicate phases of the rock agree well with the measured values. These authors conclude that pore and crack effects exert an extreme control over bulk elastic properties.

Simmons *et al.* (1975) note the presence of healed cracks that displace twin lamellae in plagioclase xenocrysts.

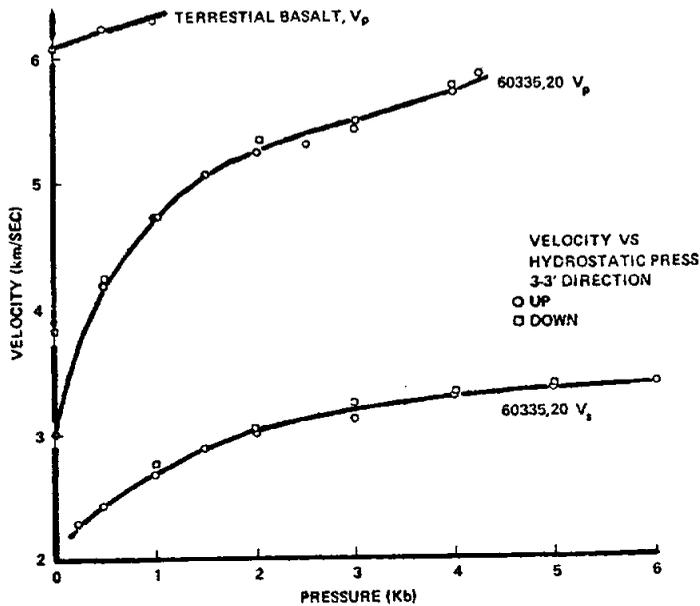


FIGURE 10. Velocity profiles; from Warren *et al.* (1973).

PROCESSING AND SUBDIVISIONS: In 1972, 60335 was cut into three main pieces, including a slab. All three of these pieces have been extensively subdivided as shown in Figure 11. Not all splits are shown. Allocations have been made from many portions of the rock.

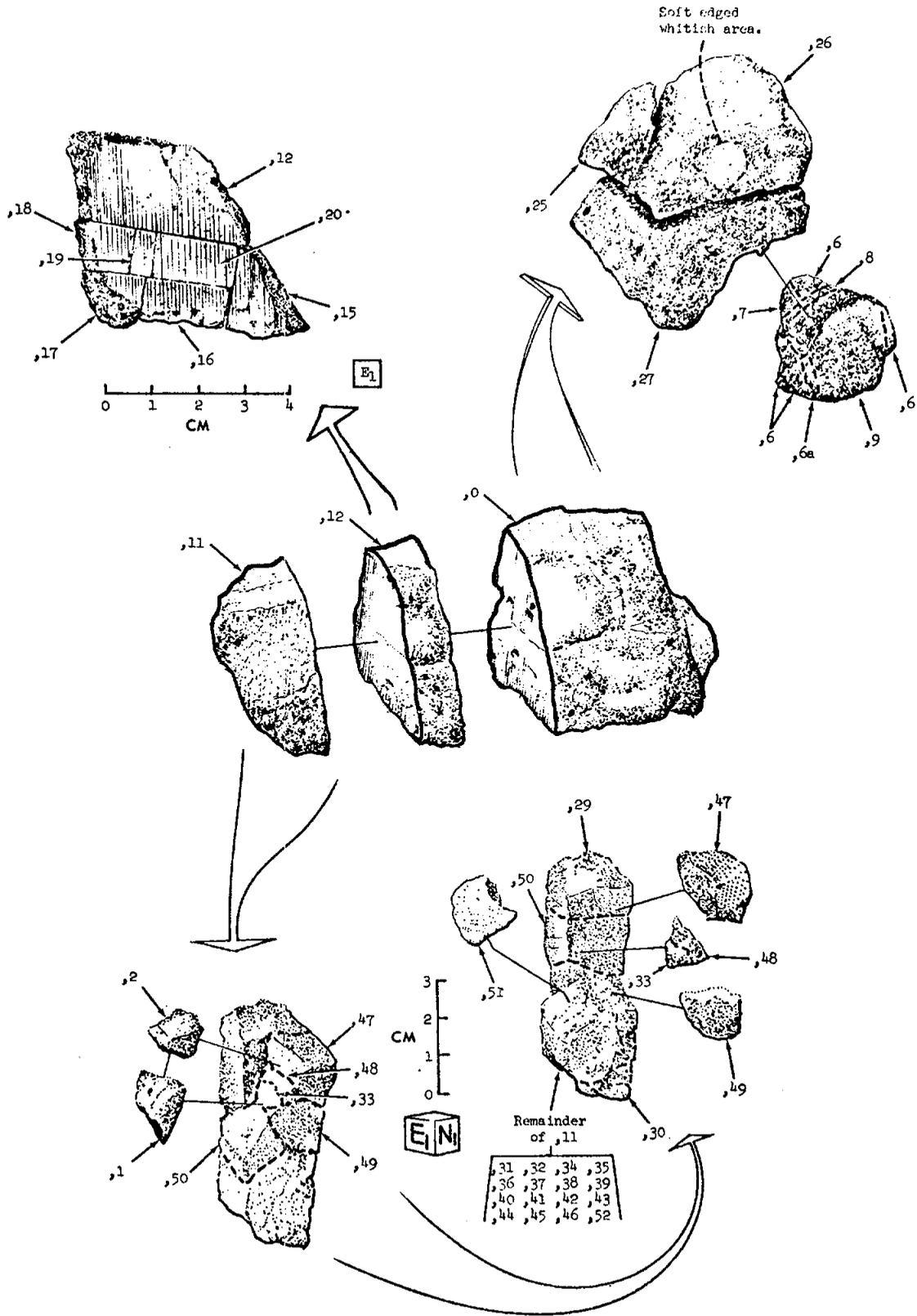


FIGURE 11. Cutting diagram.

INTRODUCTION: 60515 is a white, moderately coherent anorthosite with only minor mafic phases (Fig. 1). It is rounded with a granular, finely comminuted appearance. It is a rake sample collected 50 m southwest of the Lunar Module, and has abundant zap pits (Fig. 1).

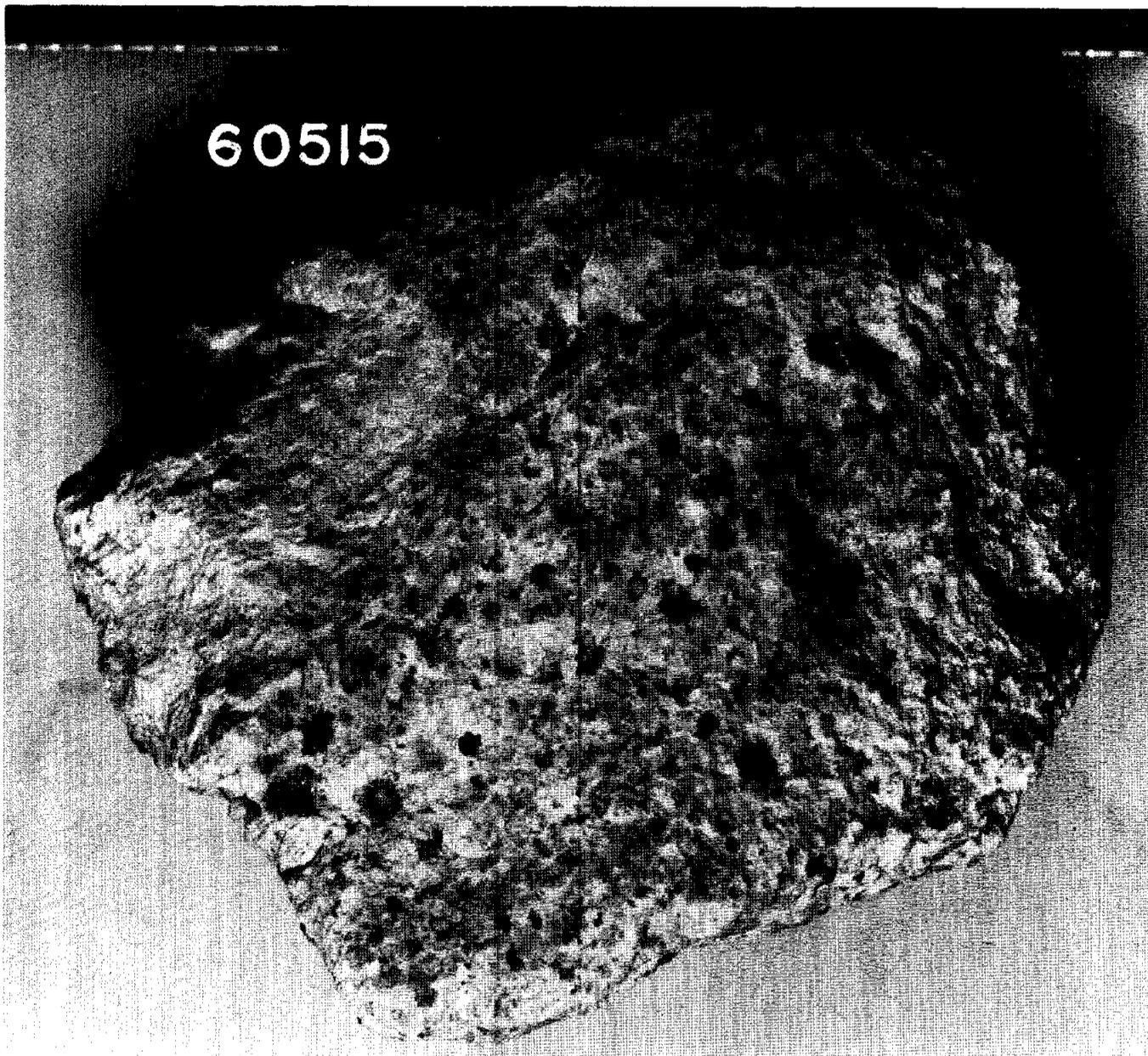


FIGURE 1.
S- 72-46333
Scale in mm.

INTRODUCTION: 60516 is a white, moderately coherent, cataclastic anorthosite (Fig. 1). It is a rake sample collected about 50 m southwest of the Lunar Module. Zap pits vary in abundance from few in some areas to many in others.

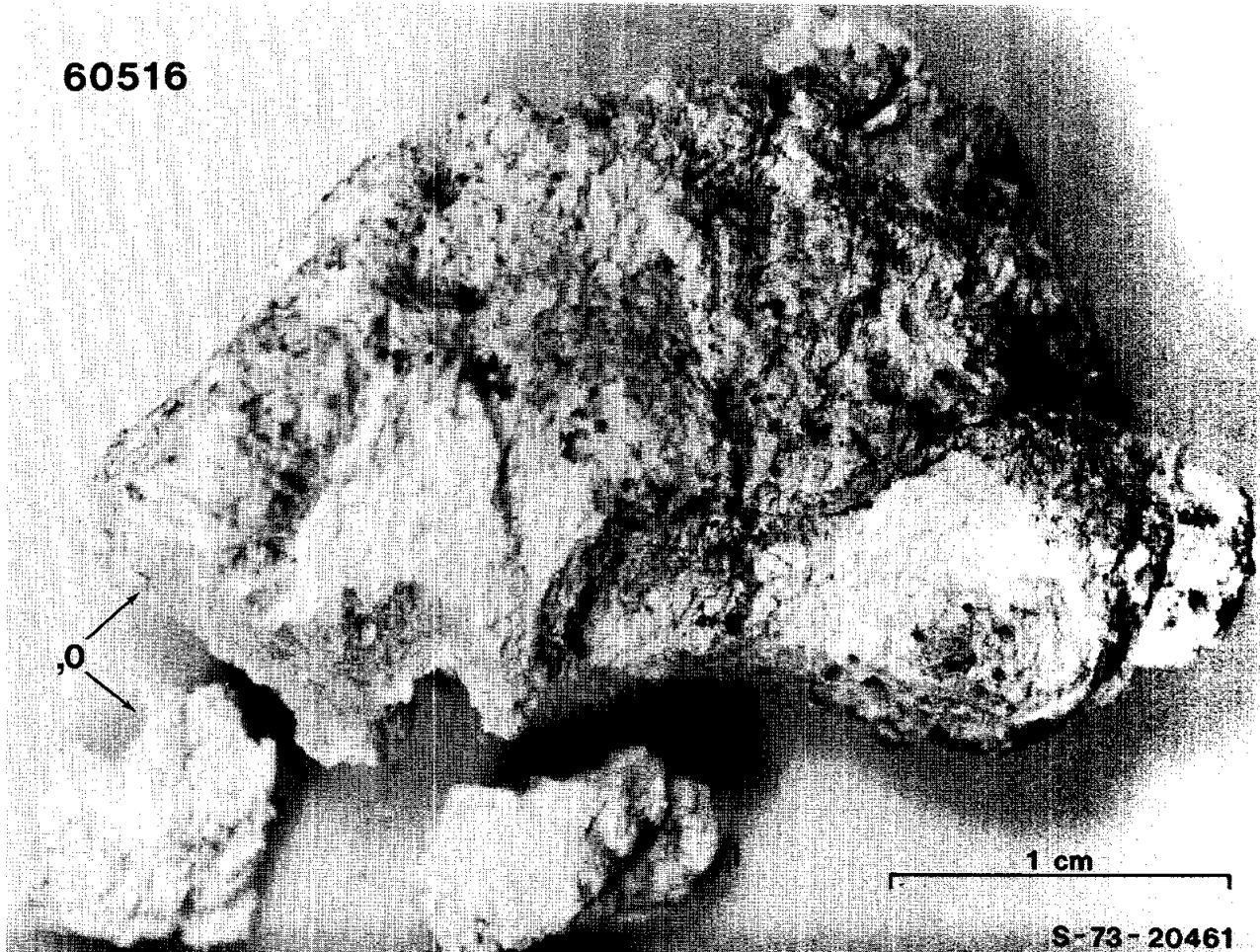


FIGURE 1.

PETROLOGY: A brief petrographic description is given by Warner et al. (1976b). 60516 is also included in a discussion of ferroan anorthosites by Dowty et al. (1974a).

The rock appears to be monomict. Angular, moderately shocked clasts of plagioclase (up to 1.5 mm) rest in a granulated matrix, which is also dominantly plagioclase (Fig. 2). Pyroxene is the only mafic mineral present and is very rare. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). The composition and equilibrated nature of the pyroxenes and the very calcic plagioclases are typical of lunar ferroan anorthosites.

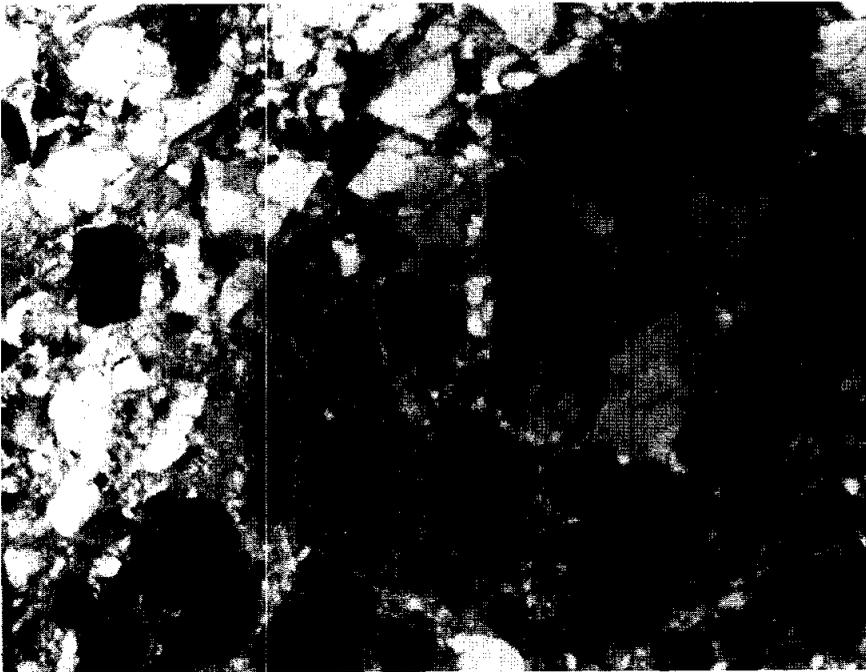


FIGURE 2. 60516,3. partly
xpl. width 3mm.

CHEMISTRY: A defocussed beam analysis (DBA) is given by Dowty et al. (1974a) and reproduced by Warner et al. (1976b) and here as Table 1. This analysis shows 60516 to be nearly pure plagioclase.

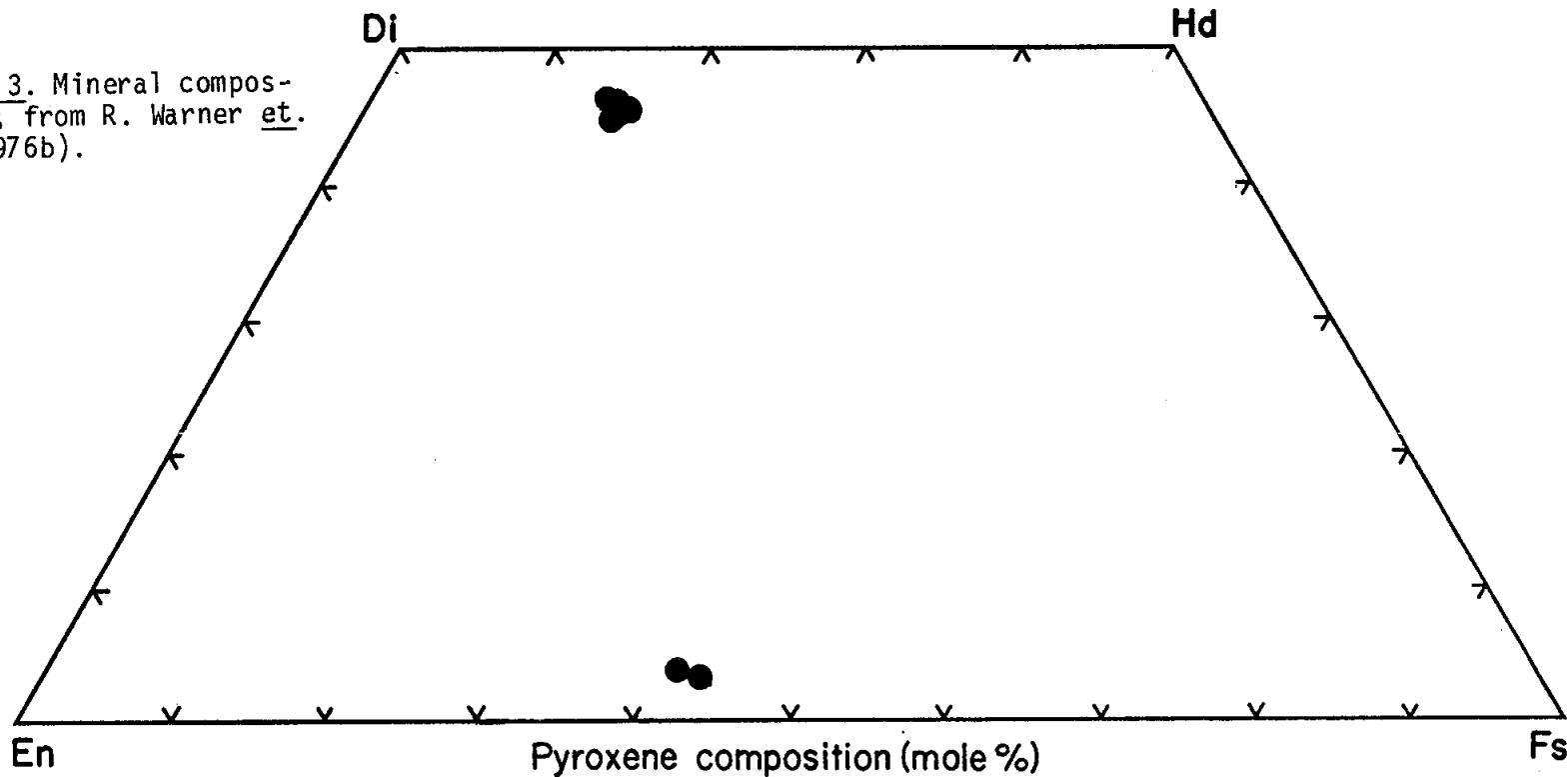
TABLE 1. Summary chemistry of 60516

(DBA, normalized to 100%)

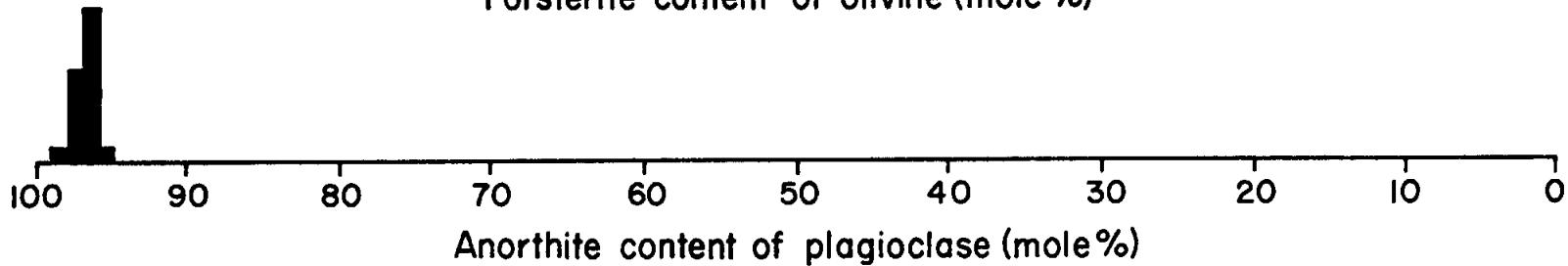
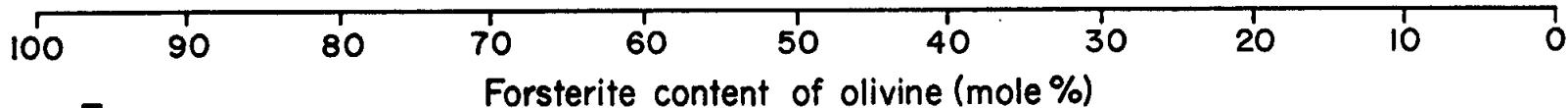
SiO ₂	44.8
Al ₂ O ₃	35.2
FeO	0.28
MgO	0.05
CaO	19.2
Na ₂ O	0.44
K ₂ O	0.01
P ₂ O ₅	0.02

PROCESSING AND SUBDIVISIONS: In 1973 ,1 was removed for thin sections (Fig.1).

FIGURE 3. Mineral compositions; from R. Warner et al. (1976b).



NO OLIVINE



INTRODUCTION: 60517 is a white, moderately coherent anorthosite with minor mafic phases (Fig. 1). It is subangular with a granular, finely comminuted appearance. The tiny (<0.05 mm) black mafic specks are scattered through the rock. It is a rake sample collected 50 m southwest of the Lunar Module. Zap pits are heterogeneously distributed.

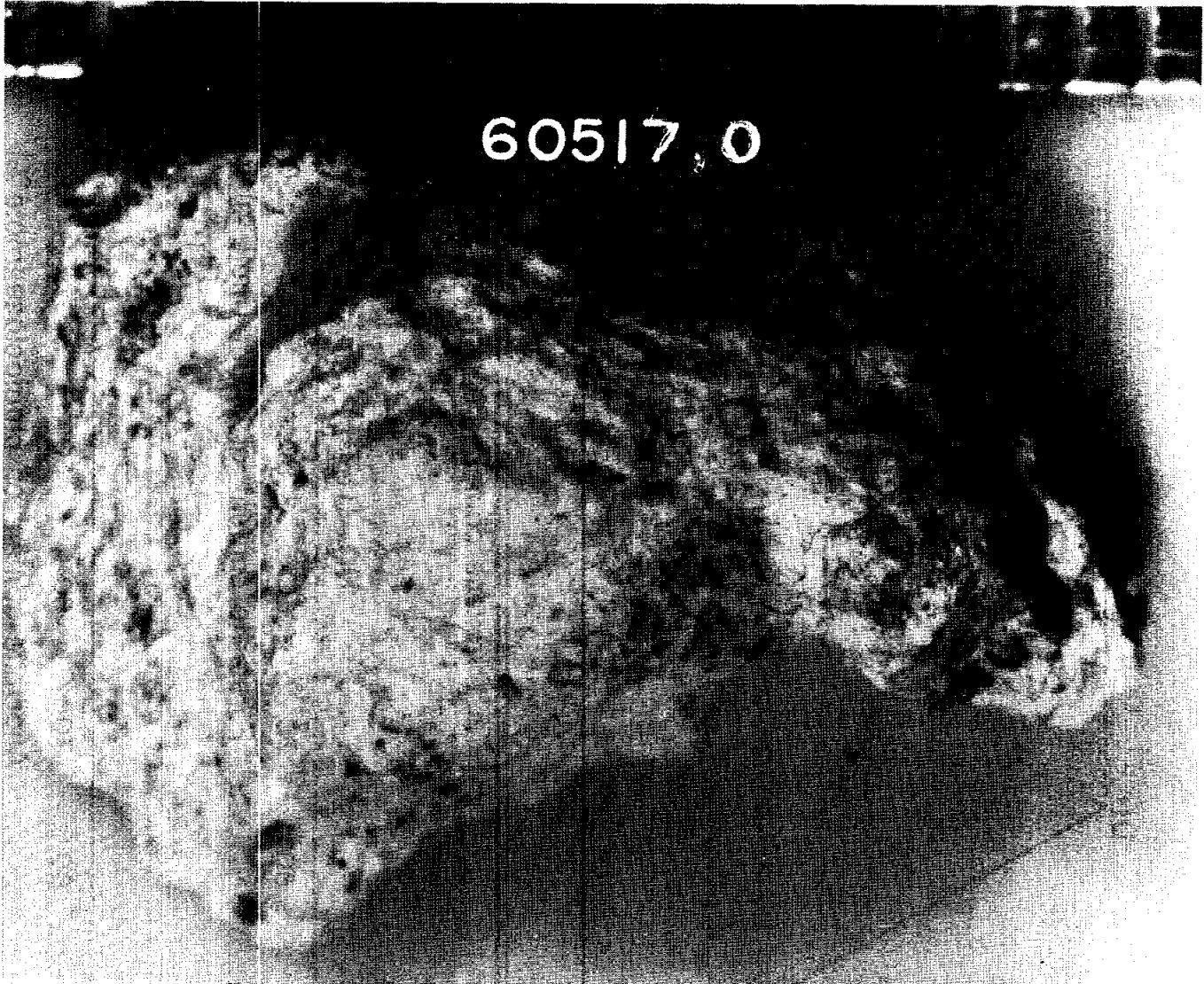


FIGURE 1. Scale in mm. S-72-46326

INTRODUCTION: 60518 is a white, moderately coherent anorthosite with only minor mafic phases (Fig. 1). It is subangular with a granular, finely comminuted appearance. The tiny (<0.05 mm) black mafic specks are scattered throughout the rock. It is a rake sample collected 50 m southwest of the Lunar Module, and has a few zap pits.

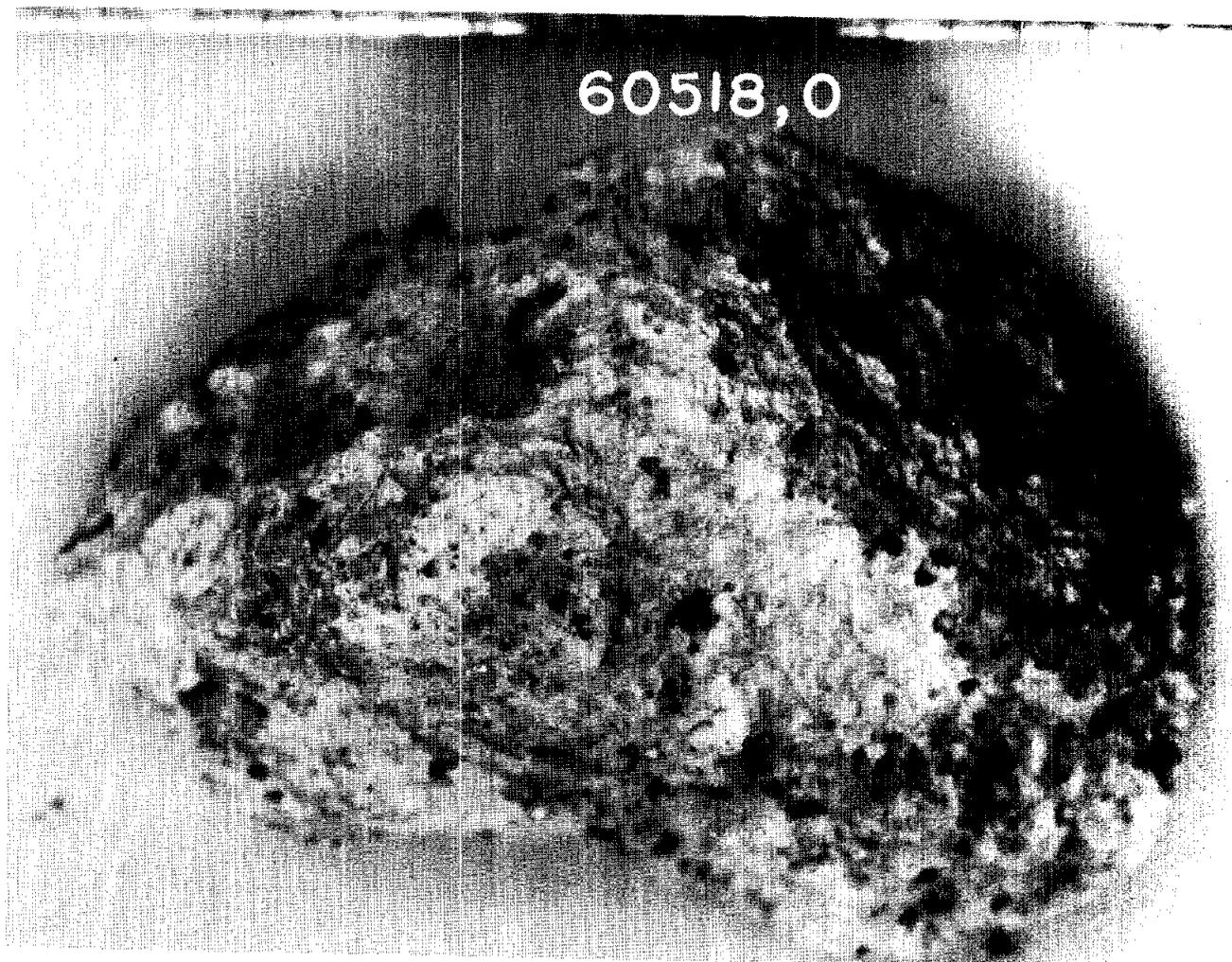


FIGURE 1. Scale in mm. S-72-46330

INTRODUCTION: 60519 is a white, moderately coherent anorthosite with only minor mafic phases (Fig. 1). It is subangular with a granular, finely comminuted appearance. The tiny (<0.05 mm) black mafic specks are scattered throughout the rock. It is a rake sample collected 50 m southwest of the Lunar Module. Zap pits and patina are rare.

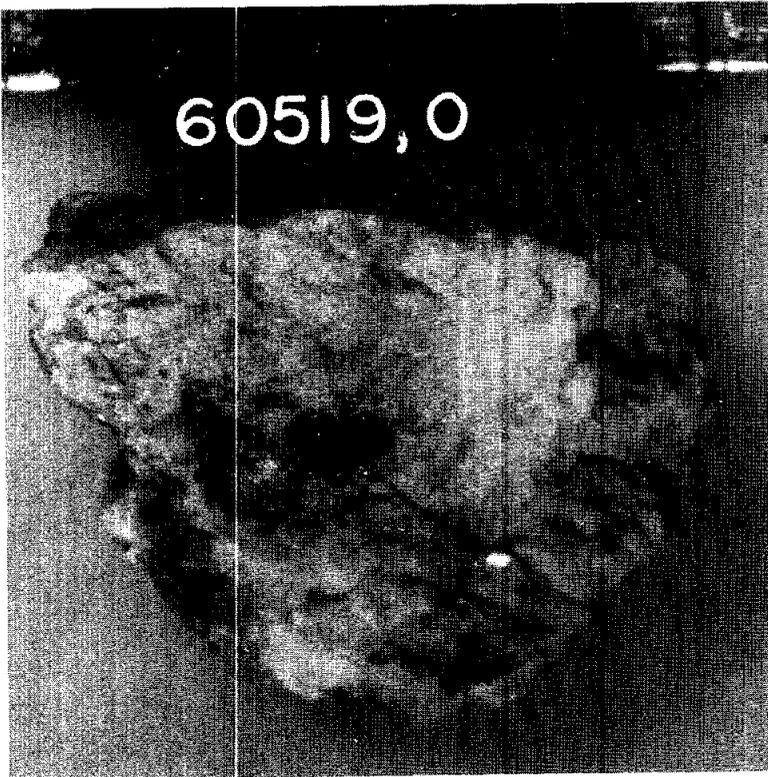


FIGURE 1. Scale in mm.
S-72-46324.

INTRODUCTION: 60525 is a medium gray, coherent, impact melt with a variable texture which is dominantly poikilitic or micropoikilitic (Fig. 1). It is a rake sample collected about 50 m southwest of the Lunar Module and has a few zap pits.



FIGURE 1.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description and mineral compositions. 60525 is texturally heterogeneous, grading from poikilitic (oikocrysts ~ 0.1 mm) to subophitic over a single thin section (Fig.2). Clasts of plagioclase, minor olivine and several lithic fragments are present. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Minor phases include spinel, ilmenite, Fe-metal (5.7-9.1% Ni, 0.4-0.6% Co), zircon and a "K-rich phase" (8-14.8%, K_2O).

CHEMISTRY: A defocussed electron beam analysis (DBA) is given by Warner et al. (1976b) and reproduced here as Table 1.

PROCESSING AND SUBDIVISIONS: In 1973 a single chip (,1) was removed for thin sections (Fig.1).

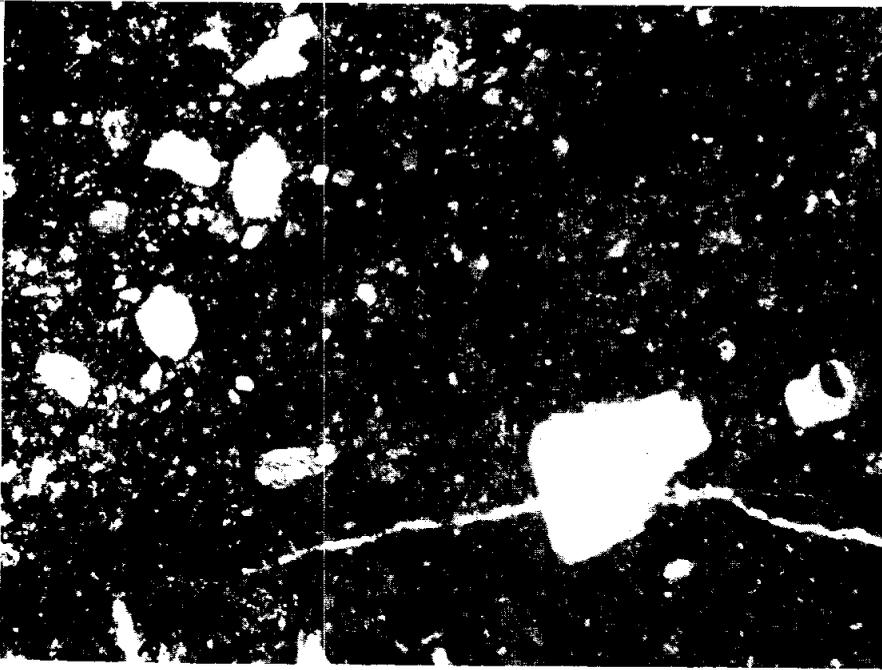


FIGURE 2. 60525,2. general view, ppl. width 3mm.

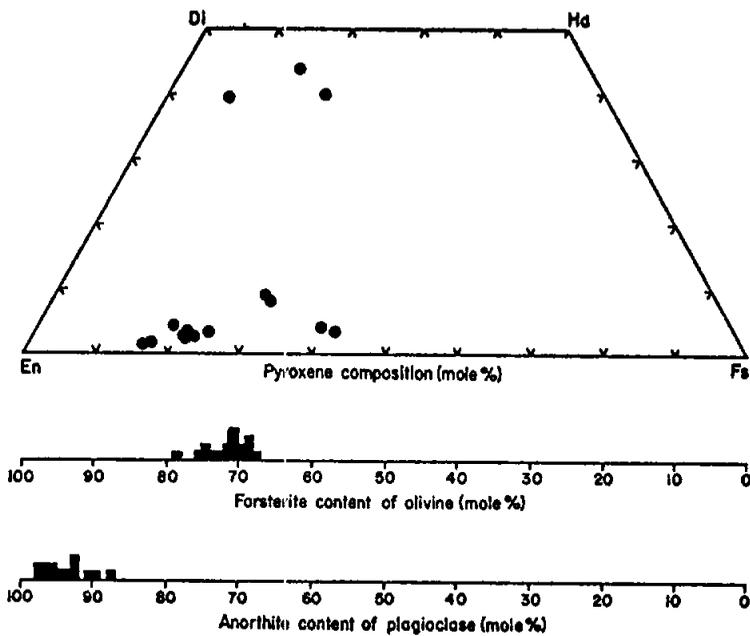


TABLE 1. Chemistry of 60525 (DBA)

SiO ₂	46.1
TiO ₂	1.05
Al ₂ O ₃	21.2
Cr ₂ O ₃	0.14
FeO	7.2
MnO	0.08
MgO	9.3
CaO	12.9
Na ₂ O	0.64
K ₂ O	0.27
P ₂ O ₅	0.26

FIGURE 3. Mineral compositions; from R. Warner et al. (1976b).

INTRODUCTION: 60526 is a medium gray, coherent, poikilitic impact melt (Fig. 1). It is a rake sample collected about 50 m southwest of the Lunar Module, and lacks zap pits. (The photograph labelled 60526 in Keil et al., 1972, p. 50 is actually of 60527; the correct photograph is on p. 62).

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description and mineral compositions. Texturally 60526 is a typical fine-grained poikilitic rock with oikocrysts ($\sim 0.3 \times 0.15$ mm) of dominantly low-Ca pyroxene enclosing abundant euhedral to subhedral plagioclase (Fig. 2). Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Accessory phases include ilmenite, armalcolite and Fe-metal (4.4-6.1% Ni, 0.3% Co).

CHEMISTRY: A defocussed electron beam analysis (DBA) presented by Warner et al. (1976b) is reproduced here as Table 1. 60526 is compositionally very similar to the well-studied poikilitic rocks such as 60315.

PROCESSING AND SUBDIVISIONS: In 1973 ,1 was removed for thin sections. In 1978 ,4 was allocated for chemistry (Fig. 1).



FIGURE 1. Large scale division in cm. S-78-27394.

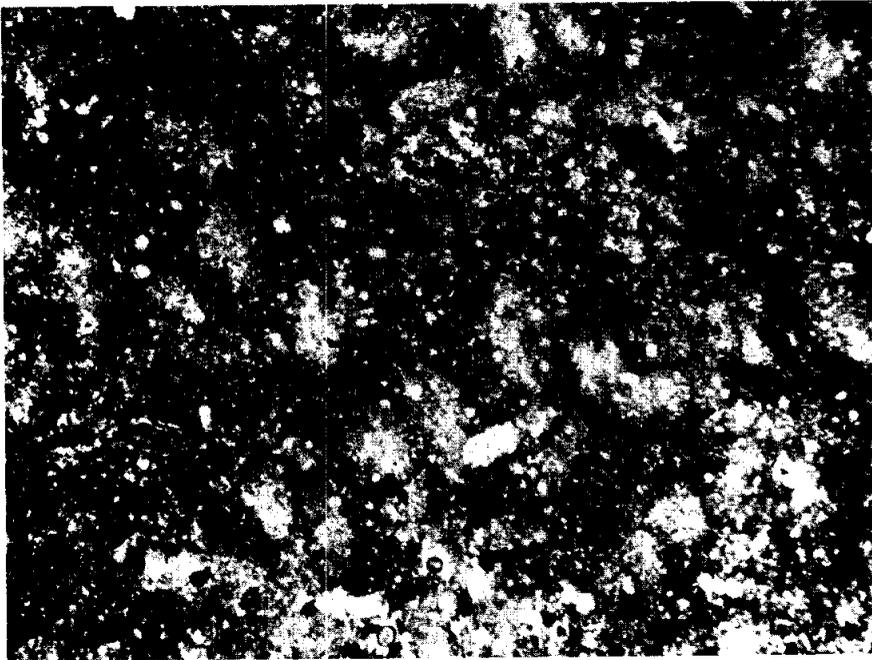


FIGURE 2. 60526,3. general view, xpl. width 3mm.

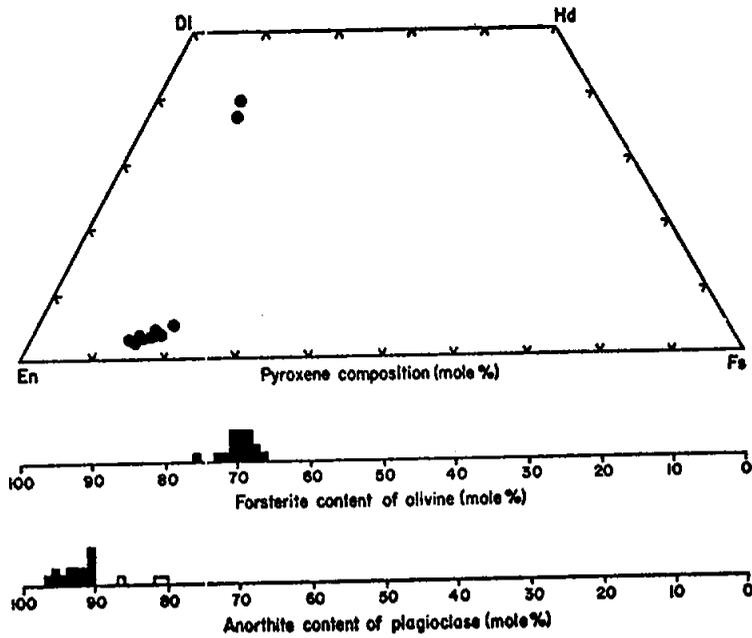


TABLE 1. Chemistry of 60526 (DBA)

SiO ₂	47.5
TiO ₂	1.40
Al ₂ O ₃	17.4
Cr ₂ O ₃	0.17
FeO	8.9
MnO	0.09
MgO	13.5
CaO	10.8
Na ₂ O	0.71
K ₂ O	0.45
P ₂ O ₅	0.44

FIGURE 3. Mineral compositions; from R. Warner et al. (1976b).

INTRODUCTION: 60527 consists of a rectangular clast of coherent, crystalline rock thickly coated by highly vesicular, glassy impact melt and a separate piece of vesicular glass (Fig. 1). The rectangular clast has ~50% white material (in grains <0.05 mm long) embedded in dark material and is possibly a poikilitic impact melt. The glassy coat contains rare white clasts (~0.7 mm long). It is a rake sample collected 50 m southwest of the Lunar Module and has rare zap pits. (The photograph labelled 60527 in Keil *et al.*, 1972, p. 40, is actually 60528; the correct photograph is on p. 50).

PROCESSING AND SUBDIVISIONS: This rock was removed from its documented bag as two pieces which were numbered together as 60527.

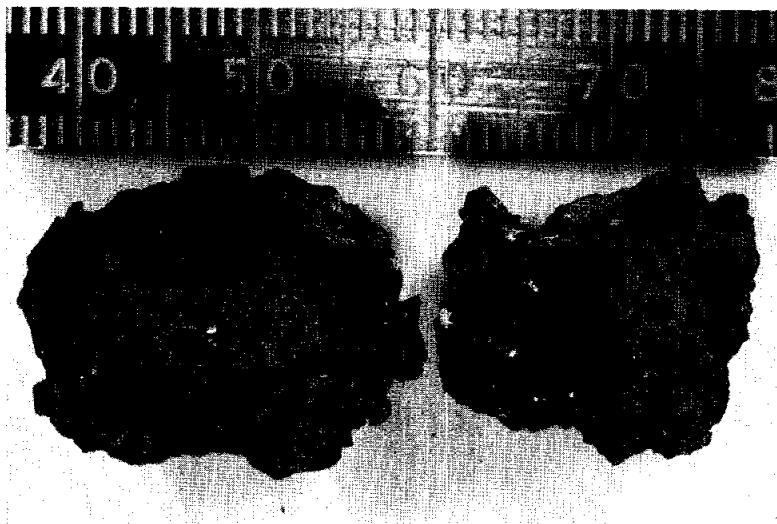


FIGURE 1.

Scale in mm.

INTRODUCTION: 60528 is a medium gray, coherent, glassy impact melt with several small (<1.5 mm) white clasts (Fig. 1). This rake sample is very irregular in shape with abundant vesicles and rare zap pits and was collected about 50 m southwest of the Lunar Module. (The photograph labelled 60528 in Keil et al., 1972, p. 61 is actually of 60529; the correct photograph is on p. 40).



FIGURE 1.

Scale in mm.

INTRODUCTION: 60529 is a medium gray, coherent basaltic impact melt (Fig. 1). It is angular with ~10% vesicles. It is a rake sample collected about 50 m southwest of the Lunar Module and has rare zap pits. (The photograph labelled 60529 in Keil *et al.*, 1972, p. 62 is actually of 60526; the correct photograph is on p. 61).

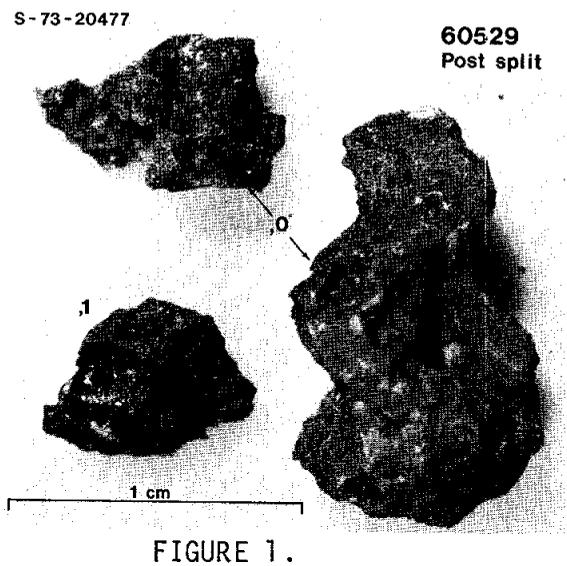


FIGURE 1.

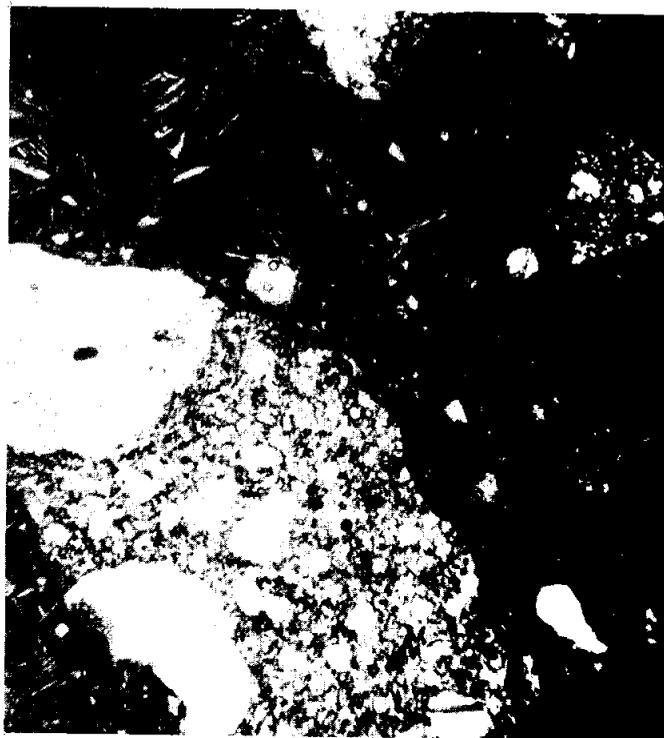


FIGURE 2. 60529,2. general view, ppl. width 2mm.

PETROLOGY: Warner *et al.* (1976b) provide a brief petrographic description. The matrix of 60529 is a very fine-grained impact melt with spherulitic needles of plagioclase separated by a cryptocrystalline to glassy mesostasis (Fig.2). Lithic clasts include breccia fragments and a few anorthosites, all of which show evidence of assimilation into the melt. Mineral clasts are relatively rare and also show evidence of assimilation.

PROCESSING AND SUBDIVISIONS: In 1973 two small chips were removed from this rock. One of these chips was allocated for thin sections as ,1 (Fig.1).

INTRODUCTION: 60535 is a medium gray, coherent, possibly regolith breccia (Fig. 1). One surface is coated with glass and another has a sheared appearance. It is a rake sample collected 50 m southwest of the Lunar Module. Zap pits are heterogeneously distributed from abundant on one side to very few of the others.

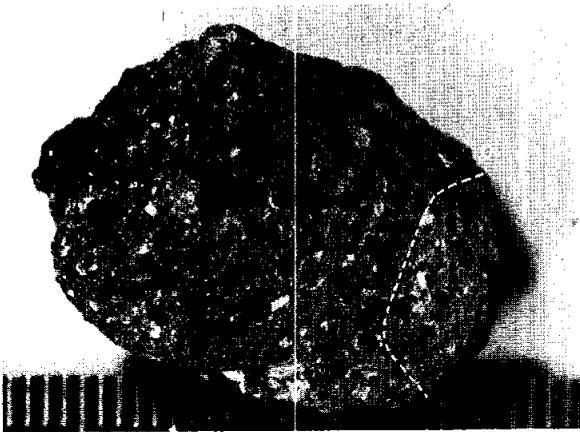


FIGURE 1.

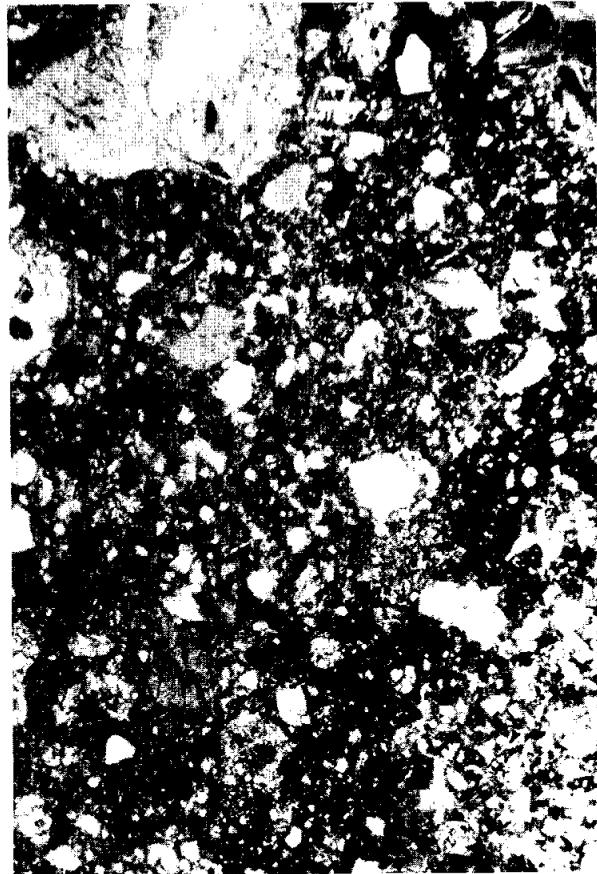


FIGURE 2. 60535,2. general view, ppl. width 2mm.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description. The matrix of 60535 is very porous and is composed of a heterogeneous mixture of mineral, lithic and glass fragments welded together by a small amount of glass. Lithic clasts include a variety of breccias, several poikilitic rocks and several anorthositic fragments. Numerous clasts of glass are also present including one 1.5 mm long shard noted by Warner et al. (1976b).

PROCESSING AND SUBDIVISIONS: . In 1973, three small chips were pried from one end of the rock. Two of these chips were allocated for thin sections as ,1 (Fig.1).

INTRODUCTION: 60615 is a light gray, coherent, basaltic impact melt. Irregularly shaped vugs (up to 13 mm across) are common (Fig. 1). Small, very thin areas of glass partially coat one surface. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are heterogeneously distributed.

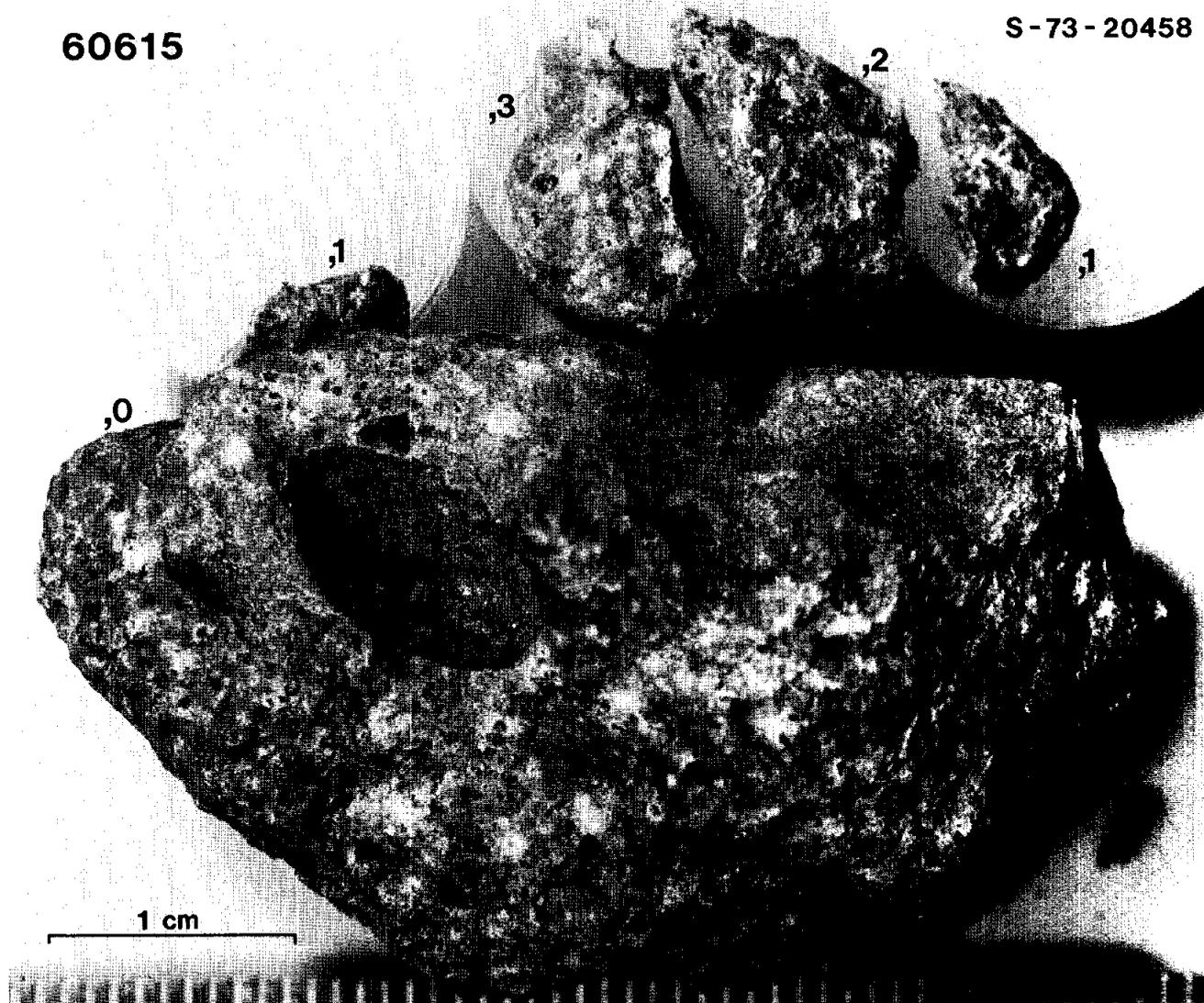


FIGURE 1.

PETROLOGY: Dowty et al. (1974b) and Warner et al. (1976b) provide petrographic descriptions. Mineral analyses are tabulated by Dowty et al. (1976). The texture of 60615 is predominantly intergranular with olivine and pyroxene confined to interstices between fine (~ 0.1 mm) plagioclase laths (Fig. 2). Mafic minerals are unusually magnesian (Fig. 3). Plagioclase laths and xenocrysts are of the same composition. Accessory phases include ilmenite, armalcolite, rutile, Fe-metal (4.3-13.6% Ni, 0.6-1.03% Co), schreibersite and troilite. Angular xenocrysts of plagioclase account for $\sim 4\%$ of the rock. One "breccia" clast is noted by Warner et al. (1976b).



FIGURE 2. 60615,8. xpl.
width 2mm.

TABLE 1. Summary chemistry of 60615

SiO ₂	44.9
TiO ₂	0.52
Al ₂ O ₃	21.8
Cr ₂ O ₃	0.144
FeO	5.3
MnO	0.071
MgO	14.2
CaO	12.5
Na ₂ O	0.386
K ₂ O	0.13
P ₂ O ₅	0.09
Sr	
La	16.9
Lu	0.77
Rb	
Sc	9.0
Ni	490
Co	32
Ir ppb	9
Au ppb	8
C	
N	
S	
Zn	
Cu	

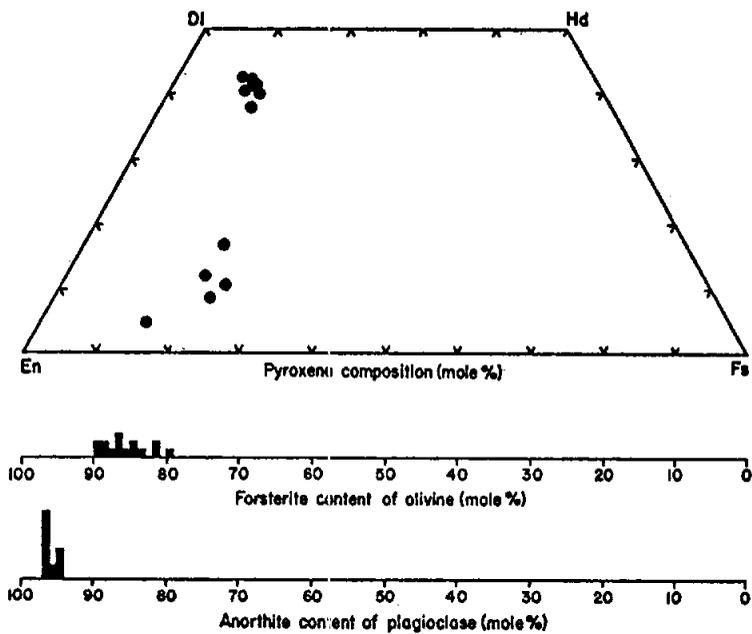


FIGURE 3. Mineral compositions; from
R. Warner et al. (1976b).

Oxides in wt%; others in ppm except as noted.

CHEMISTRY: Major and trace element abundances are reported by Laul and Schmitt (1973). A defocussed electron beam analysis (DBA) of a thin section is presented by Dowty et al. (1974b) and reproduced by Warner et al. (1976b).

60615 is somewhat less aluminous than most other basaltic impact melts from Apollo 16 (Table 1). The bulk Mg/Fe is quite high as reflected in the mineral compositions. Rare earth elements are slightly enriched compared to local soils. Siderophiles indicate a significant meteoritic component.

PROCESSING AND SUBDIVISIONS: In 1973 representative chips were removed and allocated for thin sections and petrography (,1), chemistry (,2) and for isotopic analyses (,3).

INTRODUCTION: 60616 is a medium gray, coherent, poikilitic impact melt (Fig.1). It is a rake sample collected about 70 m west southwest of the Lunar Module and lacks zap pits.

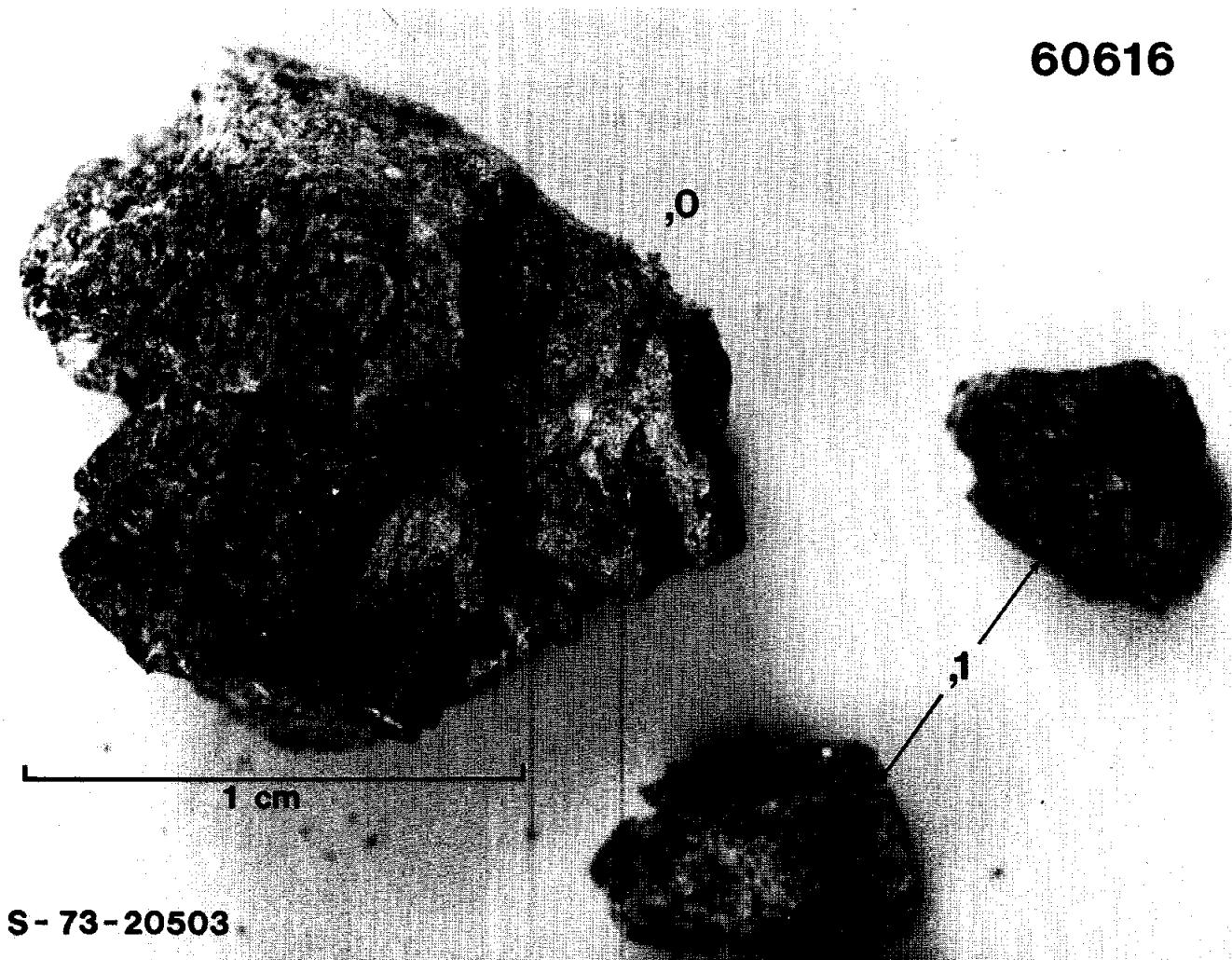


FIGURE 1.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description and mineral compositions. Oikocrysts are less abundant in 60616 than in most other poikilitic rocks, enclosing only ~ 60-70% of the area of the section (Fig.2). Inter-oikocryst areas have a subophitic texture. Clasts are predominantly plagioclase and are abundant. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Minor phases include ilmenite and Fe-metal (6.1-8% Ni, 0.3-0.4% Co).

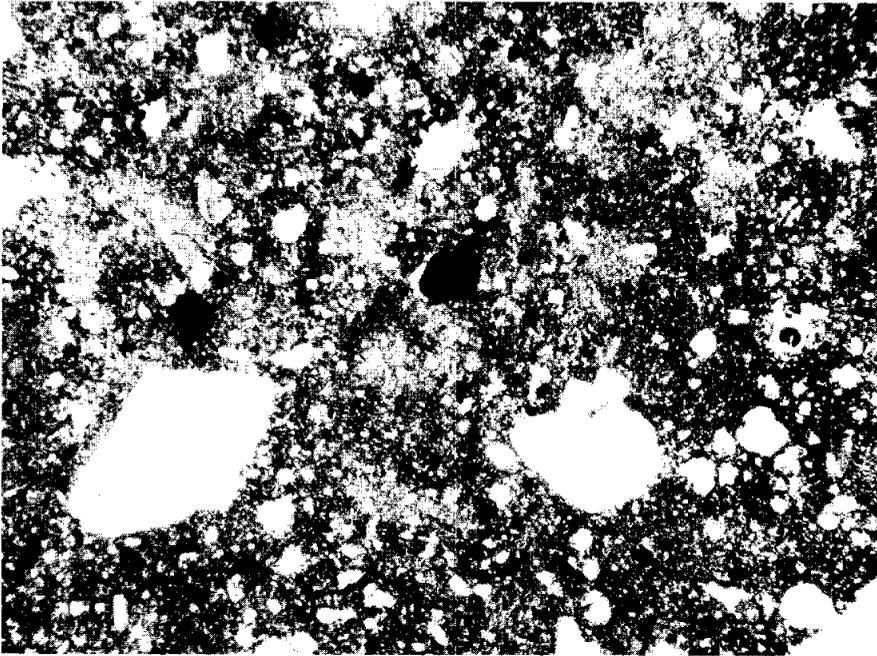


FIGURE 2. 60616,2. ppl.
width 3mm.

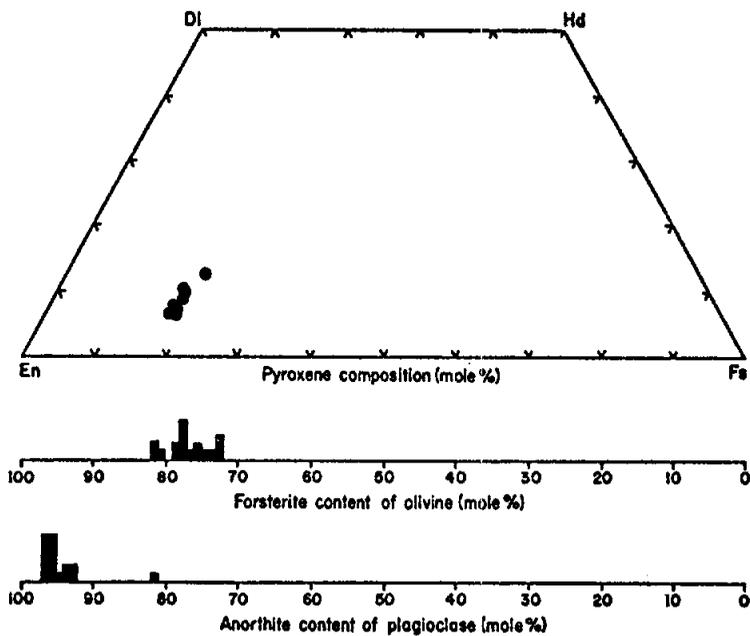


TABLE 1. Chemistry of 60616 (DBA)

SiO ₂	45.5
TiO ₂	0.68
Al ₂ O ₃	24.5
Cr ₂ O ₃	0.11
FeO	5.9
MnO	0.06
MgO	8.3
CaO	14.3
Na ₂ O	0.56
K ₂ O	0.20
P ₂ O ₅	0.22

FIGURE 3. Mineral compositions; from R. Warner *et al.* (1976b).

CHEMISTRY: A defocused electron beam analysis (DBA) is given by Warner *et al.* (1976b) and reproduced here as Table 1. 60616 is more aluminous than most other Apollo 16 poikilitic rocks.

PROCESSING AND SUBDIVISIONS: In 1973, two chips (,1) were allocated for thin sections (Fig.1).

INTRODUCTION: 60617 is a medium gray, coherent, impact melt (Fig. 1). It is subangular with a few small areas of dark splash glass. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.

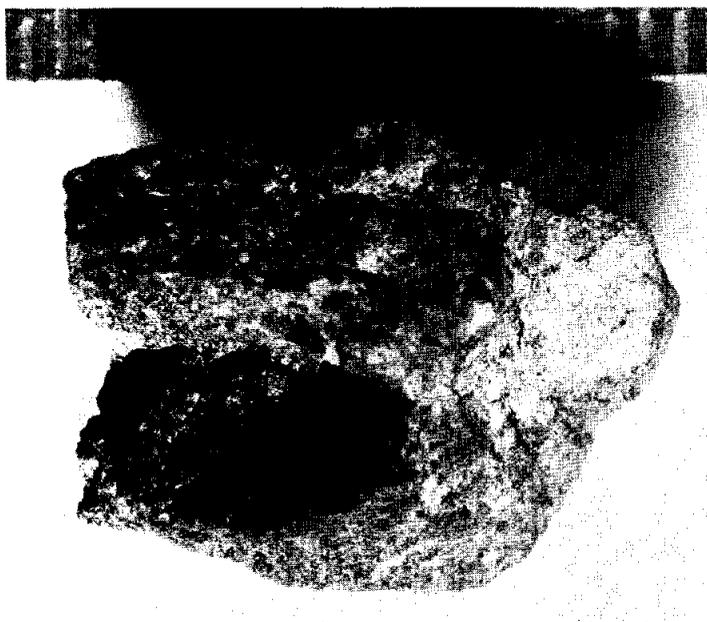


FIGURE 1.
Scale in mm.

INTRODUCTION: 60618 is a tough, light gray rake sample consisting of basaltic impact melt and cataclastic anorthosite (Fig. 1). The anorthosite is not ferroan. Possible clast-matrix relations have not been determined but the anorthosites are probably clasts in the basalt. A few 2-3 mm vesicles are present, some of which appear to be lined with metal.

60618 is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.



FIGURE 1.

PETROLOGY: Two distinct lithologies, a coarse-grained, cataclastic spinel-bearing anorthosite and a finer-grained basaltic melt have been recognized in this rock. Petrographic descriptions are given by Dowty et al. (1974a,b) and Warner et al. (1976b).

The anorthosite described by Dowty et al. (1974a) and Warner et al. (1976b) consists of a single large (2x3 mm) plagioclase crystal in a granulated matrix of feldspar, minor olivine, spinel, pyroxene, ilmenite, metal (6.1% Ni, 1.3% Co), and schreibersite (Fig. 2). Pyroxene occurs mainly in fine veins that cut both the large crystal and the matrix. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976), and show that the anorthosite has much more magnesian mafic minerals than typical ferroan anorthosites.

a



FIGURE 2.

a) 60618,4. cataclastic anorthosite, xpl. width 3mm.

b) 60618,3. basaltic melt, xpl. width 3mm.

b



The basaltic impact melt portion consists of many equant, but somewhat irregular, relict plagioclase grains (~ 0.5 mm) in a subophitic melt matrix of plagioclase laths (up to 0.5 mm long), olivine, and pyroxene (Fig. 2). Mineral compositions are shown in Figure 4 and tabulated by Dowty et al. (1976). Accessory minerals include ilmenite, armalcolite, Fe-metal (2.5-6.9% Ni, 0.6-1.2% Co), schreibersite, and troilite.

Meyer (1979) reports ion probe analyses of minor elements in plagioclase from an unspecified section of the rock (Table 1).

TABLE 1

Minor elements in 60618 plagioclase (ppm) (Meyer, 1979)

<u>Li</u>	<u>Mg</u>	<u>Ba</u>
4	800	16

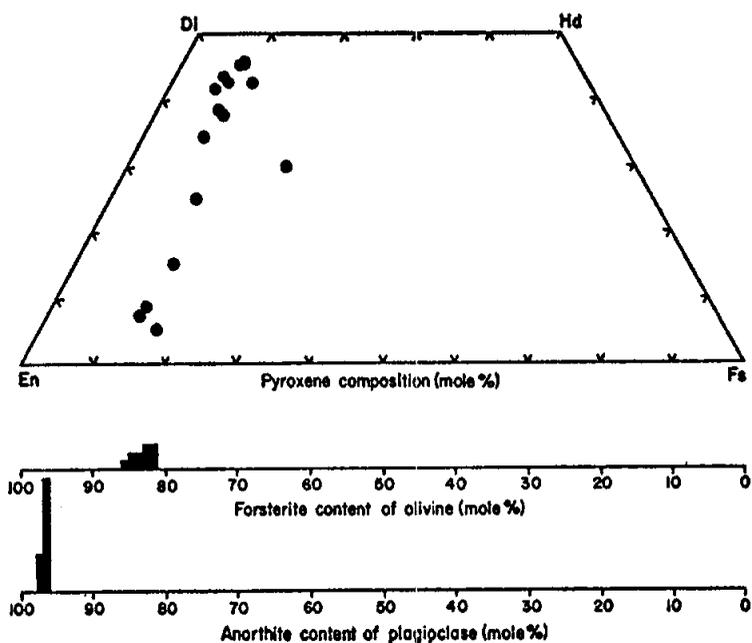


FIGURE 3. Anorthosite mineral compositions; from R. Warner et al. (1976b).

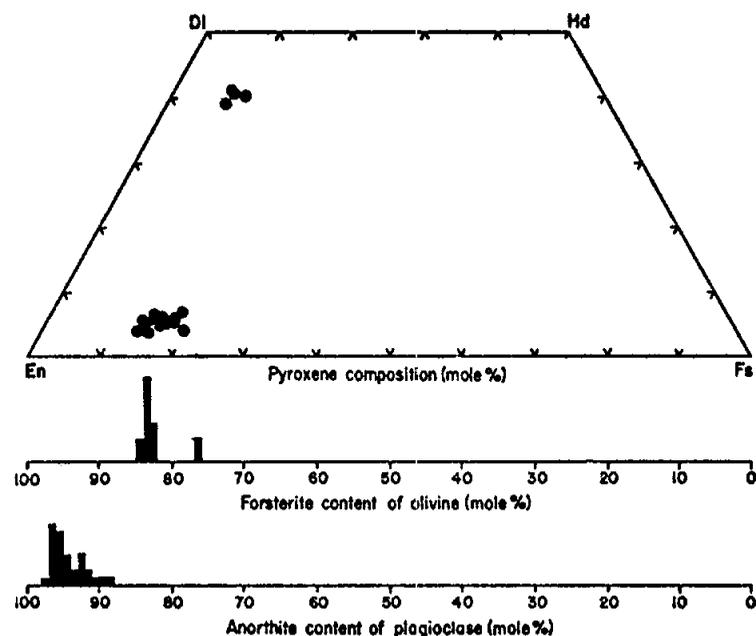


FIGURE 4. Basaltic melt mineral compositions; from R. Warner et al. (1976b).

CHEMISTRY: Major and trace element analyses of the anorthositic and the basaltic melt portions are given by Murali et al. (1977) and Ehmann et al. (1975). Eldridge et al. (1975) report whole rock abundances of natural and cosmogenic radionuclides. Jovanovic and Reed (1976b) provide halogen and other trace element abundances for a split probably rich in anorthosite. Microprobe defocused beam analyses (DBA) of each lithology are reported by Dowty et al. (1974a,b) and Warner et al. (1976b). Ca and K abundances of an anorthosite-rich split are given by Schaeffer and Schaeffer (1977) in an Ar isotopic study.

Whole rock abundances of K, U, and Th show that the rock is very low in incompatible elements (K 670 ppm, U 0.28 ppm, Th 0.63 ppm). Eldridge *et al.* (1975) note the unusually low Th/U ratio (2.3) of this rock.

The anorthositic material is nearly pure plagioclase, with low abundances of incompatible elements (Table 2). Siderophile element abundances indicate meteoritic contamination.

The basaltic melt portions are less aluminous and have higher levels of incompatible elements than the anorthositic material (Table 2).

TABLE 2 Summary chemistry of 60618 lithologies

	<u>Anorthosite</u>	<u>Basaltic impact melt</u>
SiO ₂	44.3	45.8
TiO ₂	0.03	0.27
Al ₂ O ₃	33.2	28.8
Cr ₂ O ₃	0.01	0.061
FeO	1.1	2.0
MnO	0.02	0.03
MgO	3.4	4.9
CaO	16.9	15.9
Na ₂ O	0.40	0.49
K ₂ O	0.047	0.15
P ₂ O ₅	0.009	
Sr		
La	3.2	6.0
Lu	0.13	0.29
Rb		
Sc	1.5	3.2
Ni	228	50
Co	12	4.1
Ir ppb	5	
Au ppb	3	15
C		
N		
S		
Zn		
Cu		

Oxides in wt%; others in ppm except as noted.

RADIOGENIC ISOTOPES/GEOCHRONOLOGY: Schaeffer and Schaeffer (1977) report an ^{40}Ar - ^{39}Ar plateau age of 4.00 ± 0.02 b.y. over the 900-1100°C temperature interval (Fig. 5). Large losses of low temperature Ar with an age of ~ 2.17 b.y. are also noted.

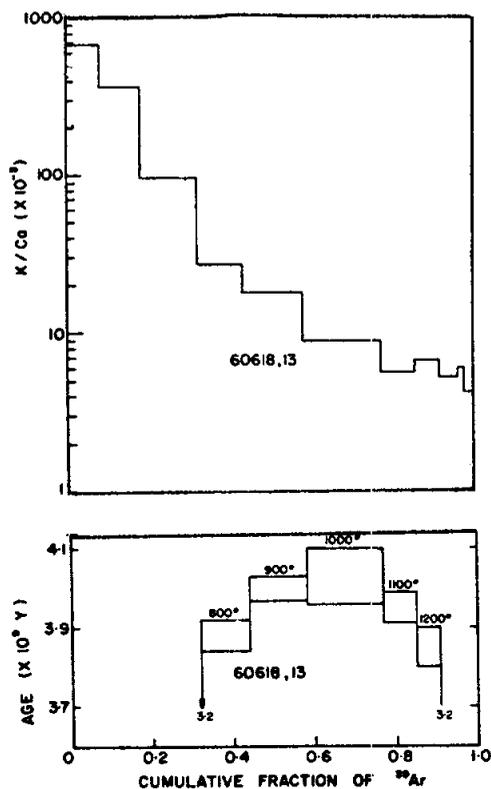


FIGURE 5. Ar release; from Schaeffer and Schaeffer (1977).

RARE GASES/EXPOSURE AGES: Whole rock ^{22}Na and ^{26}Al data indicate that 60618 is probably saturated in ^{26}Al activity (Eldridge et al., 1975). Excess ^{38}Ar at all temperatures preclude the calculation of an Ar exposure age (Schaeffer and Schaeffer, 1977).

PROCESSING AND SUBDIVISIONS: In 1973, the pieces of 60618 were numbered ,8 - ,11 (Fig. 1). The melt rock splits came from ,9. The anorthosite splits were taken from ,10.

INTRODUCTION: 60619 is a coherent, light gray anorthosite that has been extensively recrystallized to a granoblastic texture. A small amount of dark splash glass is present on some surfaces (Fig. 1). 60619 is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are heterogeneously distributed.

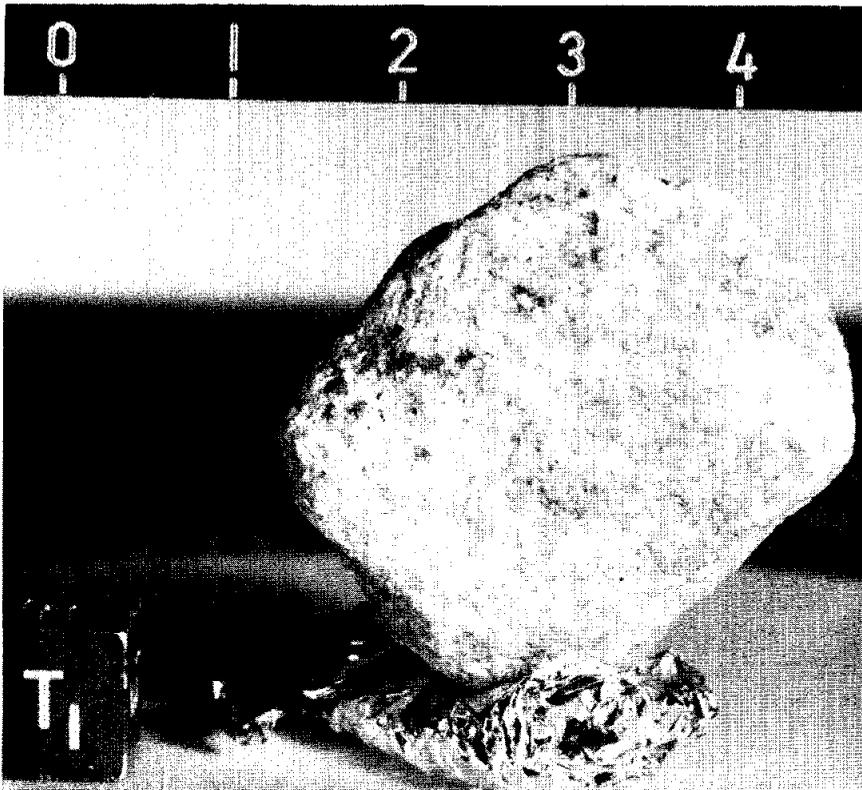


FIGURE 1.

S-72-43473. Scale
in cm.

PETROLOGY: Petrographic descriptions are given by Dowty et al. (1974a) and Warner et al. (1976b). Accurate electron microprobe analyses of Na, Fe, Mg and K in 60619 plagioclases are given by Hansen et al. (1979a).

The granoblastic texture (Fig. 2) of 60619 is indicative of extensive recrystallization. Small (<0.2 mm), anhedral grains of plagioclase have smooth boundaries and meet in triple junctions. Anhedral mafic minerals occur (i) in these triple junctions, (ii) as inclusions in plagioclase, and (iii) as somewhat larger grains partially enclosing some plagioclase. Mineral compositions are shown in Figure 3 and tabulated in Dowty et al. (1976).



FIGURE 2. 60619,2.
granoblastic anorth-
osite, partly xpl.
width 3mm.

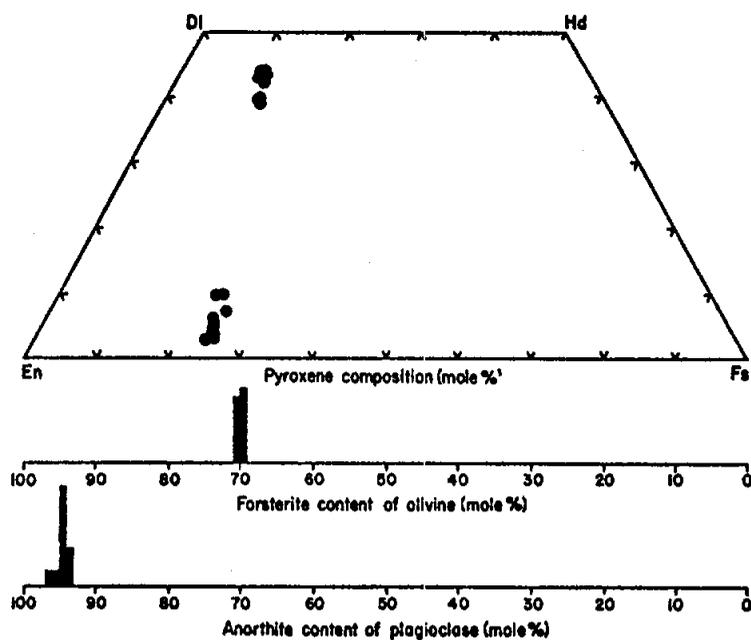


Figure 3. Mineral compositions,
from R. Warner et al. (1976b).

TABLE 1. Chemistry of 60619 (DBA)

SiO ₂	44.6
TiO ₂	0.06
Al ₂ O ₃	32.9
Cr ₂ O ₃	0.01
FeO	1.20
MnO	0.01
MgO	1.68
CaO	17.8
Na ₂ O	0.63
K ₂ O	0.04
P ₂ O ₅	0.03

CHEMISTRY: A defocussed electron beam analysis (DBA) is presented by Dowty et al. (1974a) and reproduced in Warner et al. (1976b) and here as Table 1.

PROCESSING AND SUBDIVISIONS: In 1973 two small chips (,1) were taken for thin sections (Fig. 1).

INTRODUCTION: 60625 is a light gray poikilitic rake sample with rusty patches. It is fairly friable, rounded and covered with zap pits (Fig. 1). Because it is a rake sample, its orientation is unknown. It was collected about 70 m west-southwest of the Lunar Module.

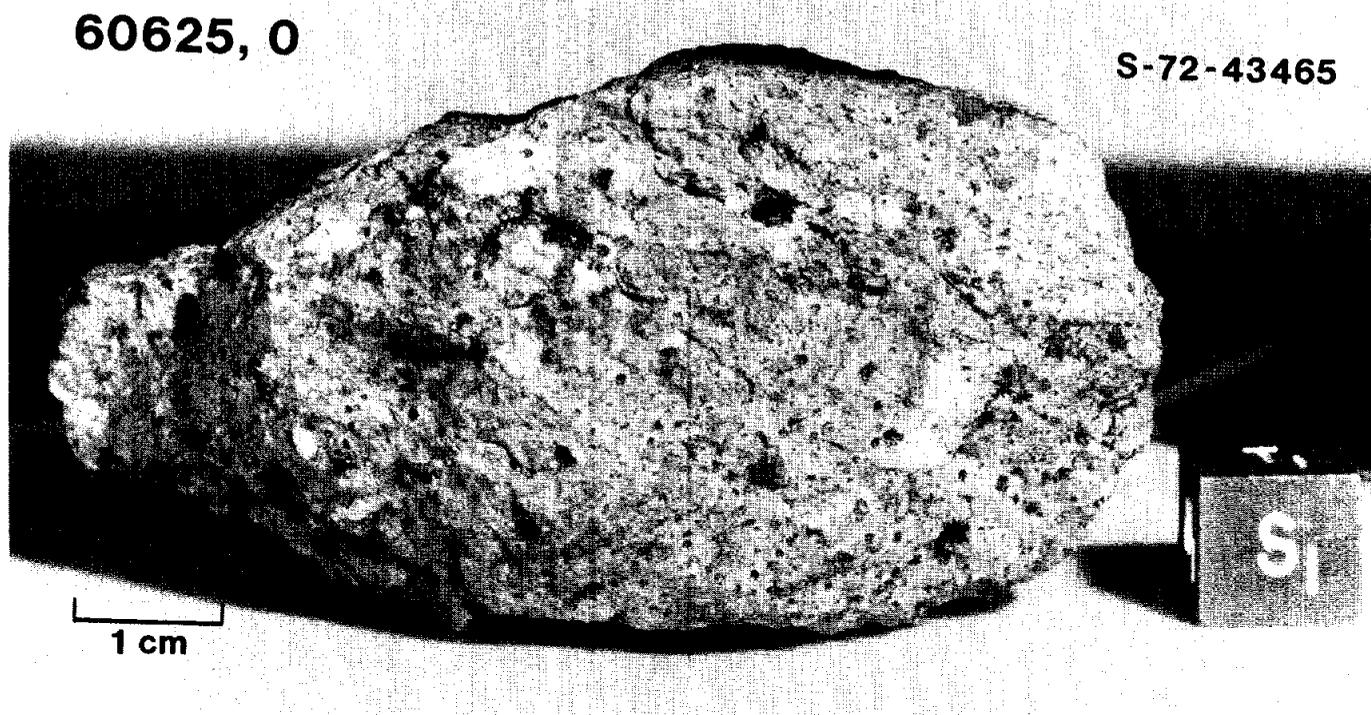


FIGURE 1.

PETROLOGY: Mineral analyses and a brief petrographic description are provided by Warner et al. (1976b). 60625 was listed as a rusty rock by L.A. Taylor et al. (1973b).

60625 has a poikilitic texture (Fig. 2) with most oikocrysts (mafic minerals) about 500 μm long and slightly elongated. The oikocrysts enclose lathy plagioclase chadacrysts (Fig. 2). The overall texture is diffuse because the oikocrysts also contain abundant glassy or cryptocrystalline areas, unlike the better-studied poikilitic rocks such as 60315. The interoikocryst areas are extremely narrow and contain opaque minerals, plagioclase and glass. Analyses of pyroxenes, olivines, and plagioclases are summarized in Figure 3. Warner et al. (1976b) also present compositional data for ilmenite ($\sim 9\%$ MgO), armalcolite ($\sim 9\%$ MgO, $\sim 2\%$ ZrO₂), Fe-metal ($\sim 0.45\%$ Co, 3-10% Ni) and K-rich phases (8-14% K₂O). A few lithic and plagioclase clasts are present, most of which are shocked; mafic mineral clasts are rare.

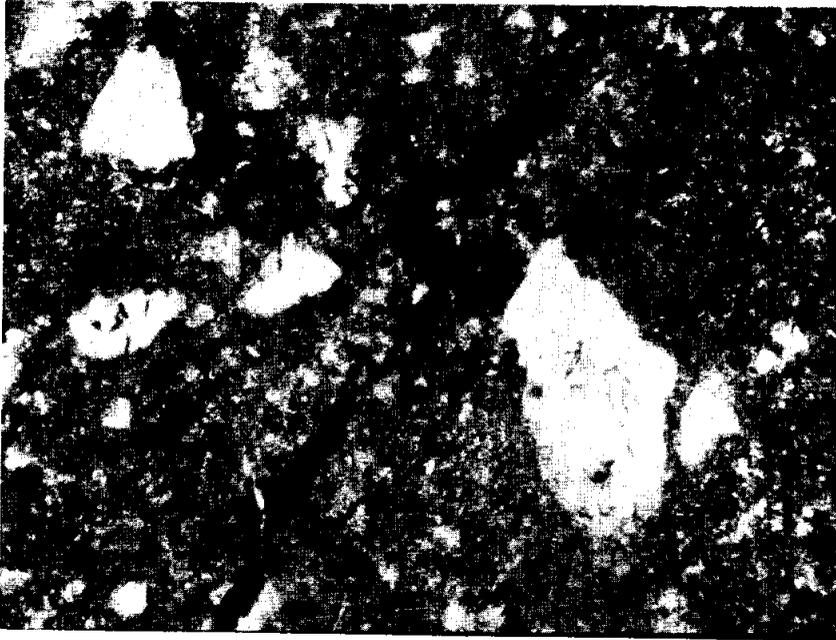


FIGURE 2. 60625,11.
general view, ppl.
width 3mm.

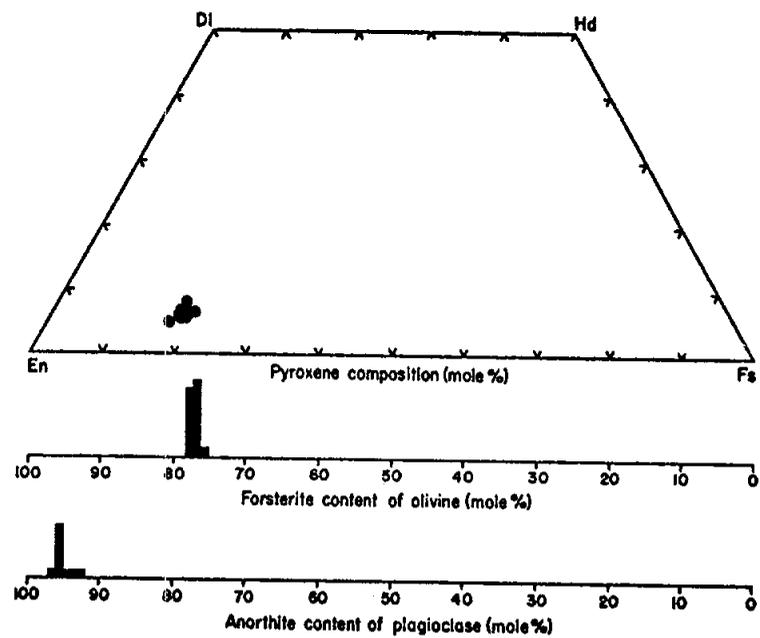


FIGURE 3. Mineral compositions; from R. Warner
et al. (1976b).

CHEMISTRY: Fruchter et al. (1974) present a partial major and trace element analysis without comment, and Warner et al. (1976b) present a defocussed beam analysis. These are summarized in Table 1.

TABLE 1. Summary chemistry of 60625 poikilitic melt

	(i)	(ii)
SiO ₂		44.7
TiO ₂		0.67
Al ₂ O ₃	25.9	22.6
Cr ₂ O ₃	0.12	0.11
FeO	5.4	7.8
MnO		0.06
MgO		9.8
CaO		13.2
Na ₂ O	0.49	0.54
K ₂ O		0.21
P ₂ O ₅		0.25
Sr		
La	20.7	
Lu	1.0	
Rb		
Sc	9.7	
Ni		
Co	27.0	
Ir ppb		
Au ppb		

Oxides in wt%; others in ppm except as noted.

(i) from Fruchter et al. (1974). (ii) DBA from Warner et al. (1976b).

PROCESSING AND SUBDIVISIONS: Only a few small pieces have fallen from or been separated from the parent ,0.

INTRODUCTION: 60626 is a light gray, coherent, poikilitic rock that has been extensively fractured. Veins of dark glass cut the rock (Fig. 1). It is a rake sample collected about 70 m west southwest of the Lunar Module. It has zap pits which are heterogeneously distributed.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description and mineral compositions. 60626 is poikilitic with irregularly shaped oikocrysts of dominantly low-Ca pyroxene. Unlike most Apollo 16 poikilitic impact melts the plagioclase chadacrysts are anhedral and equant. Clasts of plagioclase are abundant (Fig. 2). Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Accessory phases include titaniferous spinel ($\sim 21\%$ TiO_2), ilmenite, and metal (1.0-1.7% Ni, 0.8% Co).

CHEMISTRY: Major and trace element data are provided by Laul and Schmitt (1973). A defocussed electron beam analysis (DBA) is given by Warner et al. (1976b).

These data show that 60626 is much more aluminous than most Apollo 16 poikilitic impact melts, at least in part owing to its abundant clasts, and contains low levels of incompatible elements and siderophiles (Table 1).

PROCESSING AND SUBDIVISIONS: In 1973 representative chips were allocated for petrography (,1), chemistry (,3) and Ar geochronological studies (,2).

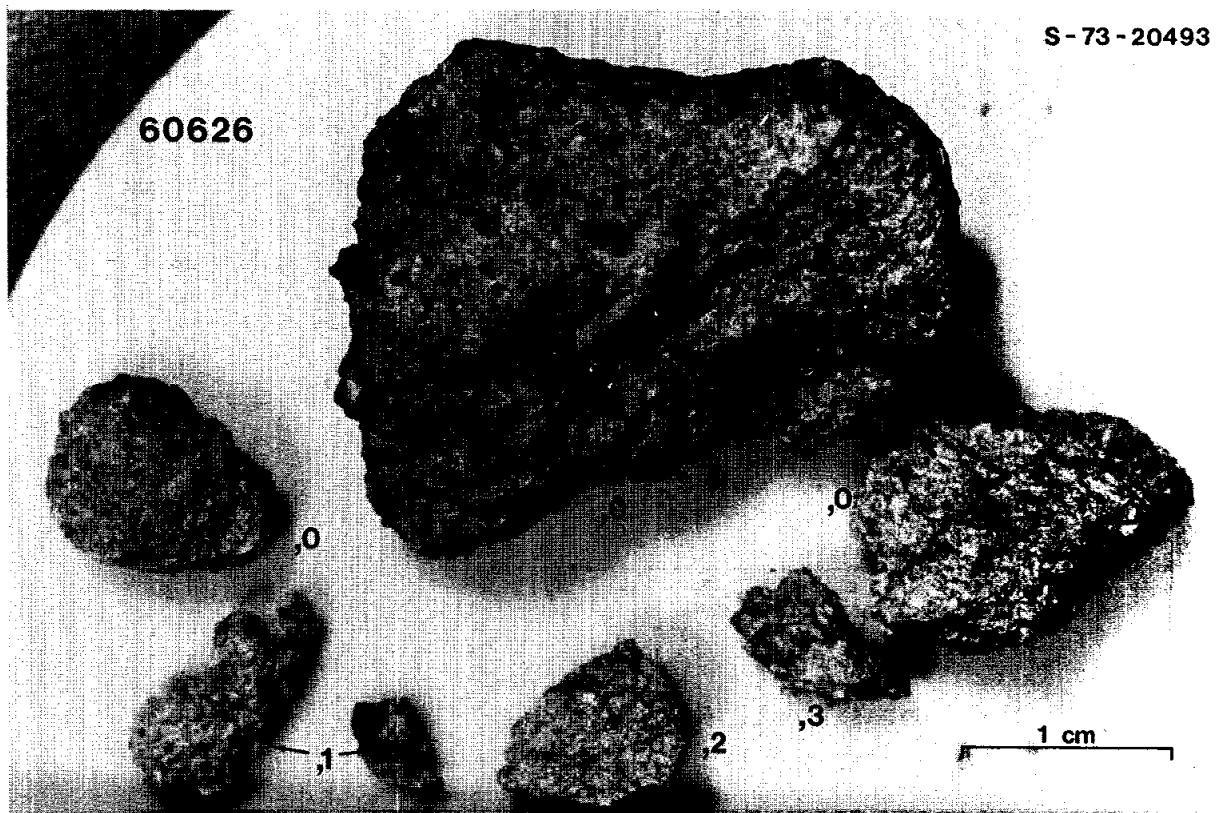


FIGURE 1.

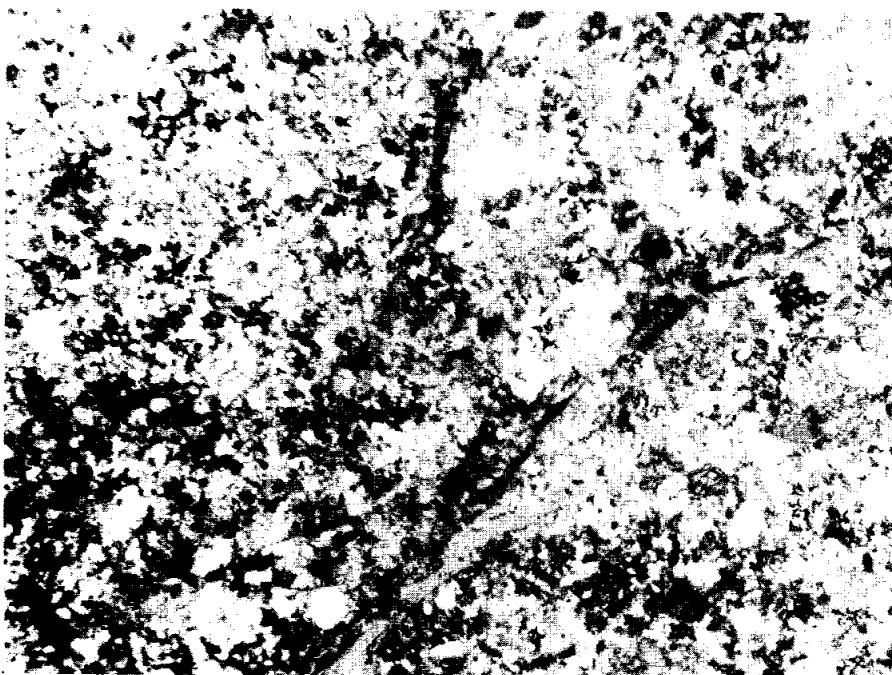


FIGURE 2. 60626,5.
general view, ppl.
width 3mm.

TABLE 1. Summary chemistry of 60626
(mainly Laul and Schmitt, 1973)

SiO ₂	45.3
TiO ₂	0.35
Al ₂ O ₃	29.4
Cr ₂ O ₃	0.096
FeO	4.4
MnO	0.061
MgO	3.3
CaO	16.7
Na ₂ O	0.444
K ₂ O	0.10
P ₂ O ₅	0.04
Sr	
La	2.1
Lu	0.14
Rb	
Sc	10
Ni	30
Co	14
Ir ppb	
Au ppb	
C	
N	
S	
Zn	
Cu	

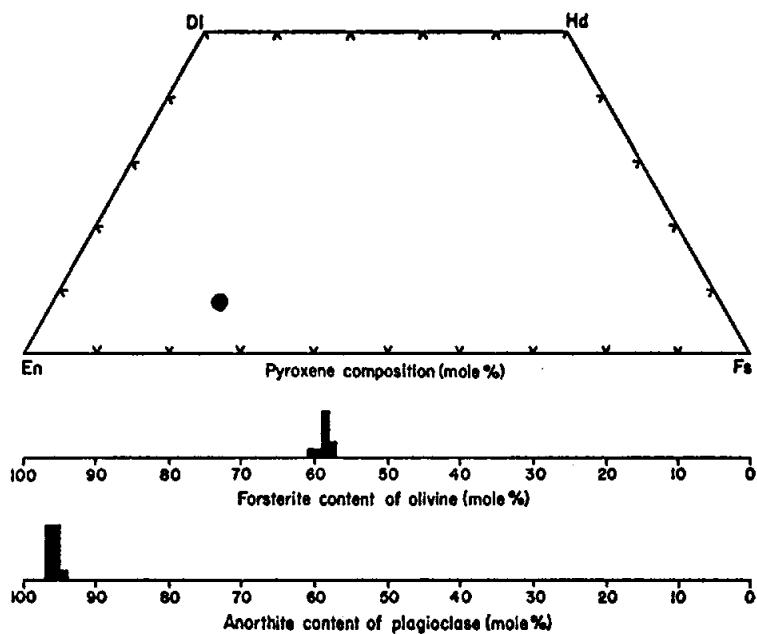


FIGURE 3. Mineral compositions; from R. Warner
et al. (1976b).

Oxides in wt%, others in ppm except as noted.

INTRODUCTION: 60627 is a light gray, coherent, impact melt with a very fine grain size (Fig. 1). A few patches of dark splash glass are present on the surface of the smooth, sub-rounded sample. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are abundant.



FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60628 is a white anorthosite of variable coherence (Fig. 1). It is subangular with a crushed appearance. Plagioclase is of variable grain size and ranges from clear to milky white. A small amount of light colored splash glass occurs on one surface; many zap pits also occur on this surface. It is a rake sample collected about 70 m west southwest of the Lunar Module.

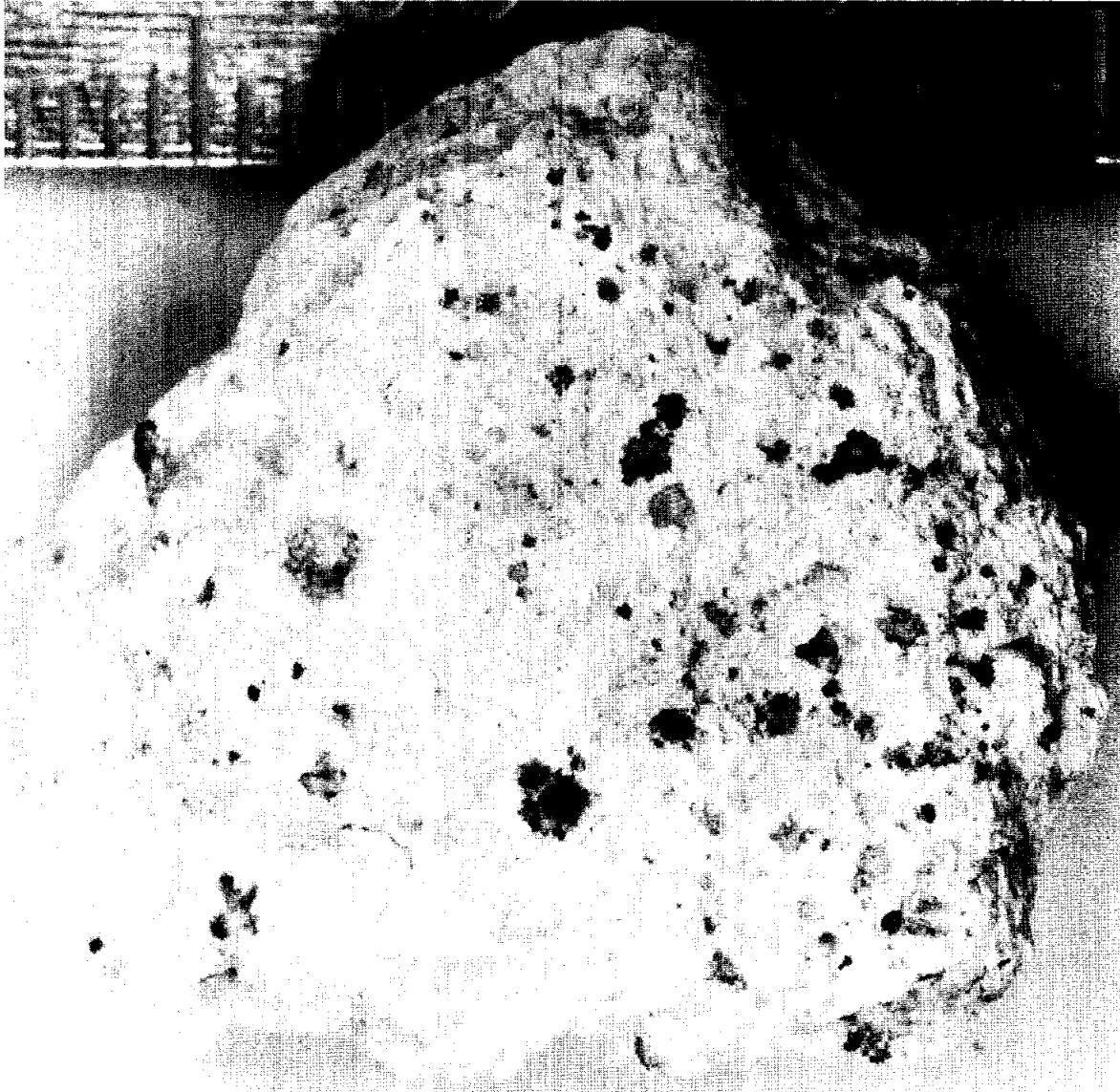


FIGURE 1. Small scale
division in mm.
S-72-46822

INTRODUCTION: 60629 is a white, coherent, cataclastic anorthosite with a partial coating of dark glass (Fig. 1). It is a rake sample collected about 70 m west southwest of the Lunar Module. Many zap pits are present on all surfaces.



FIGURE 1.

PETROLOGY: Petrographic descriptions are provided by Dowty et al. (1974a) and Warner et al. (1976b). Angular clasts of plagioclase (up to 3 mm long, mostly <0.3 mm) rest in a granulated matrix which is also dominantly plagioclase (Fig.2). Mafic minerals tend to occur as discrete grains in the matrix. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Fe-metal is an accessory phase; the single analyzed grain has 5.17% Ni and 0.43% Co (Warner et al., 1976b).

CHEMISTRY: A defocussed electron beam analysis (DBA) is given by Dowty et al. (1974a) and reproduced by Warner et al. (1976b) and here as Table 1.

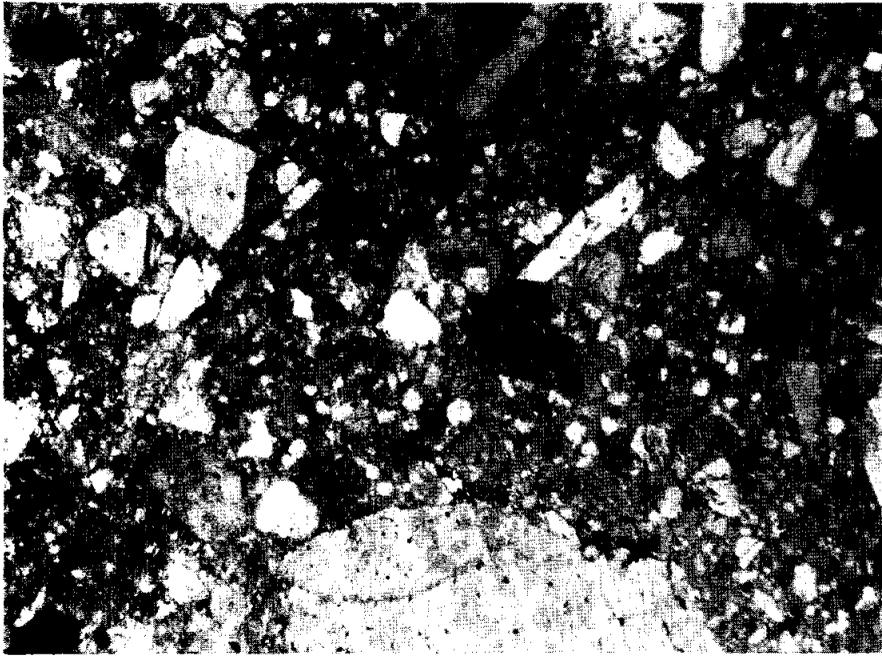


FIGURE 2. 60629,2.
general view, partly
xpl. width 3mm.

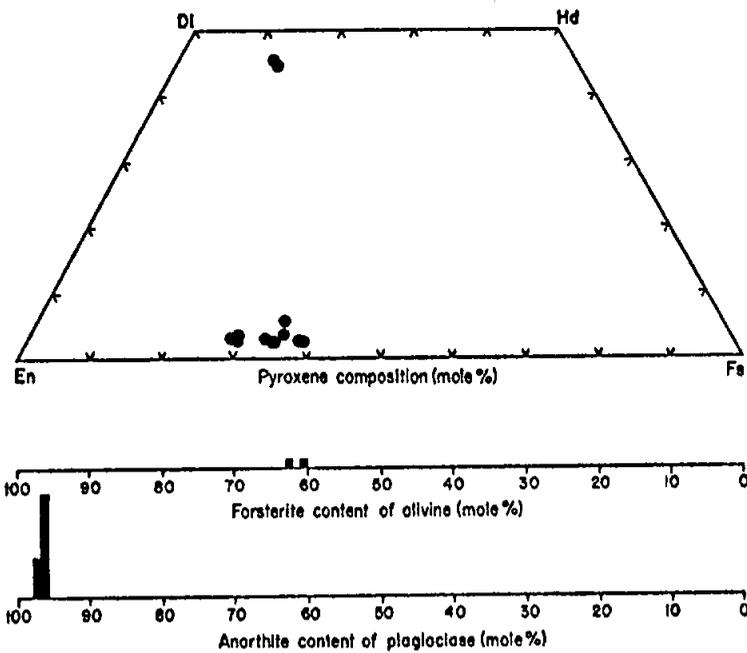


TABLE 1. Chemistry of 60629
(DBA, normalized to 100%)

SiO ₂	44.6
TiO ₂	0.01
Al ₂ O ₃	35.1
FeO	0.36
MgO	0.26
CaO	19.2
Na ₂ O	0.41
K ₂ O	0.02
P ₂ O ₅	0.03

FIGURE 3. Mineral compositions; from R. Warner
et al. (1976b).

PROCESSING AND SUBDIVISIONS: In 1973 a chip of the anorthosite (,1) was taken for thin sections. During this processing a portion of the glass coat fell off but has been kept with ,0 (Fig.1).

INTRODUCTION: 60635 is a medium gray, coherent, coarse-grained, basaltic impact melt (Fig. 1). Vugs and vesicles are abundant. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.

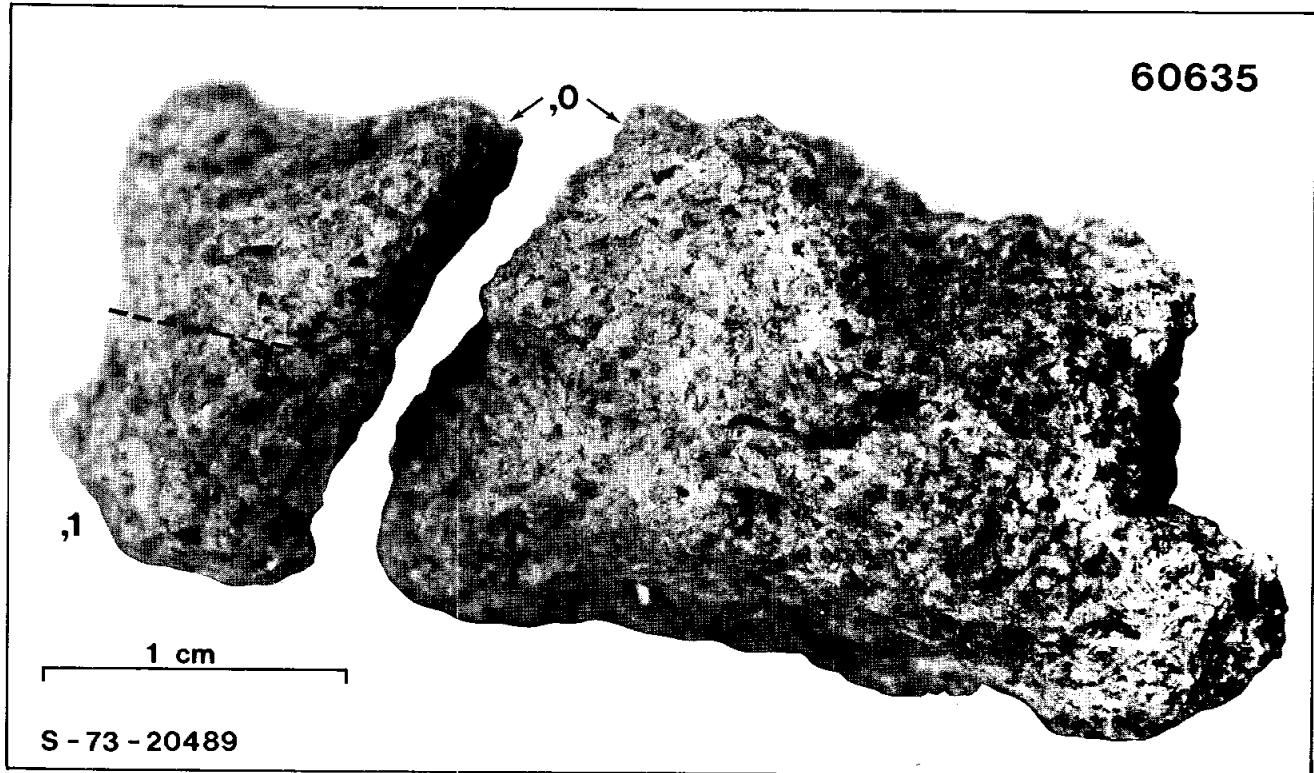


FIGURE 1.

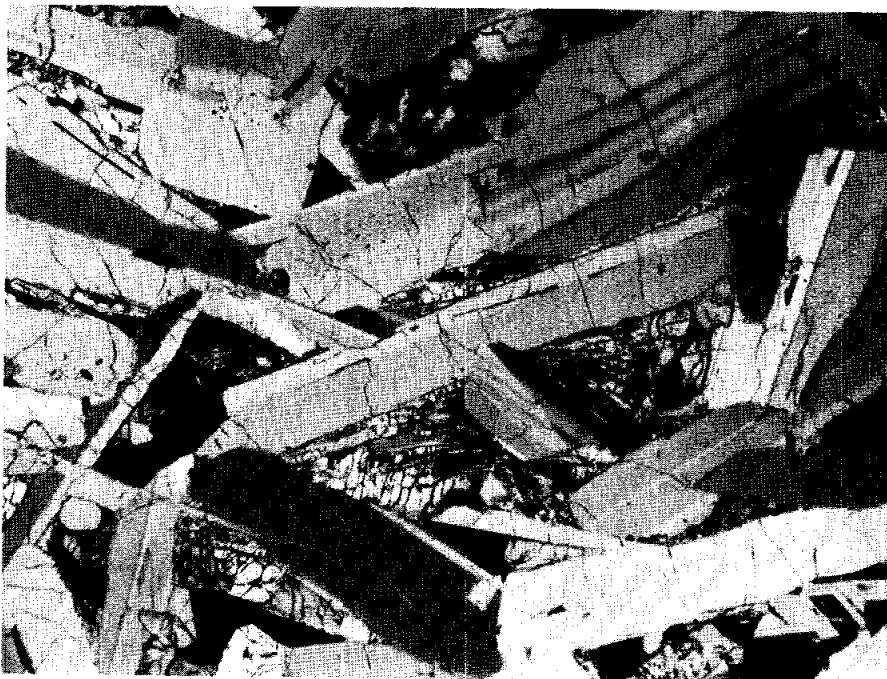


FIGURE 2. 60635,2.
general view, partly
ppl. width 3mm.

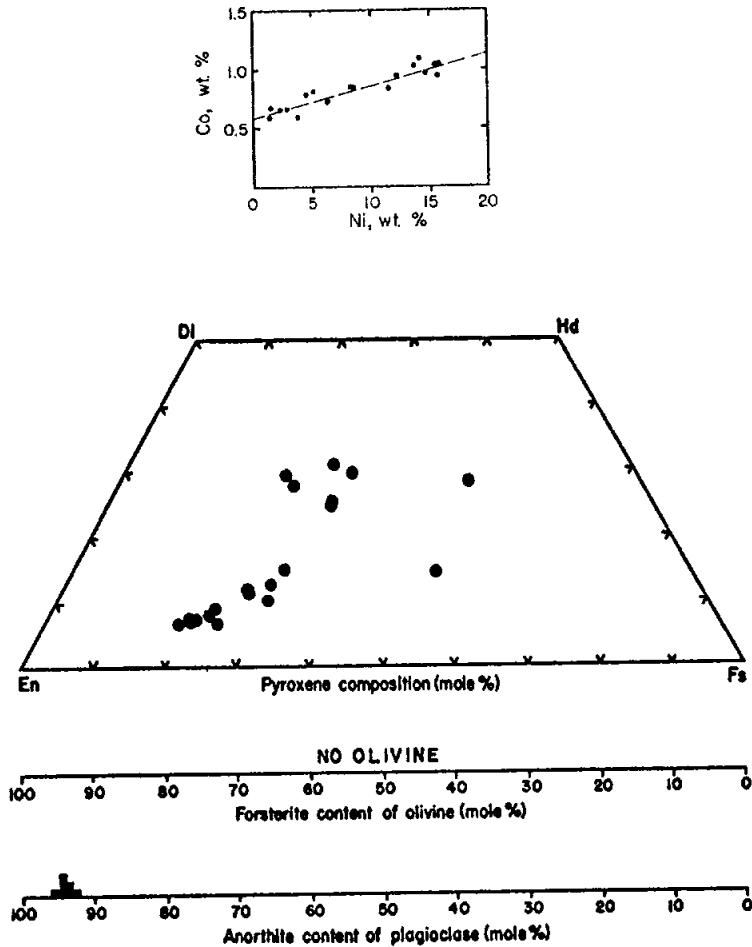


FIGURE 3. Mineral compositions; metals from Dowty et al. (1974b), silicates from R. Warner et al. (1976b).

TABLE 1. Chemistry of 60635 (DBA)

SiO ₂	45.8
TiO ₂	0.34
Al ₂ O ₃	27.6
Cr ₂ O ₃	0.07
FeO	4.7
MnO	0.04
MgO	4.1
CaO	15.8
Na ₂ O	0.54
K ₂ O	0.09
P ₂ O ₅	0.09

PETROLOGY: Dowty et al. (1974b) and Warner et al. (1976b) provide petrographic descriptions. This is a coarse-grained rock with abundant phenocrystic laths and prisms of plagioclase (0.6-2.5 mm long) and smaller grains of plagioclase and pyroxene confined to interstices (Fig. 2). Olivine is absent and clasts are very rare. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Minor phases include nearly pure ulvöspinel, Fe-metal, troilite and K-feldspar.

CHEMISTRY: A defocussed electron beam analysis (DBA) is presented by Dowty et al. (1974b) and reproduced by Warner et al. (1976b) and here as Table 1.

This analysis shows 60635 to be compositionally similar to local mature soils but with a higher Fe/Mg and lower TiO₂.

PROCESSING AND SUBDIVISIONS: During initial processing at JSC 60635 fell into two pieces. In 1973 a single chip (,1) was removed and allocated to Keil for petrography.

INTRODUCTION: 60636 is a medium gray, coherent impact melt with many crystallized vugs (Fig. 1). Some splash glass is present. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.

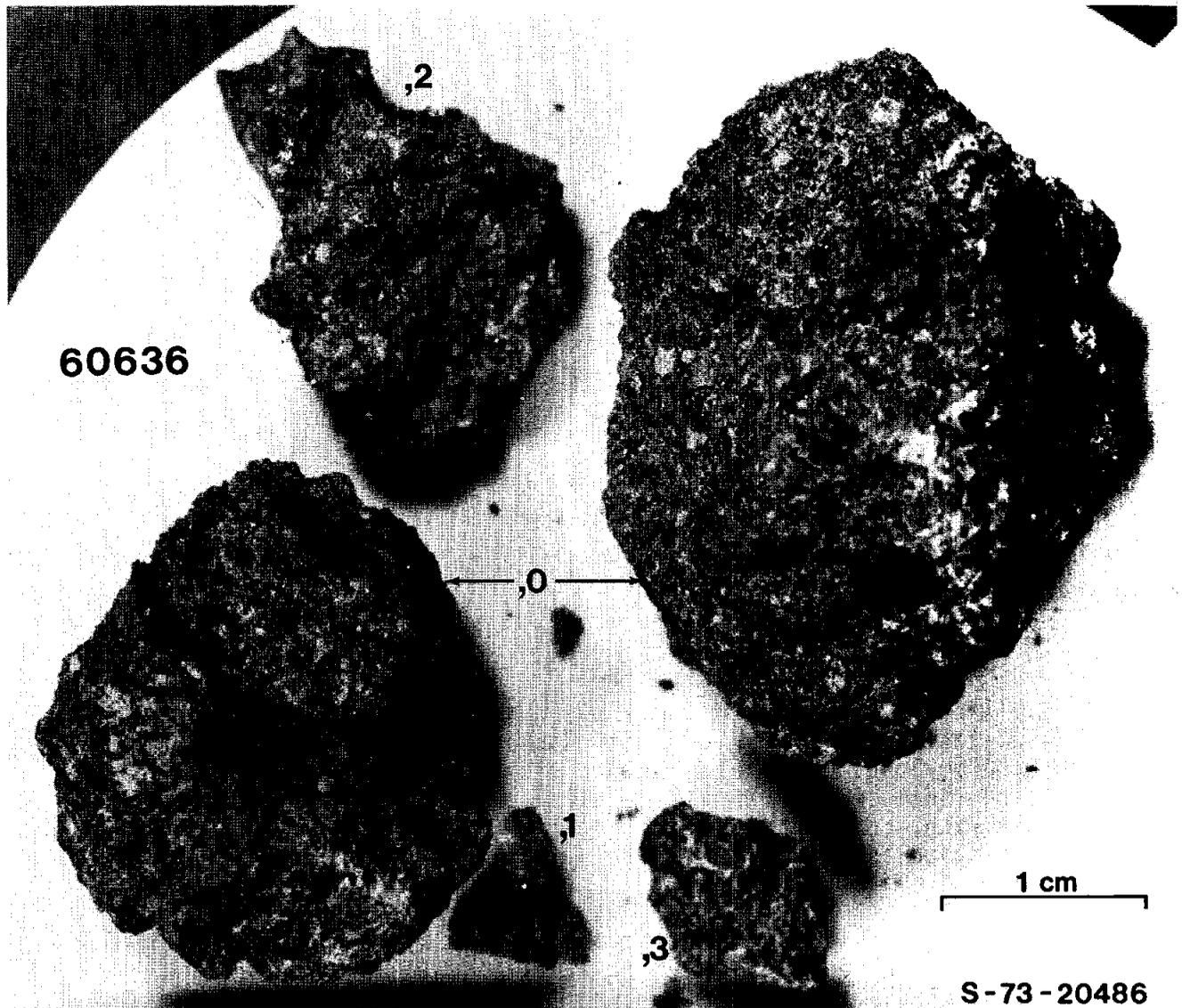


FIGURE 1.

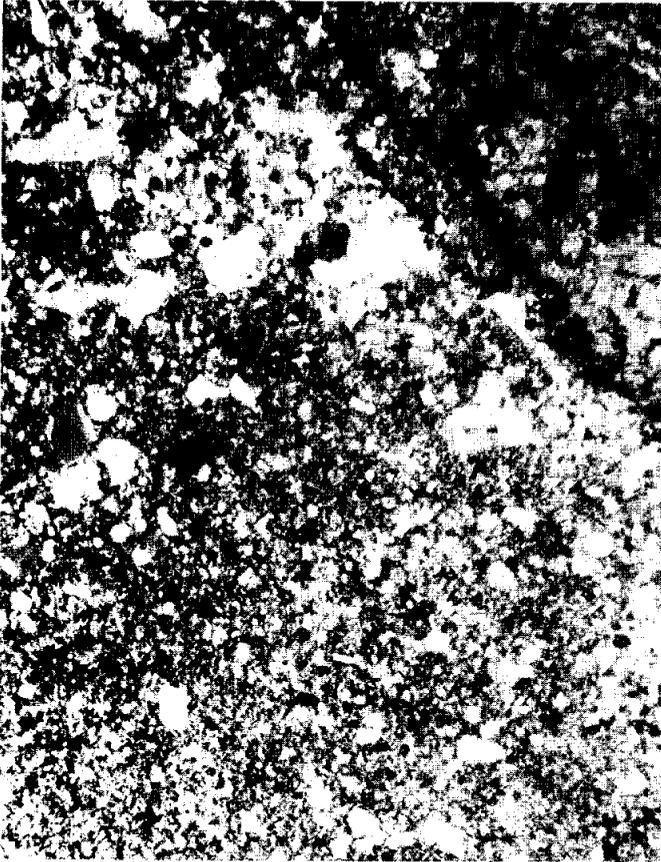


FIGURE 2. 60636,6. general view, partly ppl. width 2mm.

TABLE 1. Chemistry of 60636 (DBA)

SiO ₂	48.0
TiO ₂	0.93
Al ₂ O ₃	24.2
Cr ₂ O ₃	0.11
FeO	6.2
MnO	0.07
MgO	6.1
CaO	13.9
Na ₂ O	0.79
K ₂ O	0.73
P ₂ O ₅	0.40

PETROLOGY: A brief petrographic description is given by Warner et al. (1976b). 60636 is a clast-laden impact melt with tablet-shaped plagioclase grains (0.01 - 0.02 mm long) enclosed by subophitic to poikilitic pyroxene (Fig.2). Clasts of plagioclase and subordinate olivine are abundant. One fragment of plagioclase-rich, poikilitic breccia is noted by Warner et al. (1976b). Matrix and clast plagioclase grains are slightly rounded suggesting minor recrystallization or resorption.

CHEMISTRY: A defocussed electron beam analysis (DBA) is presented by Warner et al. (1976b) and reproduced here as Table 1. U, Th, and Pb data are provided by Tera et al. (1974) in a geochronological study. 60636 has very high levels of incompatible elements (Table 1).

GEOCHRONOLOGY: U, Th and Pb isotopic data are presented by Tera et al. (1974). These data are within error of concordia at ~ 3.94 b.y. Virtually all of the radiogenic lead in 60636 has been produced by in situ decay, yielding model ages of 3.91 - 3.95 b.y.

PROCESSING AND SUBDIVISIONS: In 1972 representative chips were allocated for petrography (,1), chemistry (,3) and radiogenic isotope studies (,2).

INTRODUCTION: 60637 is a brownish gray, polymict breccia of variable coherence (Fig. 1). It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.



FIGURE 1. Small scale divisions in mm.

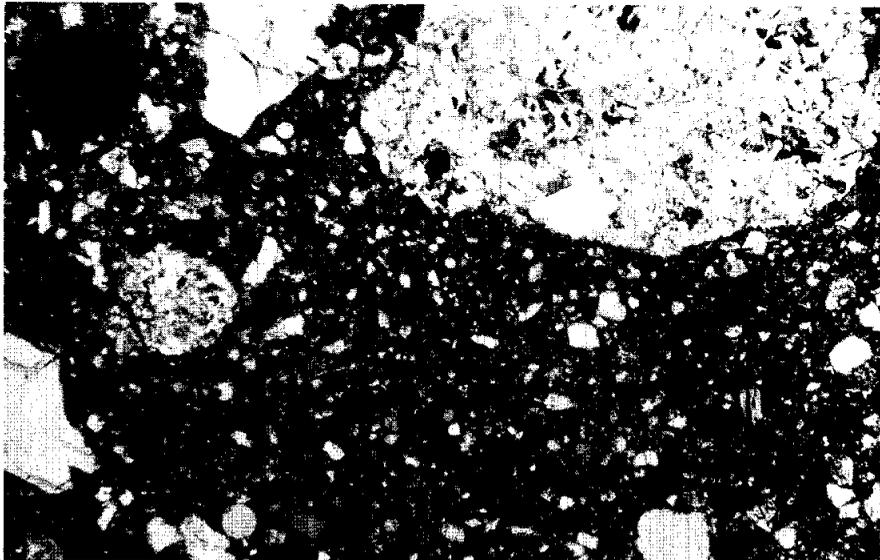


FIGURE 2. 60637,2. general view, partly ppl. width 3mm.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description. Various clasts, including a fragment of basaltic impact melt, numerous breccias and rare "chondrules," rest in a heterogeneous matrix of mineral and glass fragments welded together by a small amount of interstitial glass (Fig.2). Porosity of the matrix is high.

PROCESSING AND SUBDIVISIONS: In 1973 60637 was split into several fragments and one chip (,1) allocated for thin sections (Fig.1).

INTRODUCTION: 60638 is a brownish gray breccia of variable coherence (Fig. 1). Small white clasts are scattered through the angular sample. It is a rake sample collected about 70 m west southwest of the Lunar Module.



FIGURE 1. Small scale divisions
in mm.

INTRODUCTION: 60639 is a fragmental polymict breccia with a low porosity. A wide variety of clasts is present, a mare basalt and a pristine anorthosite (Fig. 1a) being of particular significance. One side of the subangular rock is covered with a smooth dark glass (Fig. 1b).

The sample was a rake sample from an area 70 m west-southwest of the Lunar Module, hence its orientation is unknown. Zap pits occur in a few areas.

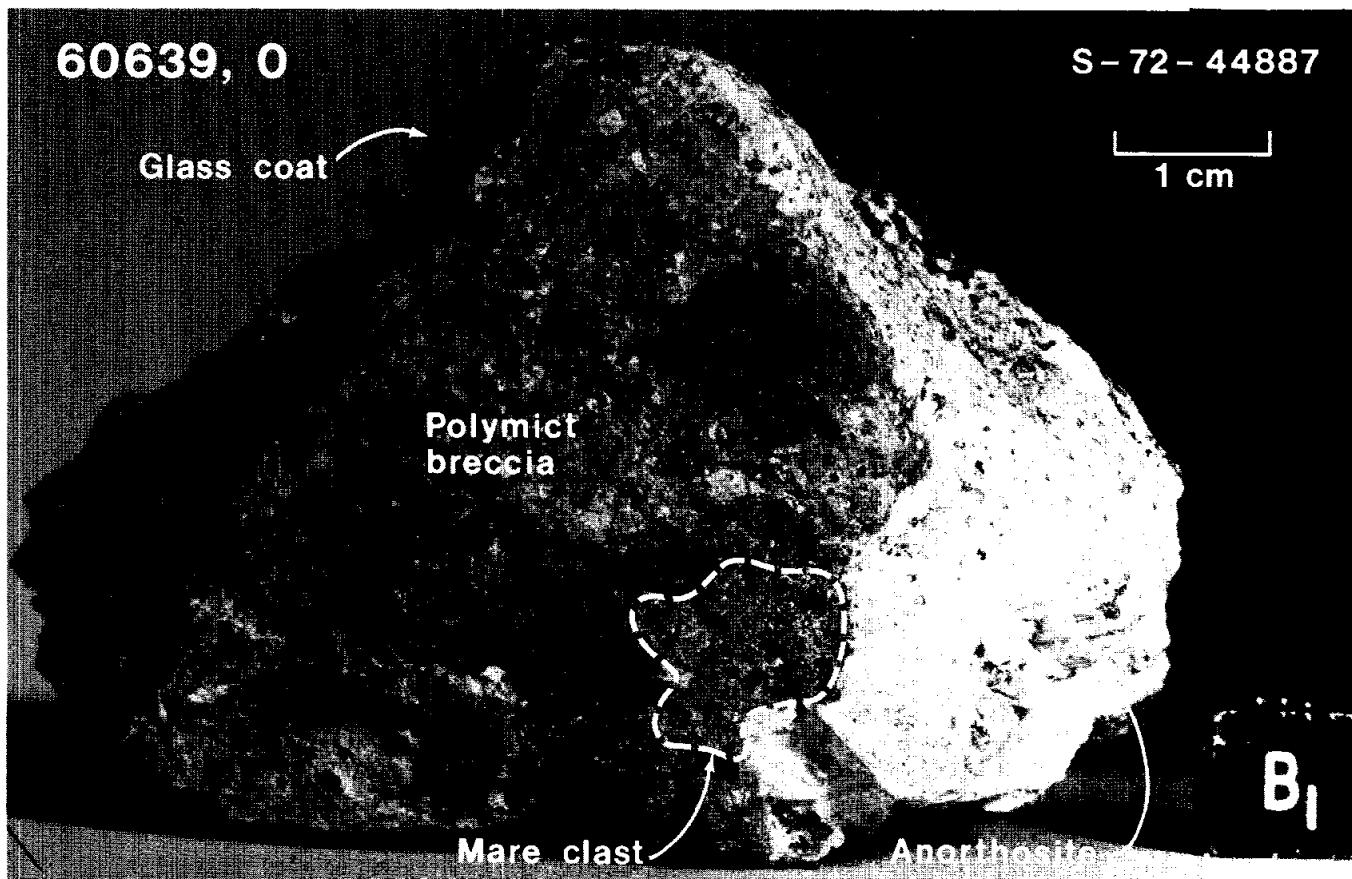


FIGURE 1a.

PETROLOGY: The matrix is briefly described by Warner *et al.* (1976b). The mare basalt clast is described, with mineral analyses, by Dowty *et al.* (1974b), Delano (1975) and Warner *et al.* (1976b). The pristine anorthosite is briefly described, with mineral analyses, by Warren and Wasson (1978).

The matrix is fragmental (Fig. 2) with a low porosity. Apart from the mare basalt and pristine anorthosite, lithic clasts include poikilitic, aphanitic, and glassy breccias.

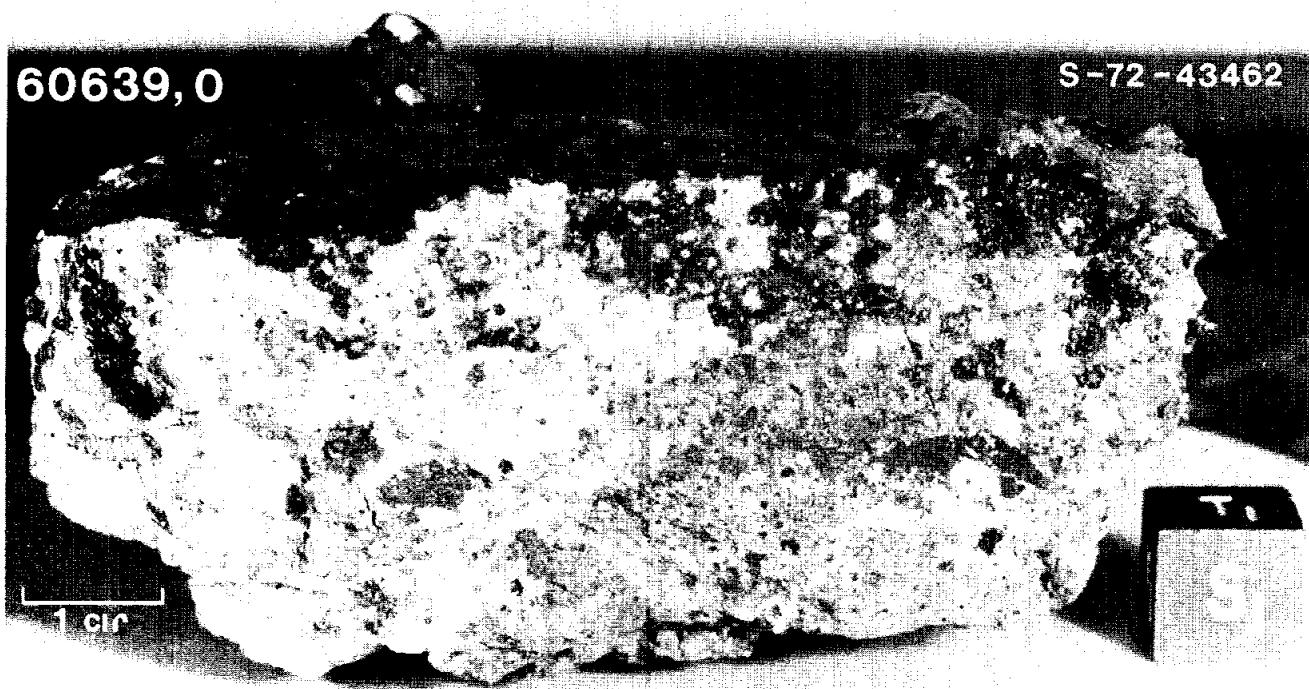


FIGURE 1b.

The mare basalt is subophitic, with plagioclase needles 300-500 μm long enclosed in clinopyroxene grains (Fig. 2). It contains $\sim 5\%$ olivine, $\sim 35\%$ plagioclase, $\sim 50\%$ pyroxene, $\sim 5-10\%$ ilmenite, and accessory spinels (Delano, 1975). Mineral data are shown in Figure 3. Modal mineralogy, zoning trends, and chemistry (below) are very similar to the intermediate- TiO_2 Luna 16 basalts.

The anorthosite is intensely cataclased (Fig. 2), and consists almost entirely of plagioclase with a few tiny pyroxene grains. Mineral compositions have very narrow ranges (Warren and Wasson, 1978): plagioclases $\text{An}_{96.0-96.8}$; pyroxenes $\text{En}_{64-66} \text{Wo}_{1-2}$ and $\sim \text{En}_{42} \text{Wo}_{43}$. Some other pyroxenes are incompletely exsolved pigeonites. These mineral compositions are typical of ferroan anorthosites.

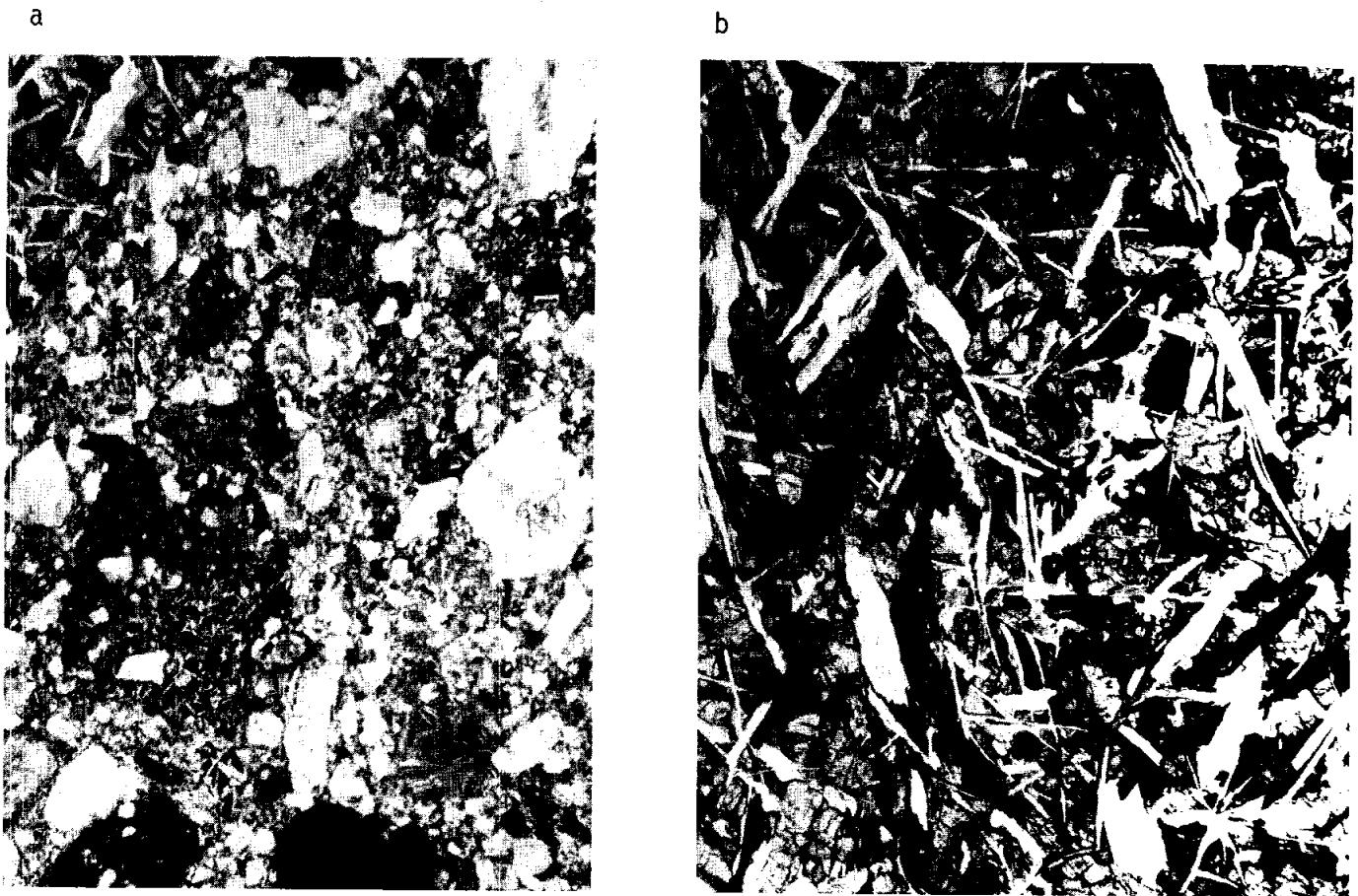


FIGURE 2. 60639,2. a) general view, partly ppl. width 2mm. b) mare basalt clast, partly ppl. width 2mm.

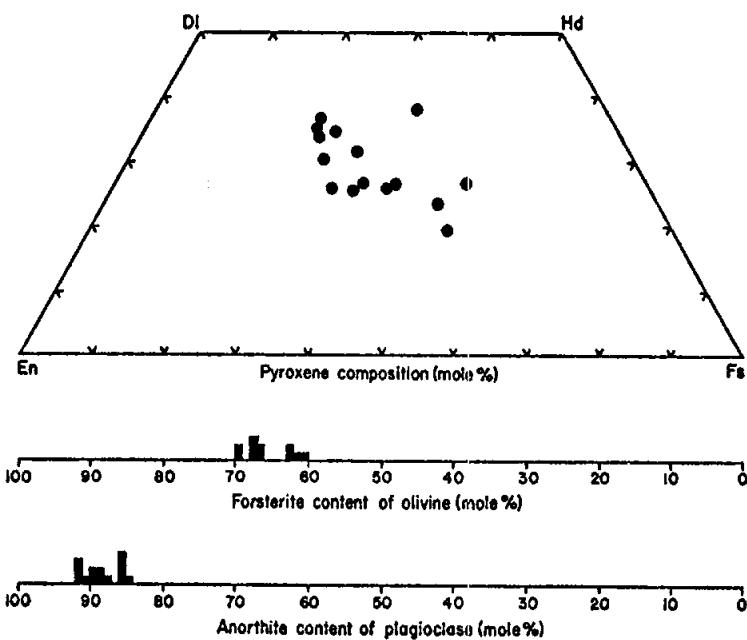


FIGURE 3a. Minerals in mare basalt clast; from R. Warner et al. (1976b).

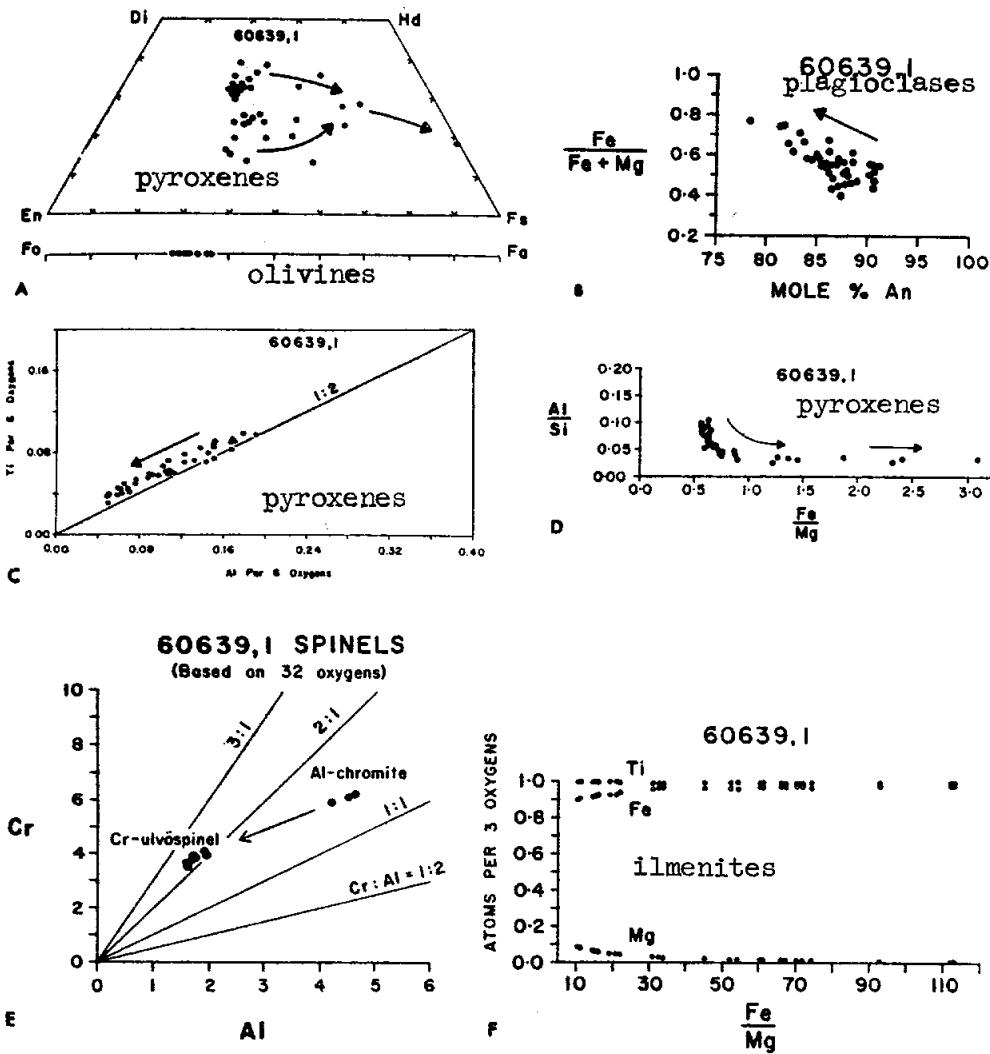


FIGURE 3b. Minerals in mare basalt clast; from Delano (1975).

CHEMISTRY: No matrix analyses are available. Data for the mare basalt (Murali *et al.*, 1976; DBA in Warner *et al.*, 1976b) and the anorthosite (Warren and Wasson, 1978) are summarized in Table 1.

The mare basalt is an intermediate-TiO₂, high-alumina basalt very similar to the Luna 16 mare basalts. The anorthosite is chemically pristine as shown by its low siderophiles, and is extremely low in mafic components and incompatible elements.

TABLE 1

Summary chemistry of 60639 mare basalt and anorthosite clasts

	<u>mare basalt</u>	<u>anorthosite</u>
SiO ₂	(42)	44.5
TiO ₂	7.4	
Al ₂ O ₃	12.4	35.1
Cr ₂ O ₃	0.30	0.006
FeO	20.0	0.34
MnO	0.25	0.01
MgO	6.5	0.35
CaO	10.6	19.4
Na ₂ O	0.58	0.379
K ₂ O	0.13	
P ₂ O ₅		
Sr		
La	15.5	0.11
Lu	1.8	
Rb		
Sc	73	0.59
Ni		0.72
Co	20	1.0
Ir ppb		~0.02
Au ppb	~16	0.019
C		
N		
S		
Zn		2
Cu		

mare basalt: Murali *et al.* (1976). anorthosite: Warren and Wasson (1978). Oxides in wt.%; others in ppm except as noted.

PROCESSING AND SUBDIVISIONS: No saw cuts have been made in 60639. All splits have been made by chipping and prying. Most of the original bulk of the rock (175 g) remains as ,0 (163 g).

INTRODUCTION: 60645 is a medium gray, coherent impact melt with a variable texture. Vesicles are very abundant (Fig. 1). It is a rake sample collected about 70 m west southwest of the Lunar Module and has rare zap pits.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description. The matrix texture varies through very fine-grained poikilitic, subophitic, and granular (Fig. 2). Minor amounts of a dark, cryptocrystalline mesostasis are present. One large cataclastic anorthosite clast is noted by Warner et al. (1976b).

PROCESSING AND SUBDIVISIONS: In 1973, three small chips were removed and allocated for thin sections as ,1 (Fig. 1).

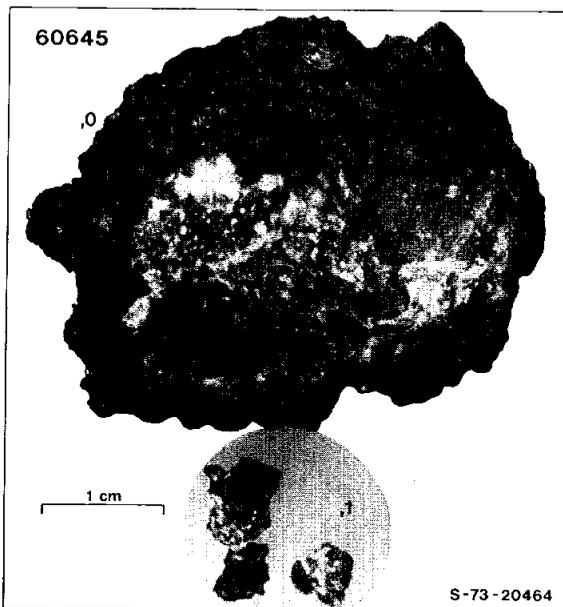


FIGURE 1.

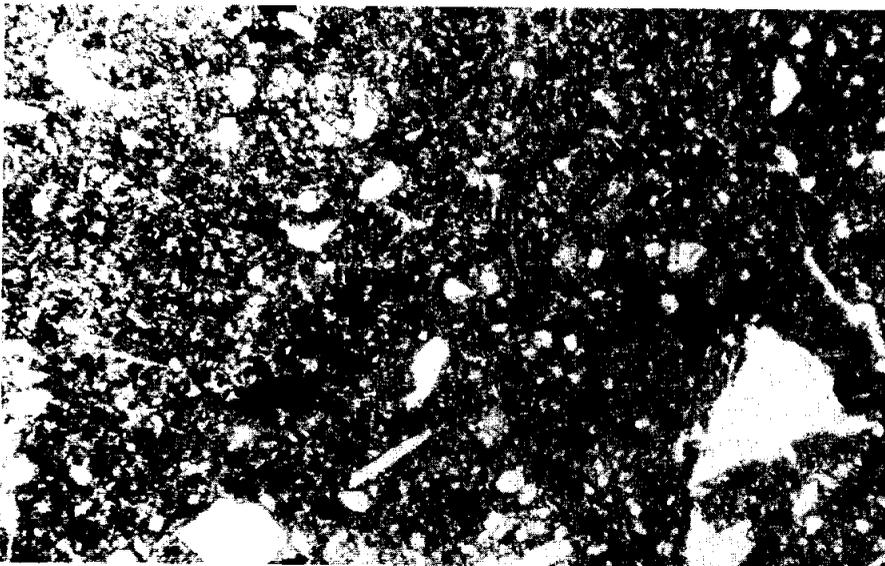


FIGURE 2. 60645,3
general view, ppl.
width 3mm.

INTRODUCTION: 60646 is a medium gray, coherent, glassy impact melt (Fig. 1). It is angular and highly vesicular. A few small (<1 mm) white clasts are present. It is a rake sample collected about 70 m west southwest of the Lunar Module and has only rare zap pits.



FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60647 is a medium gray, coherent, glassy impact melt (Fig. 1). Clasts include several white fragments (up to ~4 mm) and a fragment of coherent, crystalline rock, probably basaltic impact melt. It is angular and highly vesicular. It is a rake sample collected about 70 m west southwest of the Lunar Module and has only rare zap pits.



FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60648 is a medium gray, coherent, glassy impact melt with abundant small (<3 mm) white clasts (Fig. 1). It is angular and highly vesicular and one surface has a sheared appearance. It is a rake sample collected about 70 m west southwest of the Lunar Module and lacks zap pits.

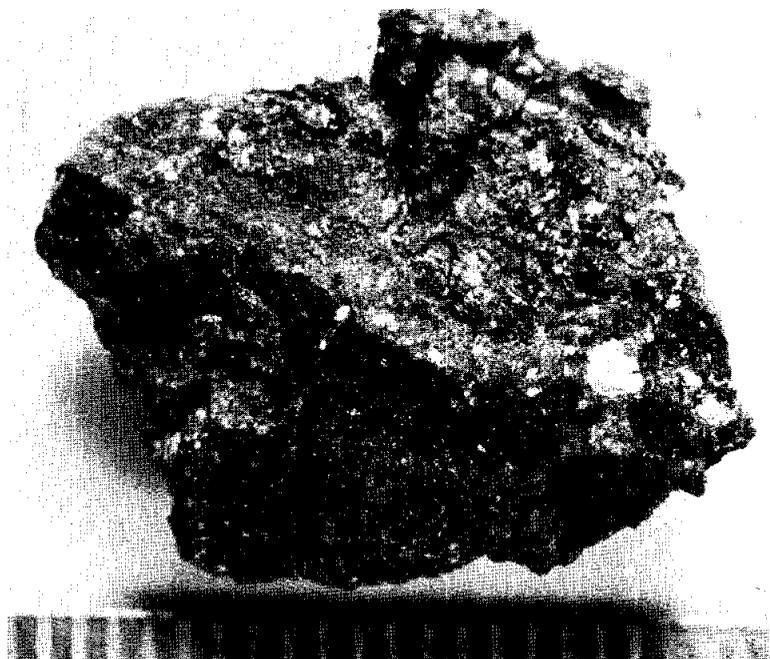


FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60649 is a medium gray, coherent, glassy breccia (Fig. 1). Small (<1 mm) white clasts are abundant. It is angular and slightly vesicular. It is a rake sample collected about 70 m west southwest of the Lunar Module and lacks zap pits.

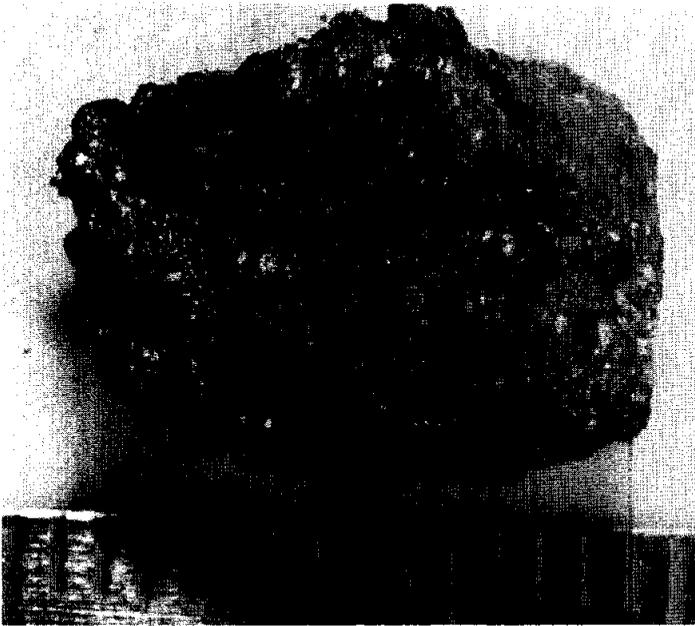


FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60655 is a medium gray, coherent, glassy impact melt (Fig. 1). Vesicles account for ~15% of the rock (Keil *et al.*, 1972). It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.

PETROLOGY: Warner *et al.* (1976b) provide a brief petrographic description. The matrix of 60655 consists of abundant glass containing angular mineral fragments (Fig. 2). Various breccia clasts and a small number of glassy fragments are present. Minor glassy veins intrude the matrix.

PROCESSING AND SUBDIVISIONS: In 1973 this rock was subdivided into six pieces. One of these pieces was allocated for thin sections as ,1 and the other five grouped as ,0 (Fig. 1).

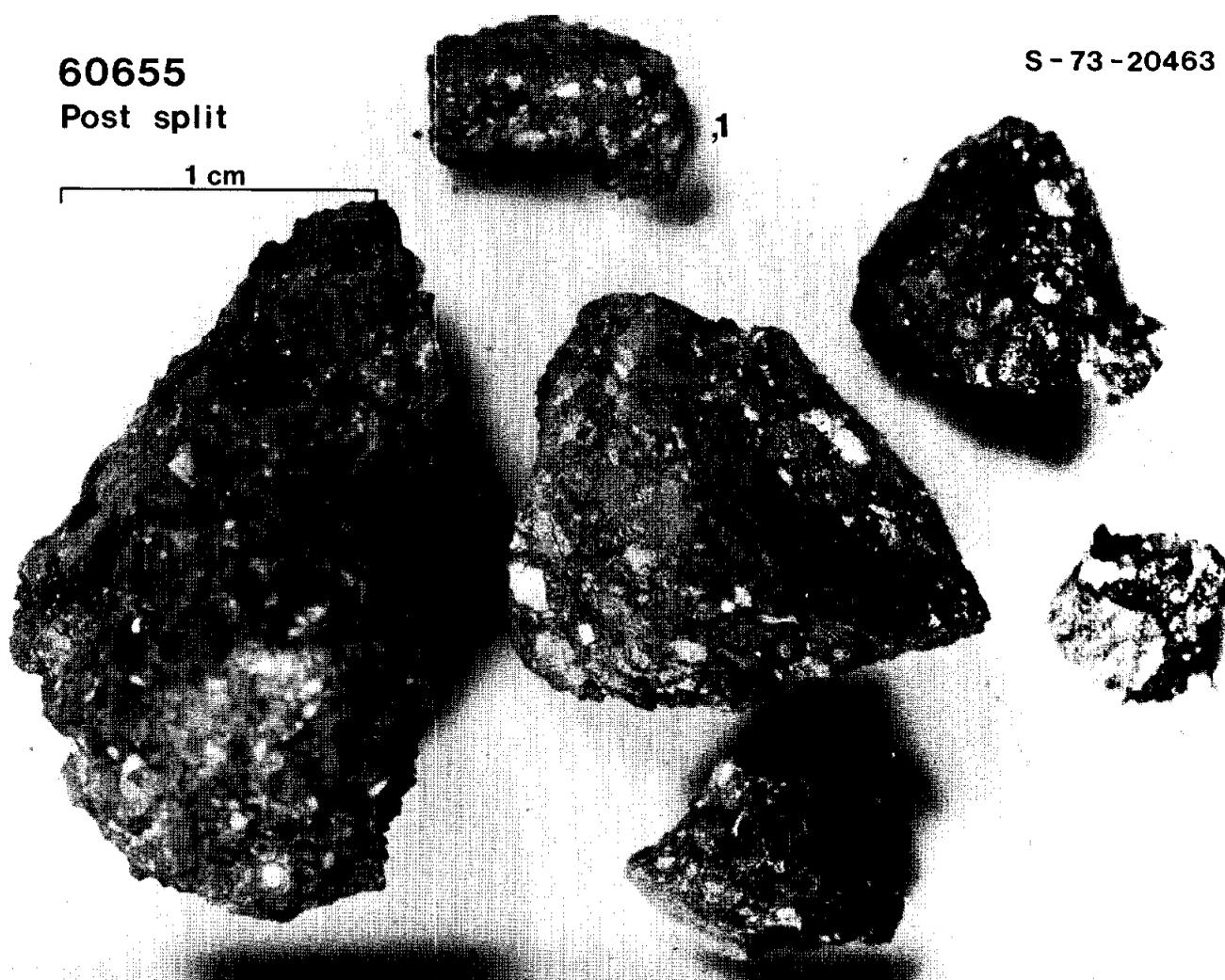


FIGURE 1.

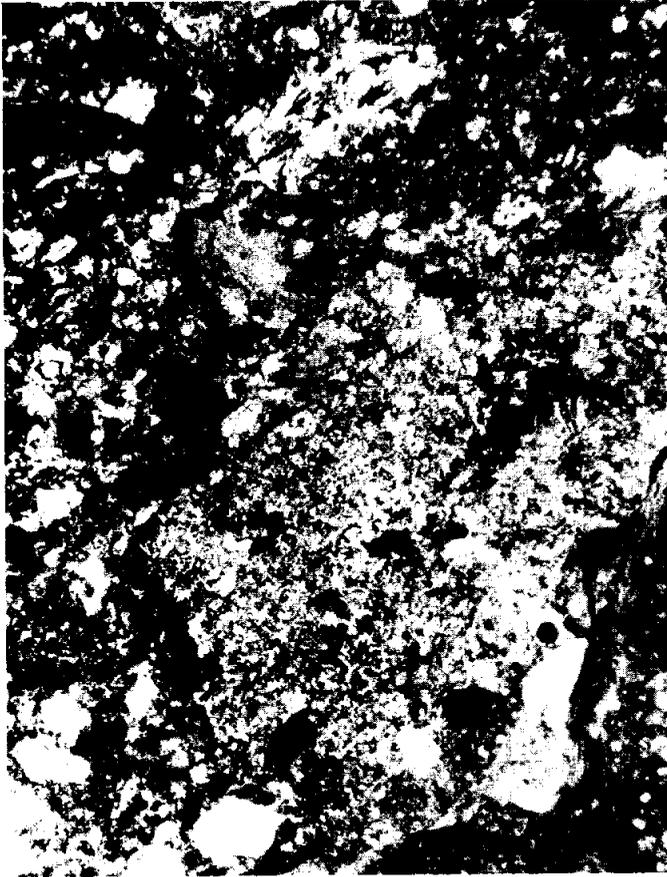


FIGURE 2. 60655,2. general
view, ppl. width 2mm.

INTRODUCTION: 60656 is a medium gray, coherent, glassy impact melt with several white clasts (Fig.1). It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description. Abundant mineral and lithic clasts reside in a glass-rich matrix (Fig.2).

PROCESSING AND SUBDIVISIONS: In 1973 four chips were removed from one end of the rock. One of these chips was allocated for thin sections as ,1 (Fig.1).

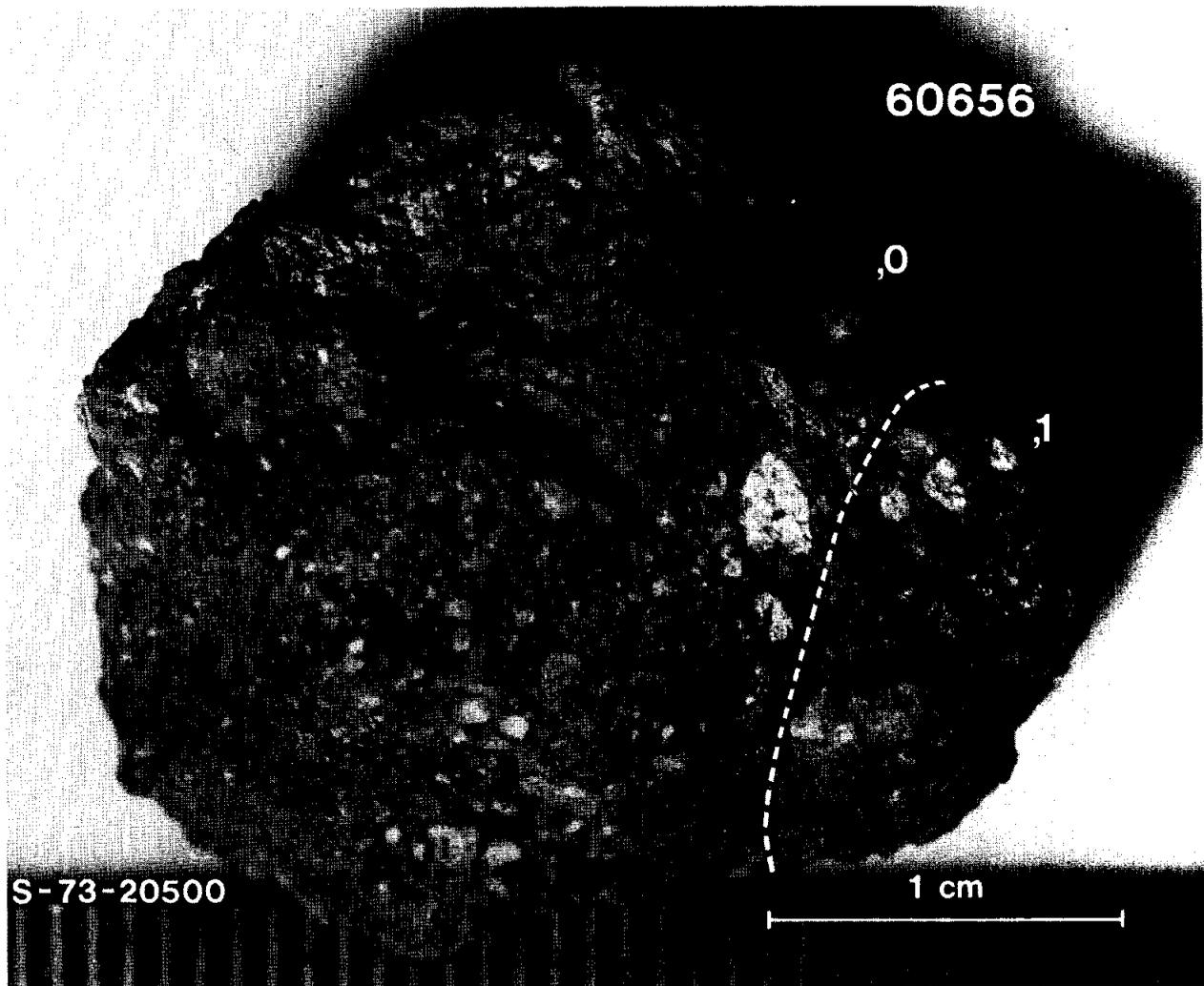


FIGURE 1.

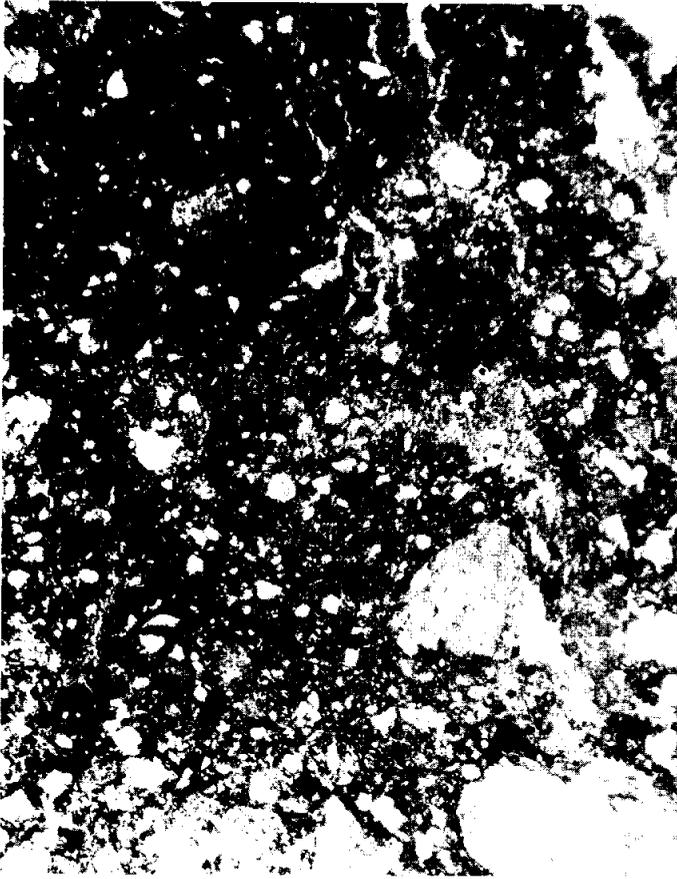


FIGURE 2. 60656,2. general view, ppl. width 2mm.

INTRODUCTION: 60657 is a light gray, coherent breccia with dark, vesicular glass attached to two ends of the rock (Fig. 1). White anorthositic clasts are abundant in both the breccia and the glass coat. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.

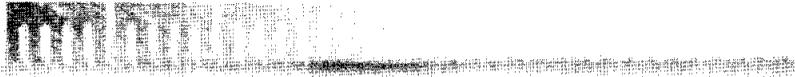
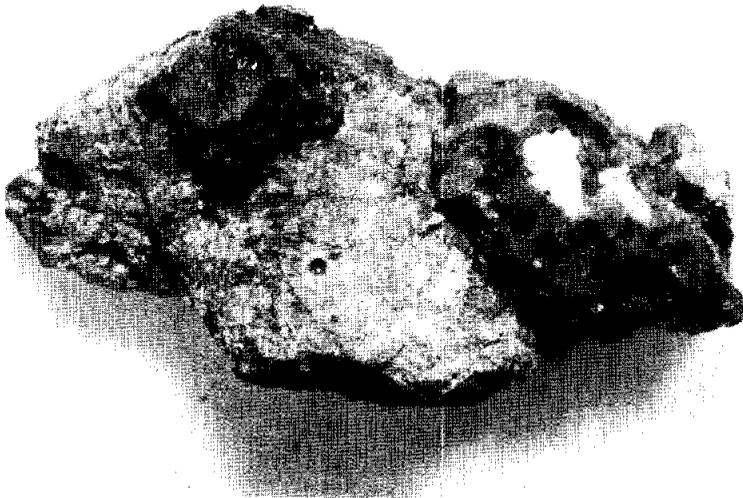


FIGURE 1. Small scale divisions in mm.



INTRODUCTION: 60658 is a light gray, coherent, glassy impact melt that was coated and intruded by dark, vesicular glass (Fig. 1). It is a rake sample collected about 70 m west southwest of the Lunar Module.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description. Abundant mineral and lithic clasts are welded together by glass (Fig. 2). Highly vesicular, flow-banded glass cuts the rock.

PROCESSING AND SUBDIVISIONS: In 1973 a single chip was removed and allocated for thin sections as ,1 (Fig. 1).

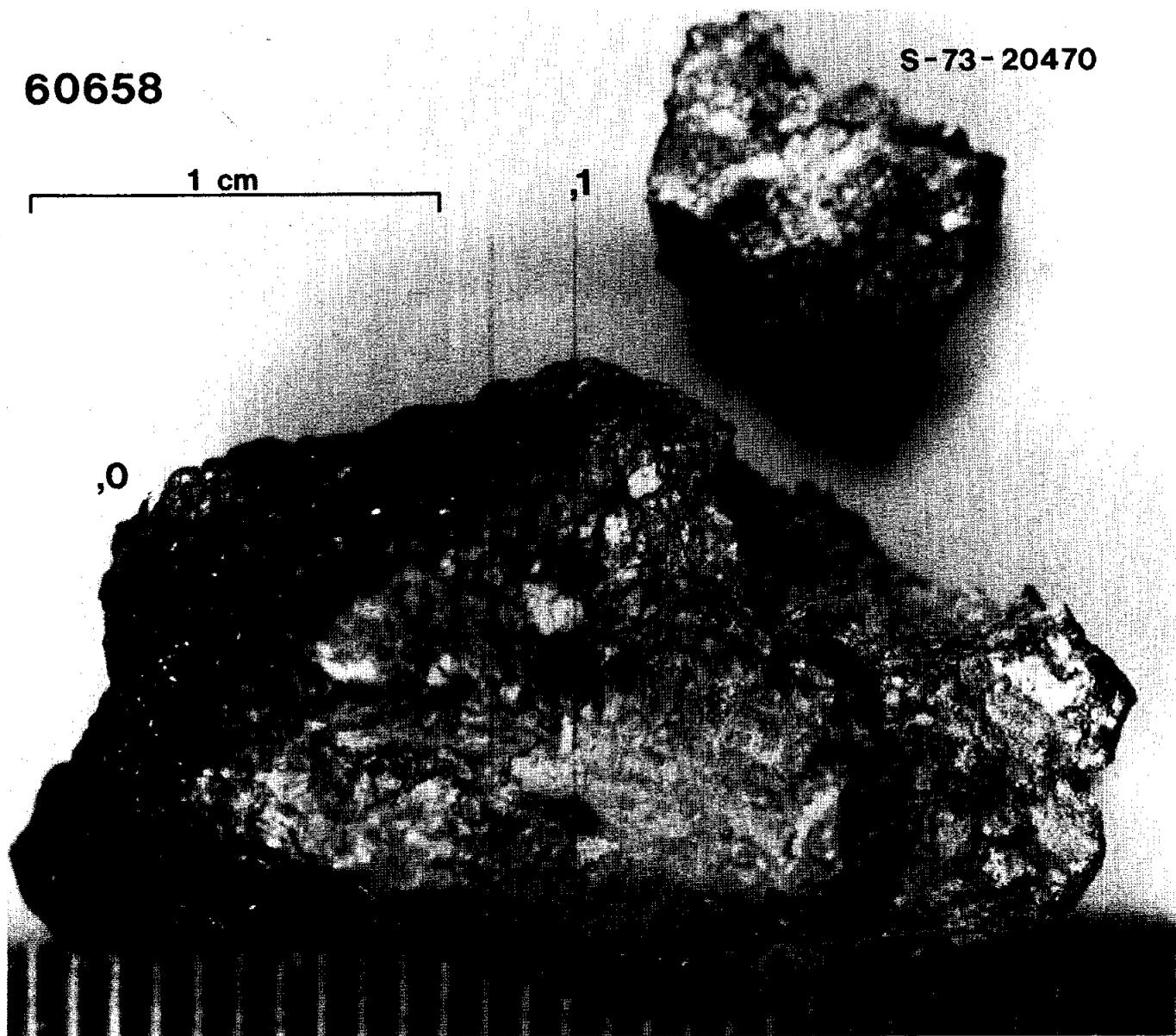


FIGURE 1.

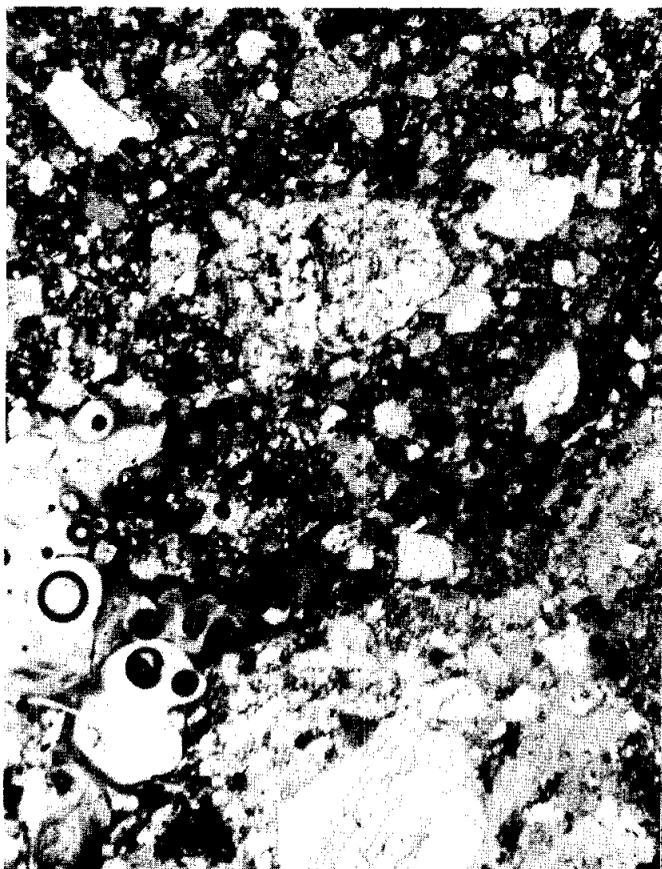


FIGURE 2. 60658,2. general
view, ppl. width 2mm.

INTRODUCTION: 60659 is a light gray, coherent breccia with many white clasts surrounded by a gray, fragmental matrix (Fig. 1). It is a rake sample collected about 70 m west southwest of the Lunar Module.

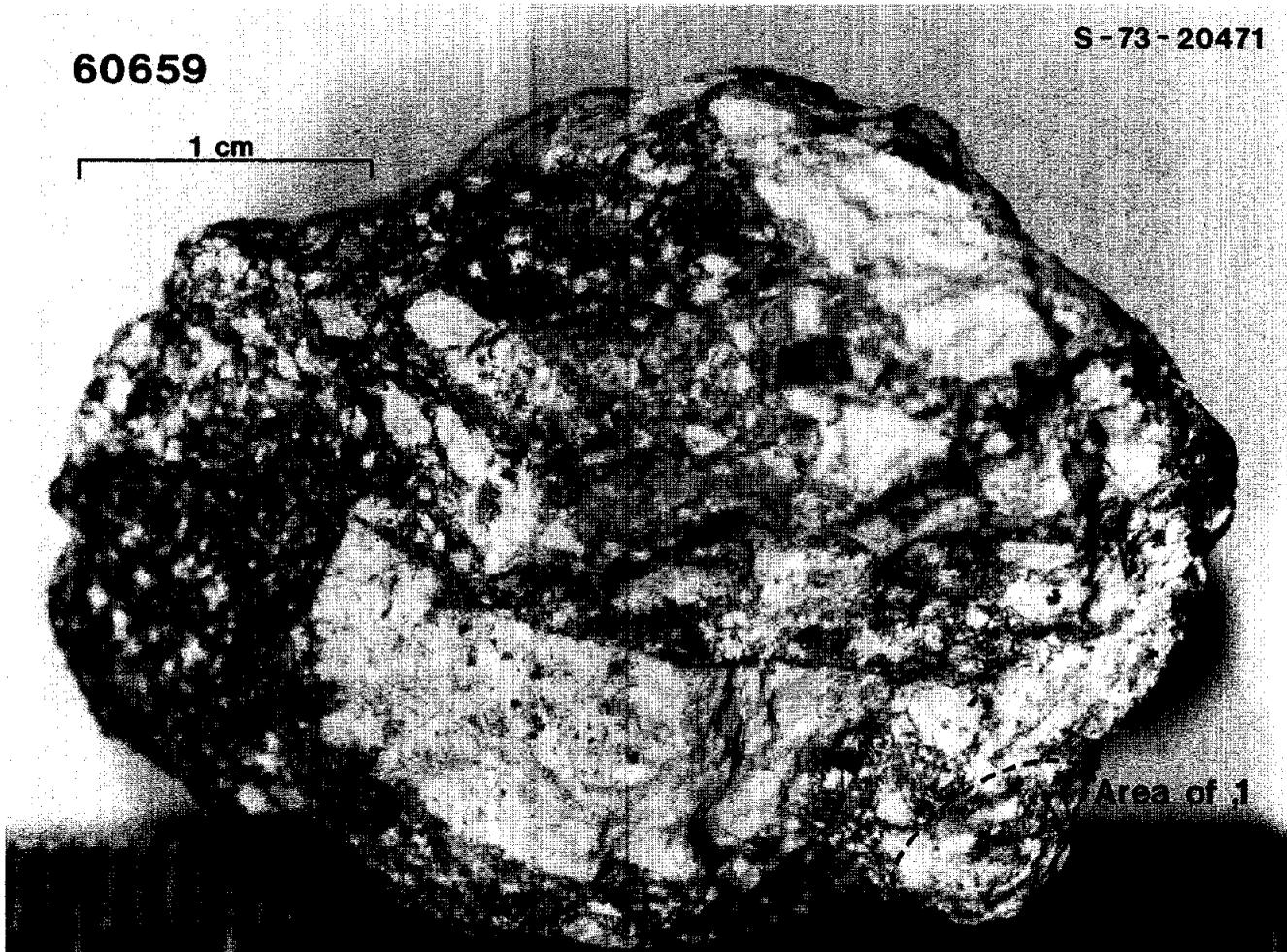


FIGURE 1.

PETROLOGY: Petrographic descriptions of the matrix and a large cataclastic anorthosite clast are given by Warner et al. (1976b). The anorthosite is included in a discussion of ferroan anorthosites by Dowty et al. (1974a).

The anorthositic clast has been severely granulated (Fig.2). Pyroxene is the only mafic mineral observed and occurs as small isolated grains in the matrix. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Accessory phases include spinel and ilmenite.

The matrix is a fragmental breccia with low porosity (Fig.2).

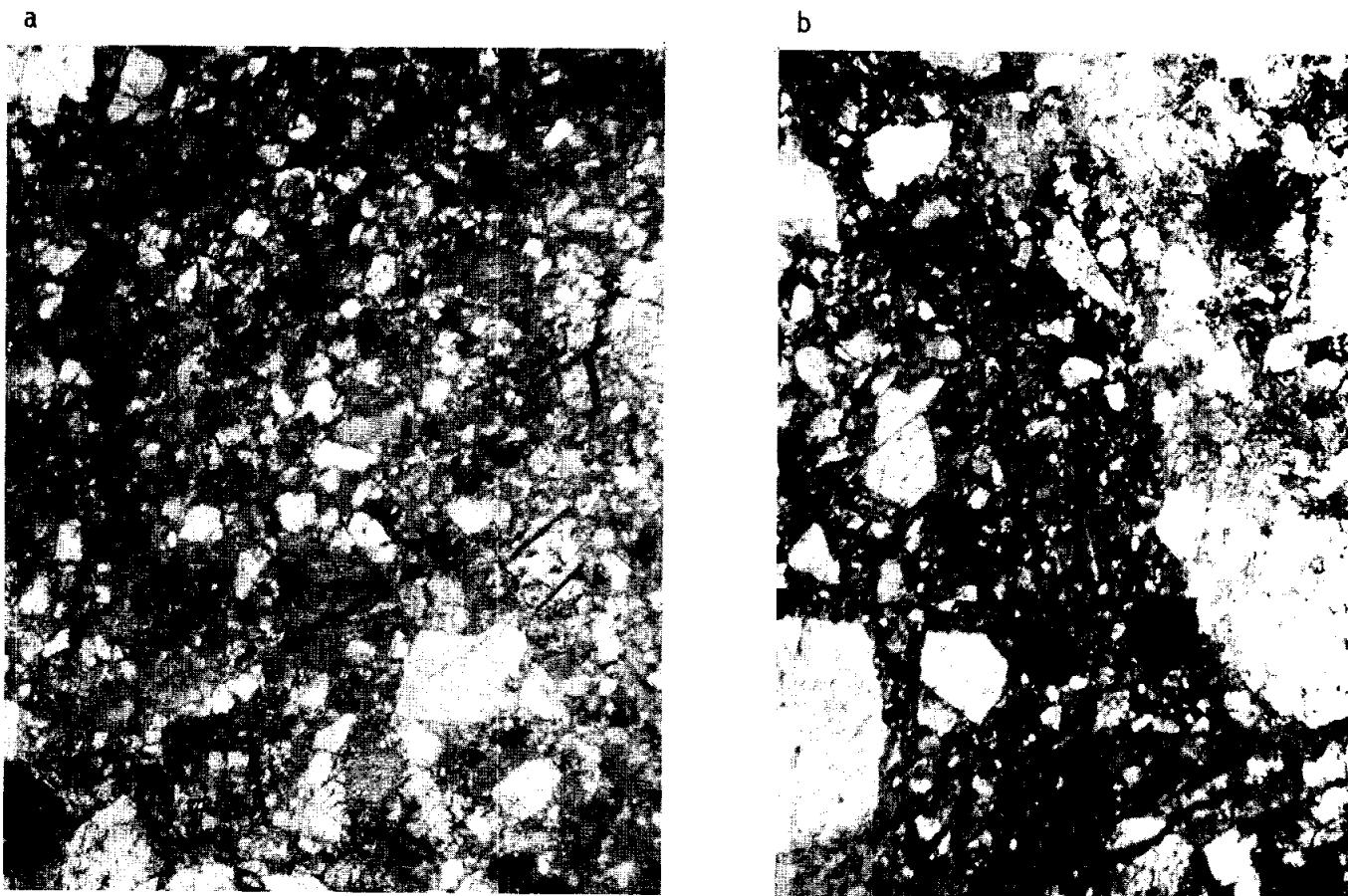


FIGURE 2. 60659,2. a) anorthosite clast, partly ppl. width 2mm.
 b) general matrix (top) and anorthosite clast (bottom), partly xpl. width 2mm.

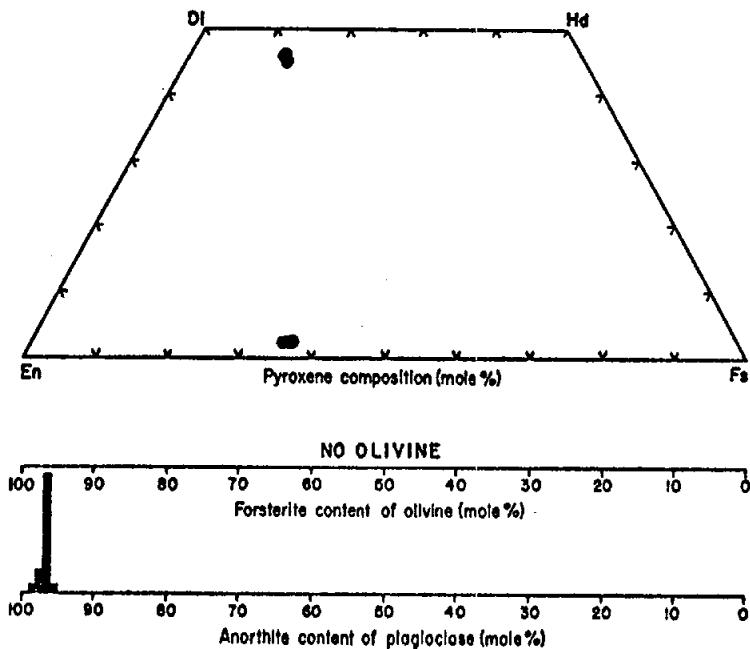


FIGURE 3. Mineral compositions; from R. Warner et al. (1976b).

TABLE 1. Chemistry of 60659 anorthosite clast
(DBA, normalized to 100%)

SiO ₂	44.3
TiO ₂	0.02
Al ₂ O ₃	35.4
FeO	0.30
MgO	0.21
CaO	19.3
Na ₂ O	0.43
P ₂ O ₅	0.03

CHEMISTRY: A defocussed electron beam analysis of the anorthosite clast is presented by Dowty et al. (1974a) and reproduced by Warner et al. (1976b) and here as Table 1. No analysis of the matrix is available.

PROCESSING AND SUBDIVISIONS: In 1973 two chips were removed from one end of the rock. One of these chips was allocated for thin sections as ,1 (Fig.1).

INTRODUCTION: 60665 is a vesicular glass containing small white clasts (Fig. 1), at least one of which is a cataclastic anorthosite. 60665 is a rake sample collected about 70 m west southwest of the Lunar Module. It has a few small zap pits.



FIGURE 1. S-73-20497. Larger pieces are about 6 cm across.

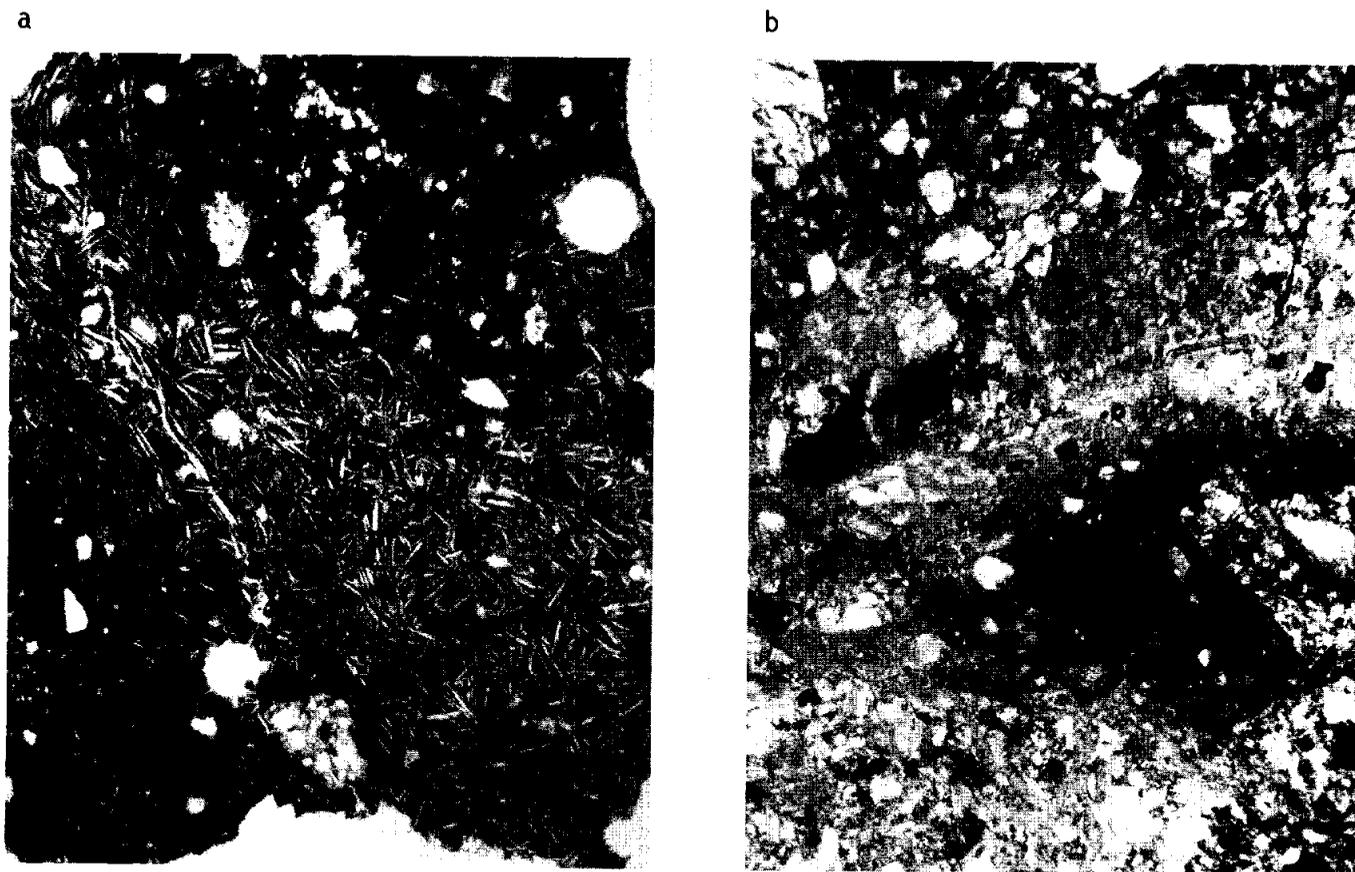


FIGURE 2. a) 60665,7. devitrified glass, ppl. width 2mm.
 b) 60665,3. anorthosite clast, partly xpl. width 2mm.

PETROLOGY: 60665 is a glass with many small clasts, and is largely devitrified (Fig. 2). Two white clasts are prominent macroscopically and one was sampled for thin sections (Fig. 1). Petrographic information on this clast is provided by Dowty et al. (1974a) and R. Warner et al. (1976b); Hansen et al. (1979a) report the abundances of minor elements in plagioclases and the mg of orthopyroxene (Table 1). The clast is an anorthosite (Fig. 2) which is ferroan (Fig. 3).

TABLE 1. Minor elements in plagioclase in anorthosite clast. (Hansen et al. 1979a)

Ab mole%	MgO wt%	FeO wt%	K ₂ O wt%	Opx mg
3.6	0.060	0.132	0.16	0.60

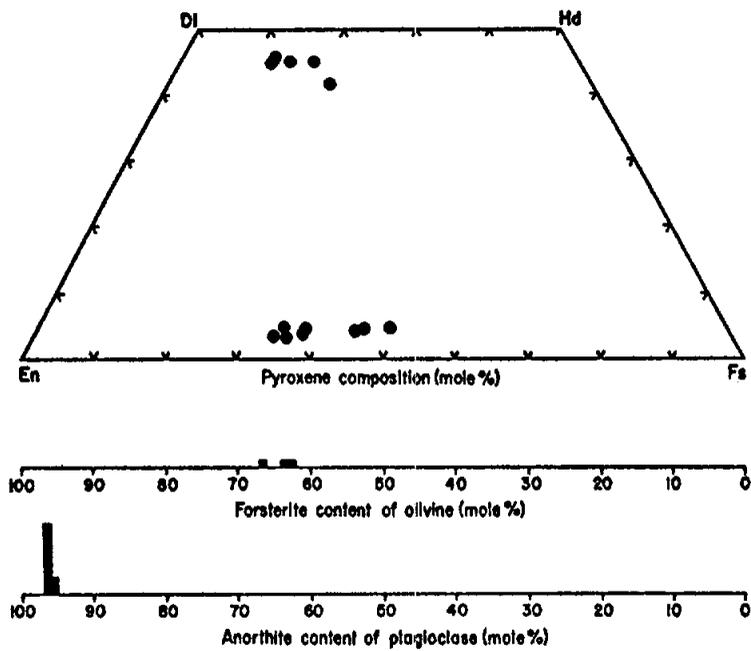


FIGURE 3. Mineral compositions for anorthosite clast; from R. Warner *et al.* (1976b).

PROCESSING AND SUBDIVISIONS: The sample has fallen into 2 pieces (Fig. 1). Part of one of the white clasts (,1) was removed for petrography (Fig. 1) and thin section ,3 cut from it. Two small white chips (,4) also exist. In 1979, two glass chips (,5) were made into a potted butt and thin section ,7 cut from it.

INTRODUCTION: 60666 is a dark gray, coherent, glassy to fine-grained impact melt with many clasts and vesicles and adhering dust. A large fragment of lighter colored basaltic impact melt dominates the interior of the rock (Fig. 1). It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.

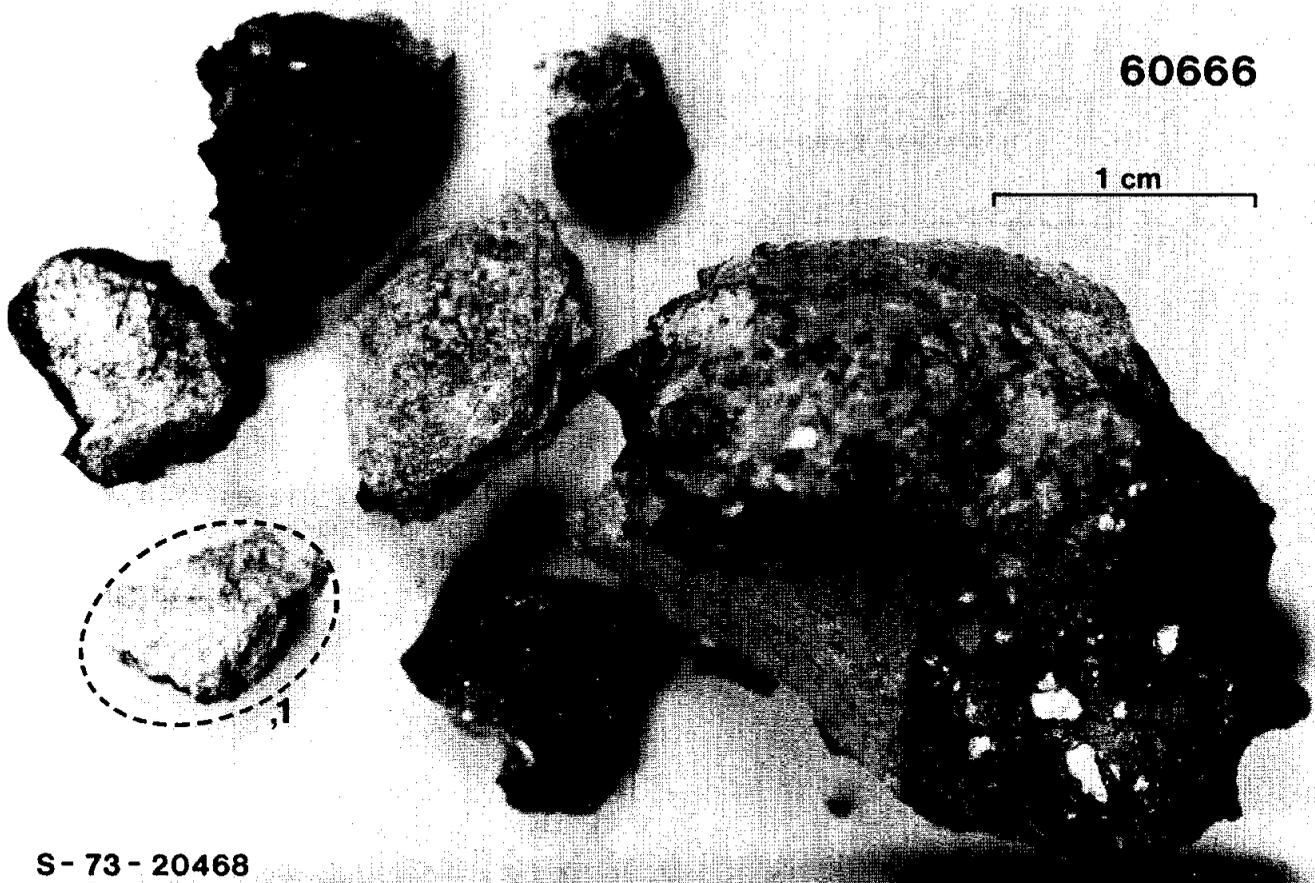


FIGURE 1.

PETROLOGY: Dowty et al. (1974b) and Warner et al. (1976b) provide petrographic descriptions of the large basaltic clast. Xenocrysts of shocked plagioclase and olivine rest in a matrix of skeletal to feathery olivine and glassy to finely crystalline mesostasis (Fig.2). Rare, very small needles of plagioclase occur interstitial to the matrix olivines. A few grains of spinel appear to have grown from the melt. The skeletal olivines are zoned (ranging from Fo_{87-96}) suggesting rapid growth from the melt. Plagioclase needles and xenocrysts are the same composition (Fig.3). Intergrowths of Fe-metal (4-21% Ni, 0.4 - 1.3% Co), schreibersite and troilite and a few discrete grains of chromite are also present. Mineral analyses are tabulated by Dowty et al. (1976).



FIGURE 2. 60666,2. general view, partly xpl. width 2mm.

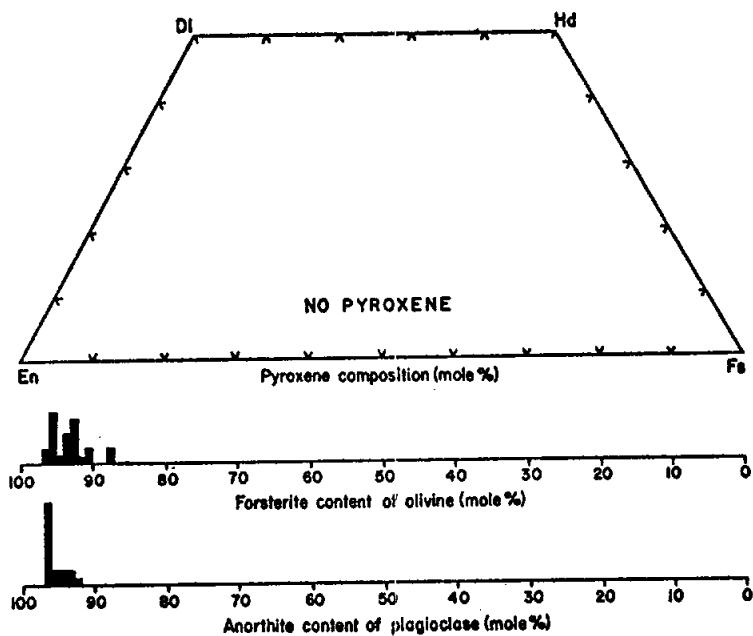


FIGURE 3. Mineral compositions; from R. Warner et al. (1976b).

TABLE 1. Summary chemistry of 60666 lithologies

	Dark, glassy melt (Wasson <u>et al.</u> , 1977)	Basaltic clast, bulk (DBA, Dowty <u>et al.</u> , 1974b)	Basaltic clast, excluding clasts) (DBA, Dowty <u>et al.</u> , 1974b)
SiO ₂		42.7	45.1
TiO ₂	0.50	0.21	0.27
Al ₂ O ₃	29.7	20.8	18.9
Cr ₂ O ₃	0.12	0.11	0.14
FeO	5.57	4.2	5.0
MnO	0.07	0.05	0.05
MgO	6.5	18.6	19.0
CaO	15.4	11.7	11.0
Na ₂ O	0.473	0.39	0.36
K ₂ O	0.084	0.10	0.11
P ₂ O ₅		0.04	0.06
Sr			
La	11.4		
Lu	0.49		
Rb			
Sc	6.5		
Ni	800		
Co	53		
Ir ppb	28		
Au ppb	9.0		
C			
N			
S			
Zn	≤5.7		
Cu			

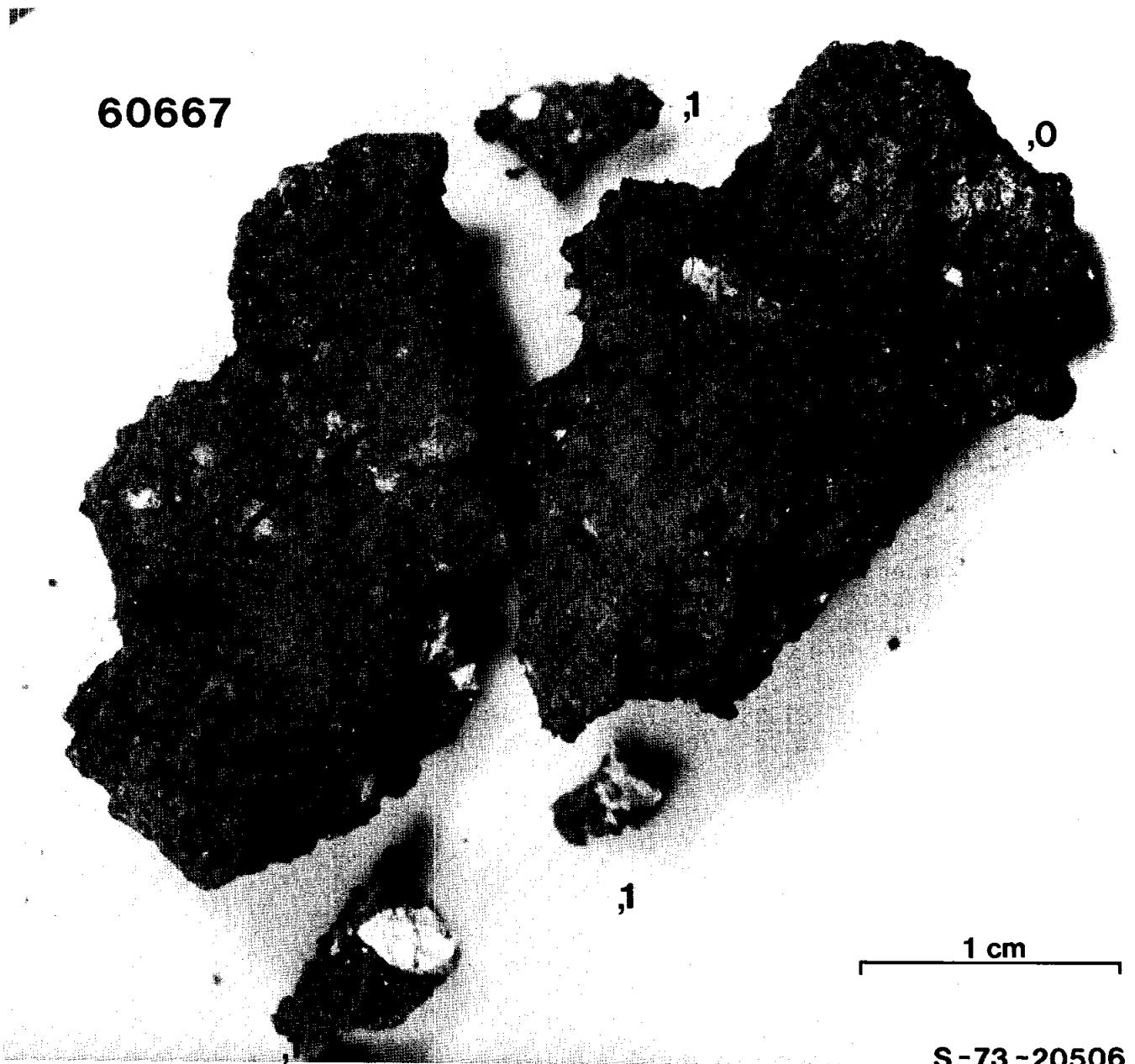
Oxides in wt%; others in ppm except as noted.

CHEMISTRY: Major and trace element data on the dark, glassy melt are presented by Wasson et al. (1977). Dowty et al. (1974b) give major elements of the lighter colored, basaltic clast and of the melt portion only of this clast (excluding xenocrysts) by DBA. The bulk DBA analysis of the basalt clast is reproduced by Warner et al. (1976b).

The two bulk analyses show that the basalt clast and the dark, glassy melt are not the same composition (Table 1). The dark, glassy material analyzed by Wasson et al. (1977) is very similar to the local mature soils. A significant meteoritic component is indicated by the siderophile data. The basaltic clast analyzed by Dowty et al. (1974b) is much less aluminous and has a higher Mg/Fe than the dark, glassy material (Table 1).

PROCESSING AND SUBDIVISIONS: In 1972 several chips were removed from the rock and a portion of the large basaltic clast (,1) allocated to Keil for petrography (Fig.1). In 1976, two small chips of dark glass (,3) were allocated to Wasson for chemistry.

INTRODUCTION: 60667 is a medium gray, coherent, basaltic impact melt (Fig. 1). Many small white clasts and a few grains of metal are scattered through the rock. It is subangular with many vugs and some splash glass. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are rare.



S-73-20506

FIGURE 1.



FIGURE 2. 60667,2. general view, partly xpl. width 2mm.

PETROLOGY: Warner et al. (1976b) provide a brief petrographic description. Abundant, cryptocrystalline to glassy mesostasis rests in interstices formed by many small plagioclase laths (Fig.2). One large, very fine-grained anorthosite clast is noted by Warner et al. (1976b).

PROCESSING AND SUBDIVISIONS: In 1972, the sample was split and three small chips (,1) allocated to Keil for petrography (Fig.1).

INTRODUCTION: 60668 is a dark gray, coherent, glassy impact melt (Fig. 1) which is angular and highly vesicular. A considerable amount of dust is welded to the glass and a few white clasts are present. It is a rake sample collected about 70 m west southwest of the Lunar Module and lacks zap pits.



FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60669 is a dark gray, coherent, glassy impact melt (Fig. 1). It is angular and highly vesicular. A few small (<1 mm) white clasts are scattered through the rock. It is a rake sample collected about 70 m west southwest of the Lunar Module and lacks zap pits.



FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60675 is a coherent, dark gray, fine-grained impact melt with abundant vugs, vesicles and white clasts (Fig. 1). It was collected as a rake sample about 70 m west southwest of the Lunar Module. Zap pits are absent.



FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60676 is a dark gray, coherent, glassy impact melt (Fig. 1). It is subangular and contains several large clasts. Few vesicles are present and most are filled with soil. It is a rake sample collected about 70 m west southwest of the Lunar Module. Zap pits are absent.

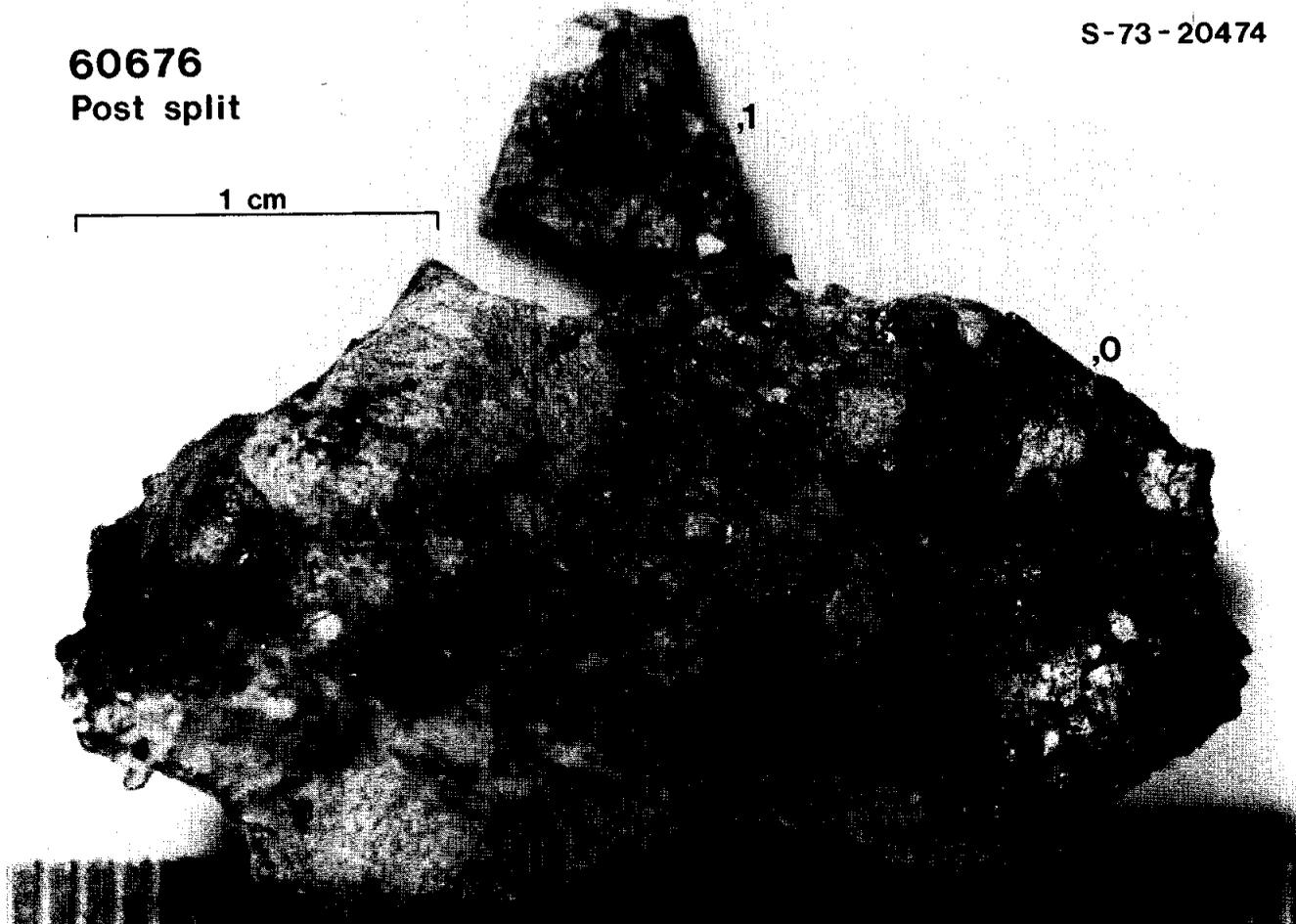


FIGURE 1.

PETROLOGY: Warner *et al.* (1976b) provide a brief petrographic description and mineral compositions. Abundant dark, banded glass encloses a variety of clasts (Fig. 2). One large poikilitic rock fragment, several heavily shocked plagioclase grains and a 0.1 mm pink spinel clast are noted by Warner *et al.* (1976b). Mineral compositions are shown in Figure 3 and tabulated by Dowty *et al.* (1976). Other minor phases include ilmenite, armalcolite, rutile and Fe-metal (5.4-6.5% Ni, 0.3-0.4% Co).



FIGURE 2. 60676,2.
general view, partly
xpl. width 3mm.

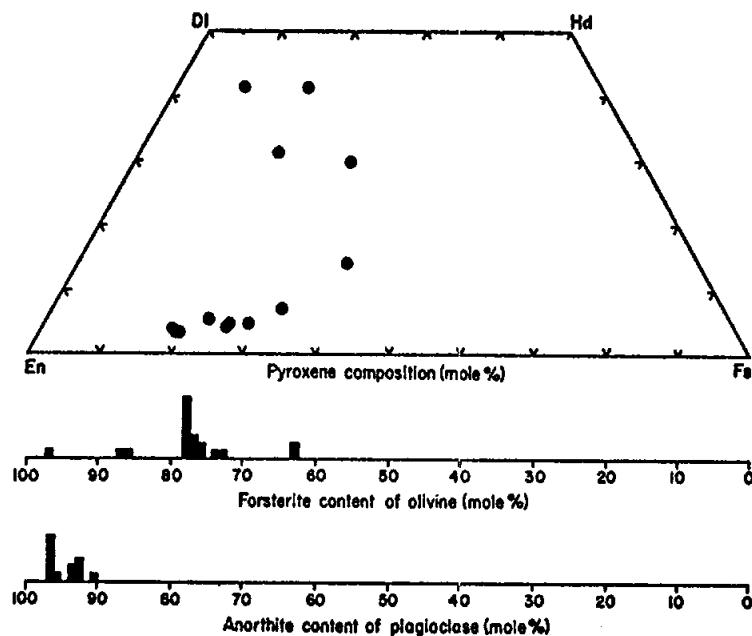


TABLE 1. Chemistry of 60676

SiO ₂	46.4
TiO ₂	0.70
Al ₂ O ₃	23.5
Cr ₂ O ₃	0.12
FeO	6.7
MnO	0.07
MgO	9.7
CaO	13.8
Na ₂ O	0.55
K ₂ O	0.18
P ₂ O ₅	0.24

FIGURE 3. Mineral compositions; from R. Warner
et al. (1976b).

CHEMISTRY: A defocussed electron beam analysis (DBA) is given by Warner et al. (1976b) and reproduced here as Table 1.

PROCESSING AND SUBDIVISIONS: In 1973 a single chip (,1) was removed and allocated to Keil for petrography (Fig. 1).

INTRODUCTION: 60677 is a coherent, dark gray, glassy breccia with several different clasts, including a large (14x2 mm), friable clast of granoblastic anorthosite (Fig. 1). Many vesicles are present on all surfaces. It is a rake sample collected about 70 m west-southwest of the Lunar Module and lacks zap pits.

S-73-20465

60677

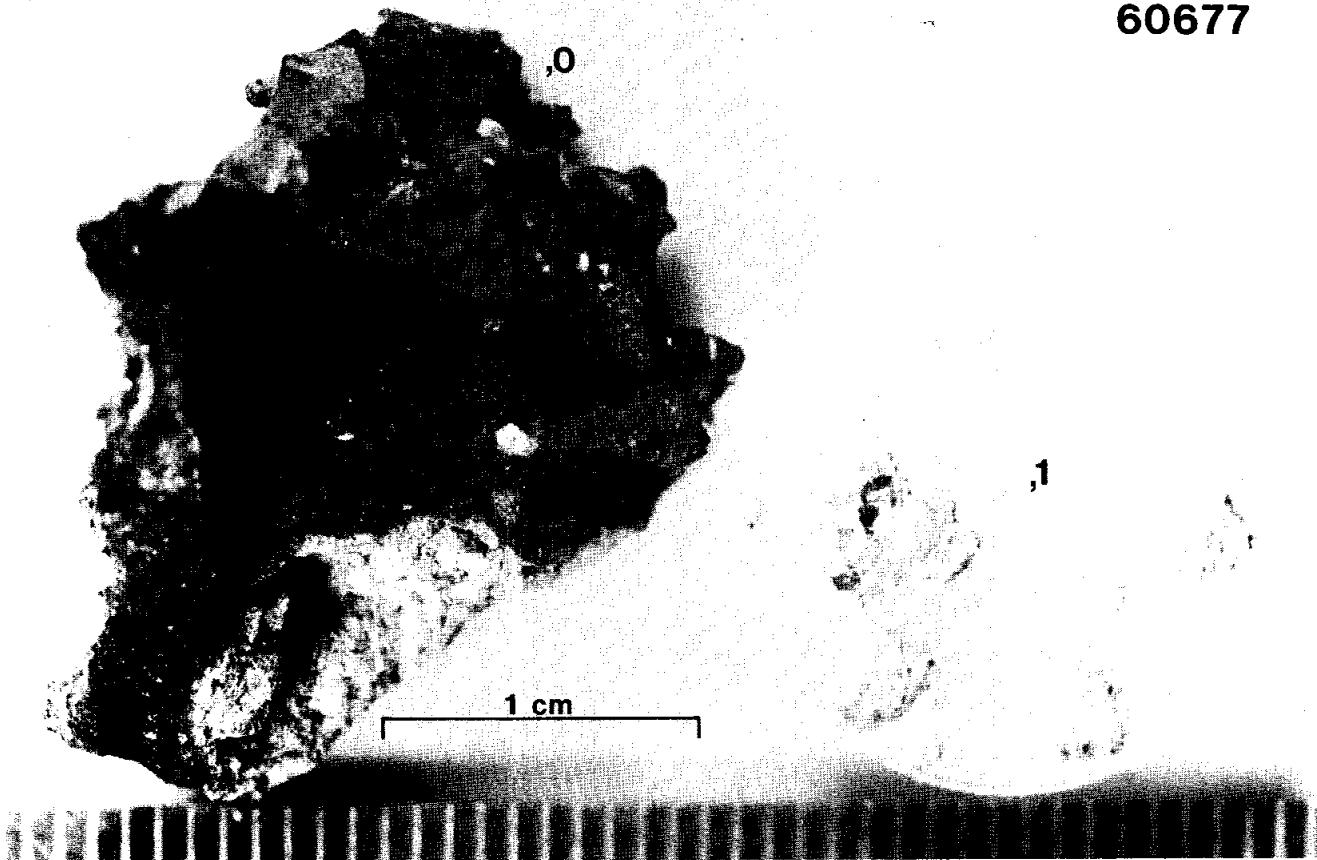


FIGURE 1.

PETROLOGY: Warner et al. (1976b) provide petrographic descriptions of both the glassy matrix and a granoblastic anorthosite clast. Dowty et al. (1974a) describe the same anorthosite clast.

The large white clast shown in Figure 1 is an annealed anorthositic breccia with a granoblastic texture (Fig. 2). Small, anhedral olivine grains reside in triple junctions formed by polygonal plagioclases. Pyroxene is absent. Mineral compositions are shown in Figure 3 and tabulated by Dowty et al. (1976). Ilmenite is an accessory phase.

The matrix of 60677 is a very porous mixture of mineral, lithic and glass clasts welded together by glass (Fig. 2). Several breccia clasts and one poikilitic-textured clast are mentioned by Warner et al. (1976b).

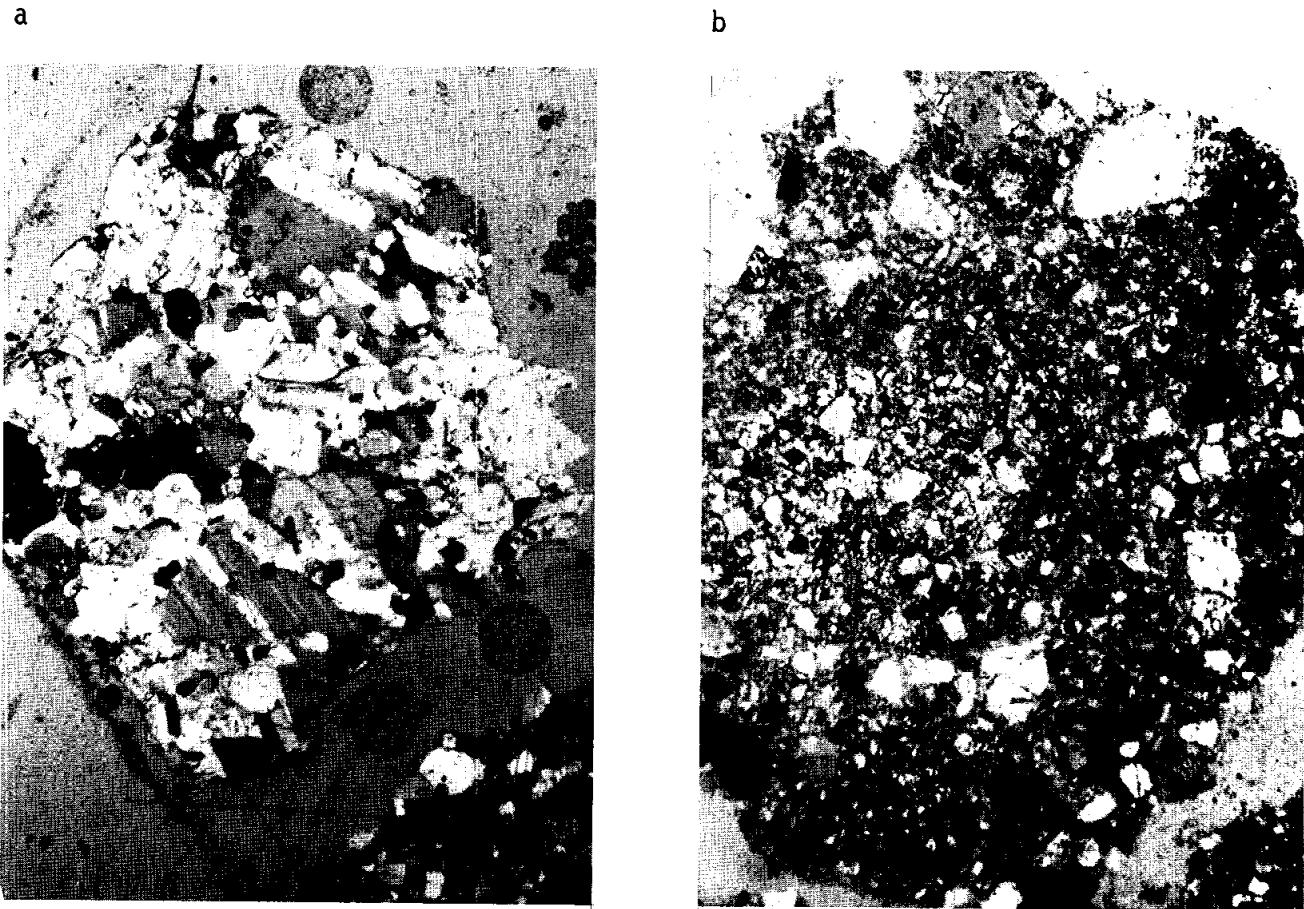


FIGURE 2. 60677,2. a) granoblastic anorthosite, partly xpl. width 2mm.
 b) glassy breccia matrix, partly xpl. width 2mm.

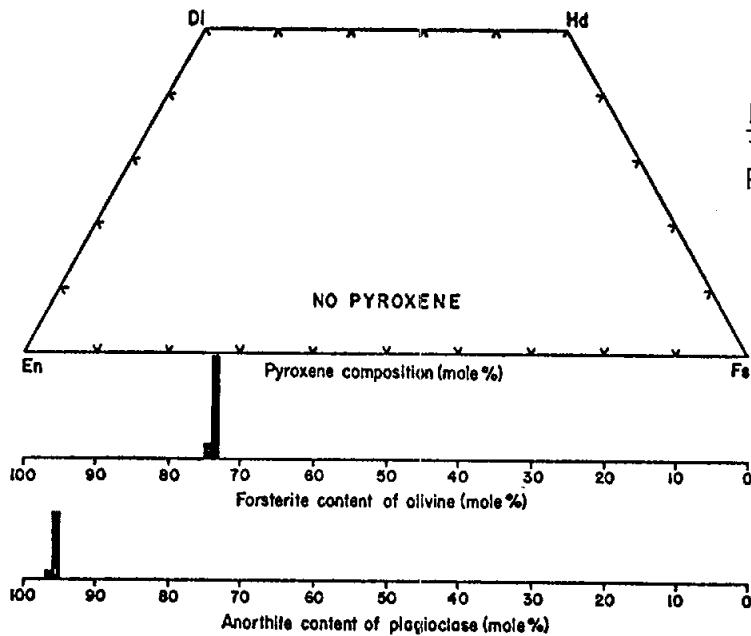


FIGURE 3. Mineral compositions in granoblastic anorthosite; from R. Warner *et al.* (1976b).

TABLE 1. Chemistry of 60677 anorthosite clast (DBA)

SiO ₂	44.3
TiO ₂	0.04
Al ₂ O ₃	34.2
Cr ₂ O ₃	0.01
FeO	1.04
MnO	0.01
MgO	1.40
CaO	18.3
Na ₂ O	0.56
K ₂ O	0.03
P ₂ O ₅	0.03

CHEMISTRY: A defocussed electron beam analysis (DBA) of the granoblastic anorthosite clast described above is presented by Dowty et al. (1974a) and reproduced by Warner et al. (1976b), and here as Table 1. No analysis of the glassy matrix is available.

PROCESSING AND SUBDIVISIONS: In 1973 four small chips (,1) were allocated to Keil for petrography (Fig.1).

INTRODUCTION: 60678 is a dark gray, coherent, glassy impact melt (Fig. 1). It is angular and highly vesicular. Several small white clasts and a friable breccia clast (8 mm) are present. It is a rake sample collected about 70 m west southwest of the Lunar Module and lacks zap pits.



FIGURE 1. Small scale divisions in mm.

INTRODUCTION: 60679 is a dark gray, coherent, glassy impact melt (Fig. 1). It is angular and highly vesicular. Several white clasts and a friable breccia clast (13 mm) are present. It is a rake sample collected about 70 m west south-west of the Lunar Module and lacks zap pits.

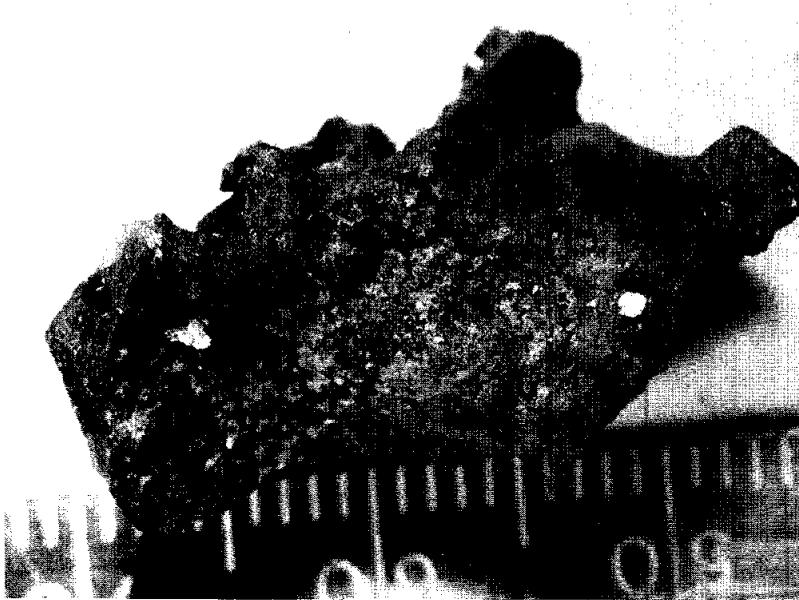


FIGURE 1. Small scale divisions in mm.

61015 DILITHOLOGIC (CATACLASTIC ANORTHOSITE AND BASALTIC IMPACT MELT) 1789 g
BRECCIA, PARTLY GLASS COATED

INTRODUCTION: 61015 consists of ~75% dark basaltic impact melt and ~25% white anorthosite. The melt/anorthosite contacts are sharp and form an unusual texture (Fig. 1). A vesicular glass partially coats two sides. The sample is tough and subangular.

61015 was collected 10 m south of Plum Crater and its orientation is known. Zap pits on only half of its surface suggest a fairly simple exposure history.

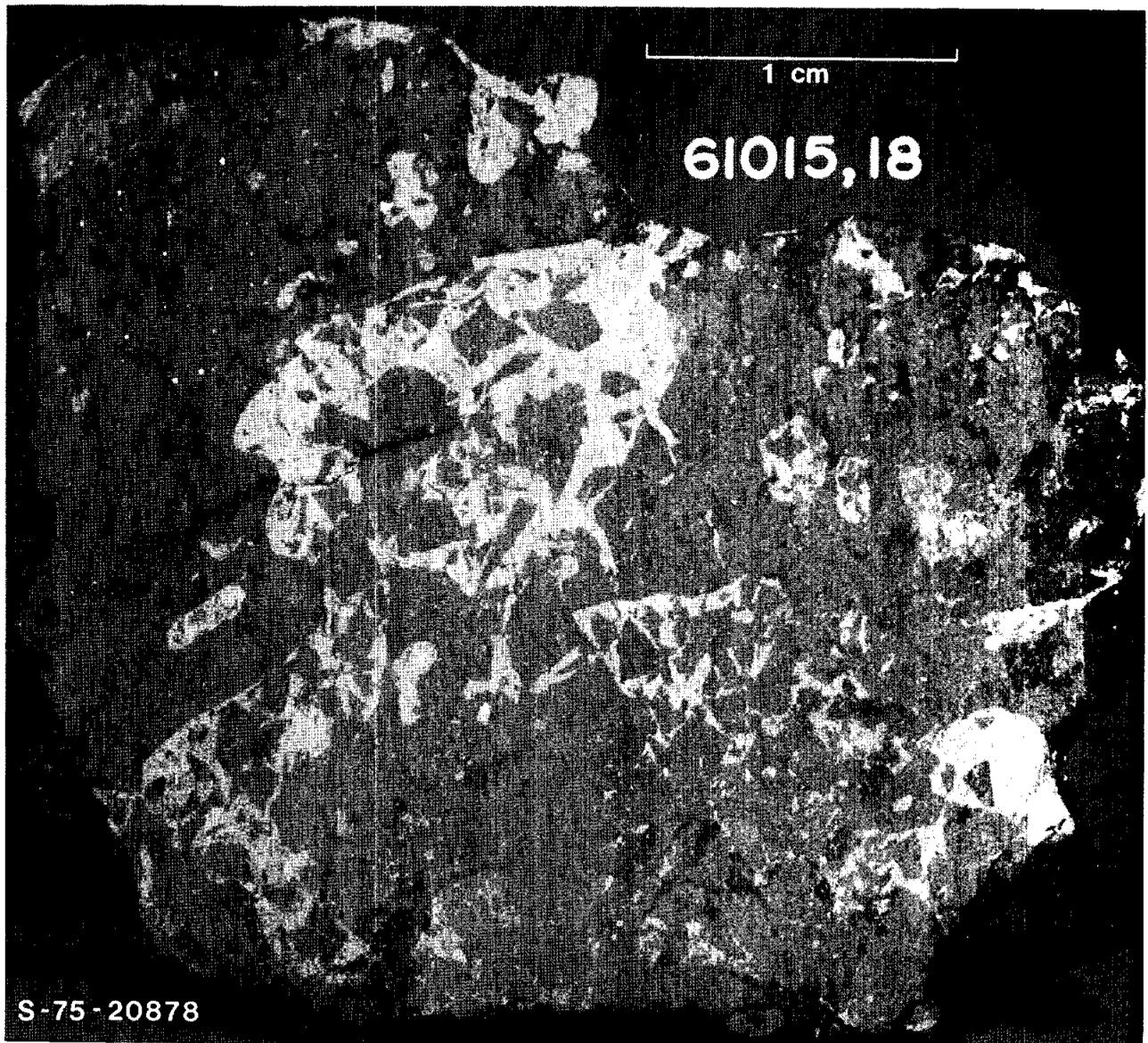


Figure 1. Saw cut face.

PETROLOGY: A brief description is given by McGee et al. (1979) and 61015 is illustrated by LSPET (1973).

The basaltic impact melt (Fig. 2) is characterized by plagioclase laths less than 100 μm long subophitically embedded in small pyroxenes and abundant interstitial glass. Engelhardt (1978) lists it as poikilitic, but a poikilitic texture is only poorly developed. Clasts of shocked plagioclase are abundant. Individual fragments of the basalt have different grain sizes; a few are aphanitic and some glassy. No chilled margins are present.

The anorthosite is cataclastic and coarse--some plagioclases are 2 mm in diameter (Fig. 2). A few pyroxenes (up to 300 μm) are present; some have either exsolution or shock lamellae. Some opaques (chromite?), troilite, and Fe-metal are also present. Except for the distinct dark fragments, the anorthosite appears pure i.e. it is not intimately mixed on a small scale with extraneous material.

The anorthosite probably intruded the basaltic impact melt in the rock-forming event. The saw-cut faces (e.g. Fig. 1) show zones of white material whose boundaries with the main dark masses are mainly smooth and curving; within the white zones, angular black fragments are prominent. In a few places the white forms small apophyses into the dark material. The anorthosite must have been fluid (e.g. hot gas charged debris) though not a silicate liquid during its injection. None the less, relationships between dark and white are not clearly established.

The glass coat (Fig. 2) is vesicular, brown-gray, and contains small metal blebs and plagioclase fragments. Its thermal effects on the impact basalt are optically visible for 300 μm into the rock. Thin (300 μm) veinlets of gray-brown, flow-banded glass penetrate the rock, apparently from the coat; these veinlets are opaque at their margins.

CHEMISTRY: Chemical analyses of the basaltic impact melt and an impure sample of the anorthosite are presented in Palme et al. (1978). Christian et al. (1976) present an analysis of the impact melt and of a mixed black-and-white split. The analyses of the melt and the impure anorthosite are summarized in Figure 3 and Table 1. The glass coat has not been analyzed.

The basaltic melt is aluminous, meteorite-contaminated and distinct from Apollo 16 soil compositions. The impure anorthosite sample is meteorite-contaminated and the analyzed sample probably contained some of the basaltic impact melt. The data indicate that the pure anorthosite is ferroan ($\text{FeO/MgO} > 1$).

MICROCRATERS: Microcrater frequency distribution data for the surface of 61015 are reported by Neukum et al. (1973) and Morrison et al. (1973) (Fig. 4). Both papers note the rounded nature of the rock and that pits occur on only half of the surface, indicating a fairly simple exposure history. While Morrison et al. (1973) do not believe that this rock has a steady-state surface, Neukum et al. (1973) consider that such equilibrium is likely.

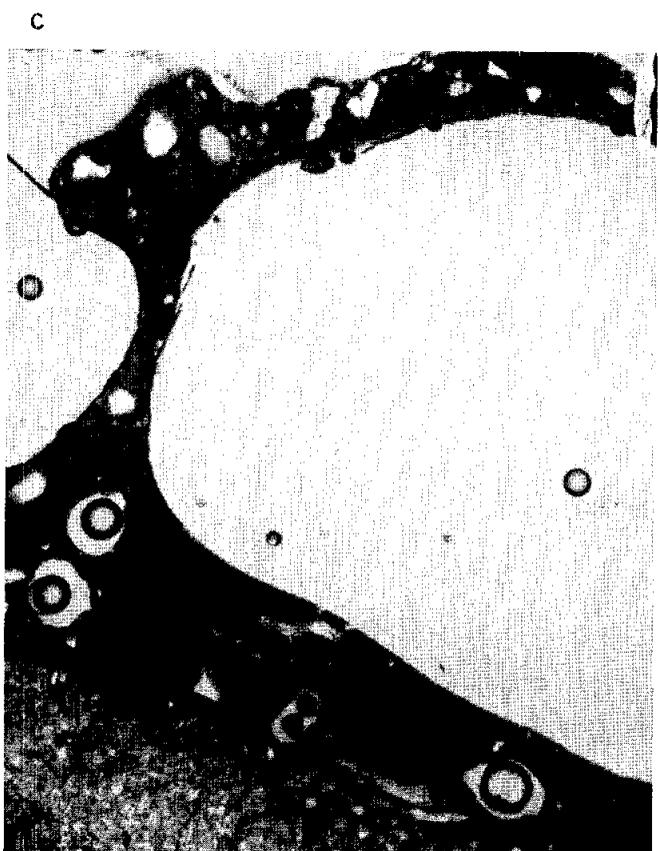
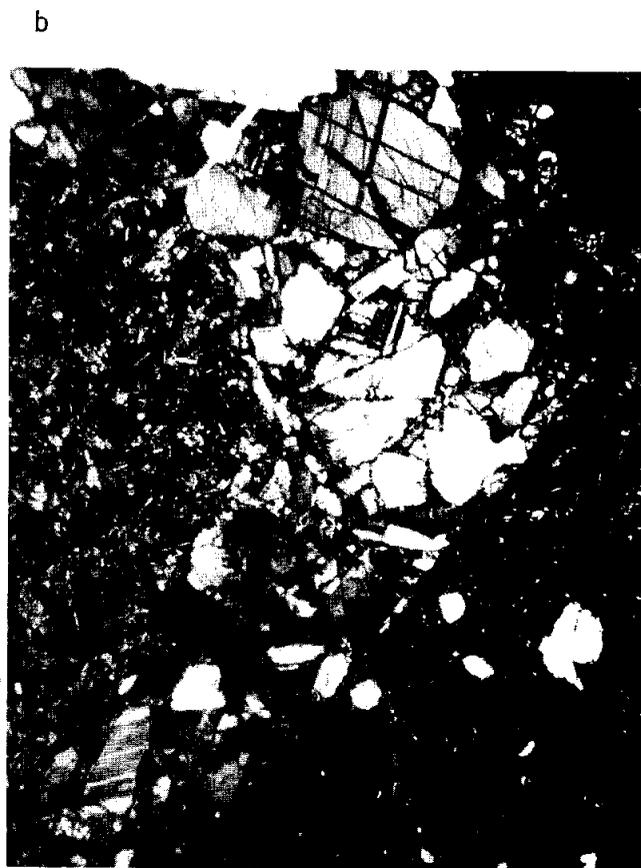


Figure 2. a) 61015,14. basaltic area,
ppl. width 2 mm.
b) 61015,14. anorthosite,
xpl. width 2 mm.
c) 61015,40. glass coat,
ppl. width 2 mm.

TABLE 1. Summary chemistry of basaltic impact melt
and impure anorthosite in 61015

	<u>Basaltic Melt</u>	<u>Impure Anorthosite</u>
SiO ₂	45.4	45.5
TiO ₂	0.70	0.27
Al ₂ O ₃	23.	32.9
Cr ₂ O ₃	0.14	0.05
FeO	6.6	3.0
MnO	0.09	0.03
MgO	9.7	2.9
CaO	13.5	17.8
N ₂ O	0.48	0.47
K ₂ O	~ 0.17	0.047
P ₂ O ₅	0.19	0.087
Sr	~153	197
La	20.	7.6
Lu	0.9	0.32
Rb	4.0	
Sc	10.5	3.9
Ni	540-1160	690
Co	30-61	39.5
Ir ppb	29	13
Au ppb	20	14
C		
N		
S	2150	470
Zn		
Cu		

Oxides in wt%; others in ppm except as noted.

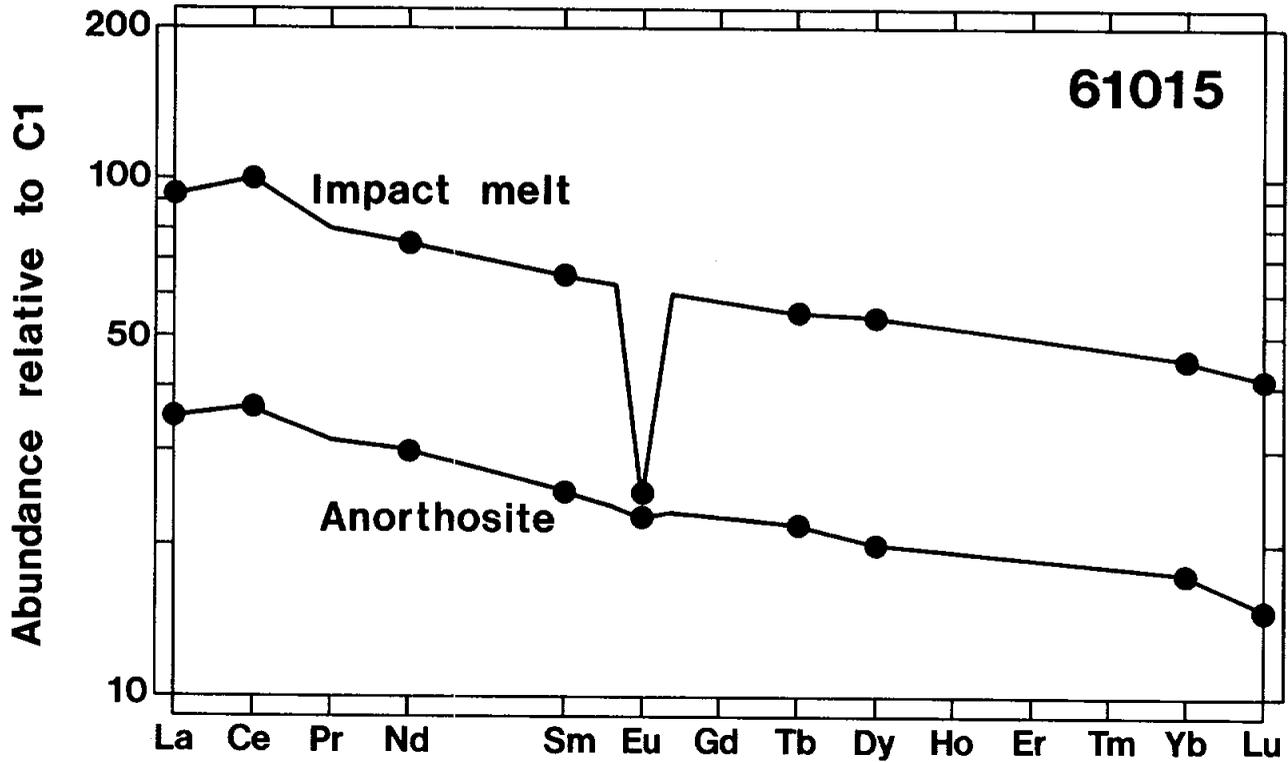


Figure 3. Rare earths; data from Palme et al. (1978).

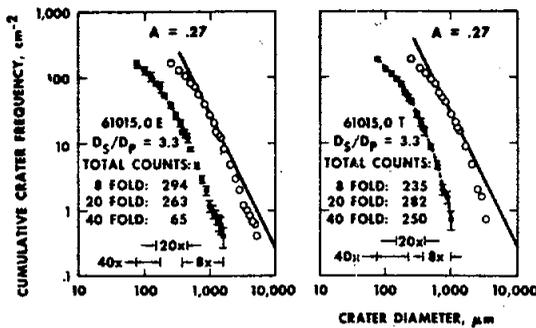


Figure 4. Microcraters; from Neukum et al. (1973).

PROCESSING AND SUBDIVISIONS: A few chips were removed from the rock prior to a saw cut being made to remove a butt end in 1973. Most of the sample remains as ,0 (1490 g). The butt end was split into ,18 (150 g); ,20 (93 g) and a number of other smaller pieces, some of which were further subdivided. Most of the allocations were from these latter chips.

INTRODUCTION: "Big Muley" is the largest rock collected on the Apollo missions. The bulk of the sample is a fragment-laden aluminous impact melt in which all plagioclase has been shocked to diaplectic glass. A chemically pristine but shocked and shock-melted anorthosite is a subordinate lithology. The shock-melted portion of the anorthosite was liquid, not diaplectic and intrudes the basalt (Fig. 1). Although the anorthosite has generally been referred to as a clast in the basalt, the contact of the non-melted anorthosite with the basalt is not in the thin sections and the relationships are obscure. Much of the rock is coated with a thin aluminous glass (Fig. 1). Warner *et al.* (1973) classify 61016 as a black-and-white rock: cataclastic anorthosite plus mesostasis-rich basalt.

61016 was collected from the east rim of Plum Crater and its orientation is known. Zap pits are absent from one side. This side was exposed on the lunar surface, indicating that a recent, and only recent, rotation of the sample occurred. Planar non-penetrative fractures are exposed on most surfaces.

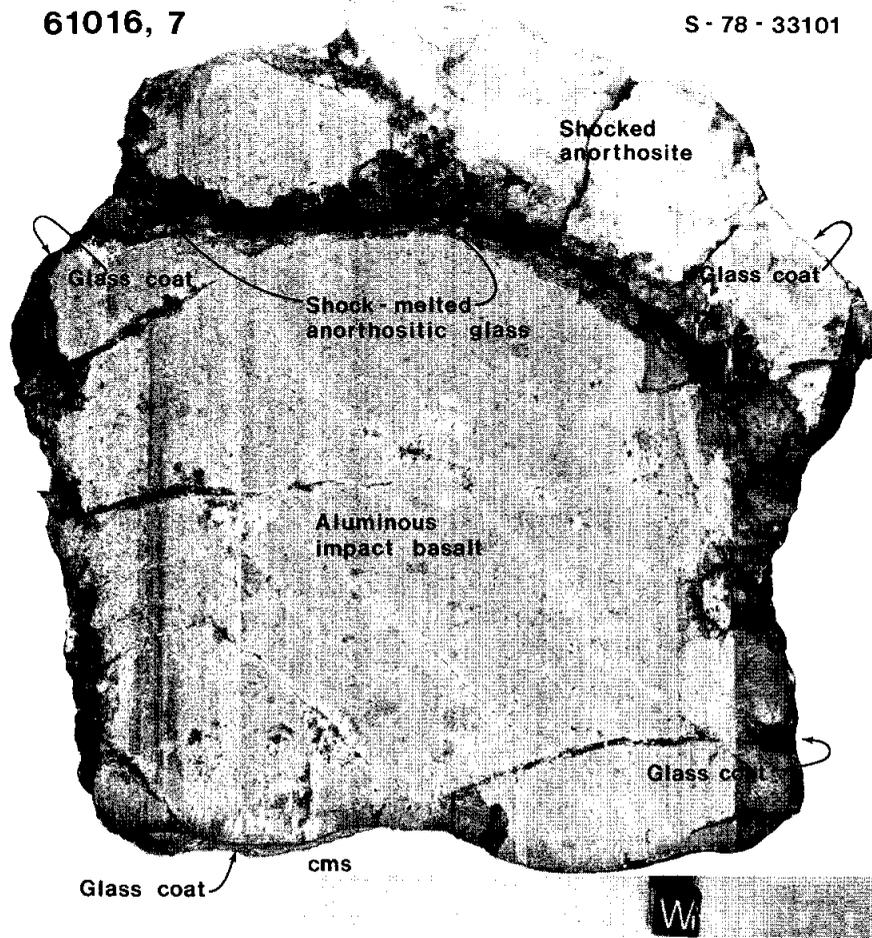


Figure 1. Sawn face of 61016 showing main lithologies and the fractures.

61016 Slab

S-72-50692

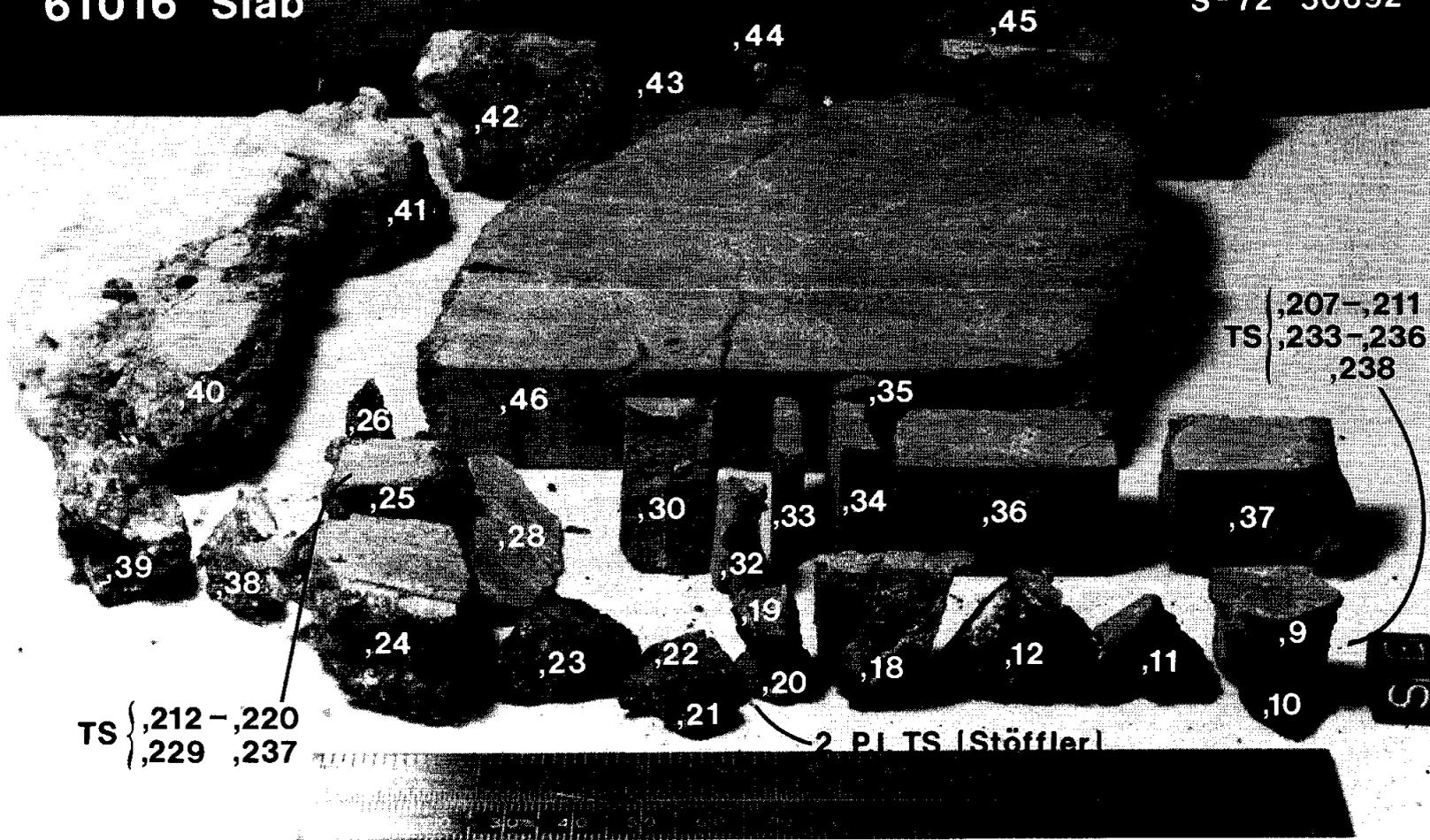


Figure 2. Slab subdivisions.

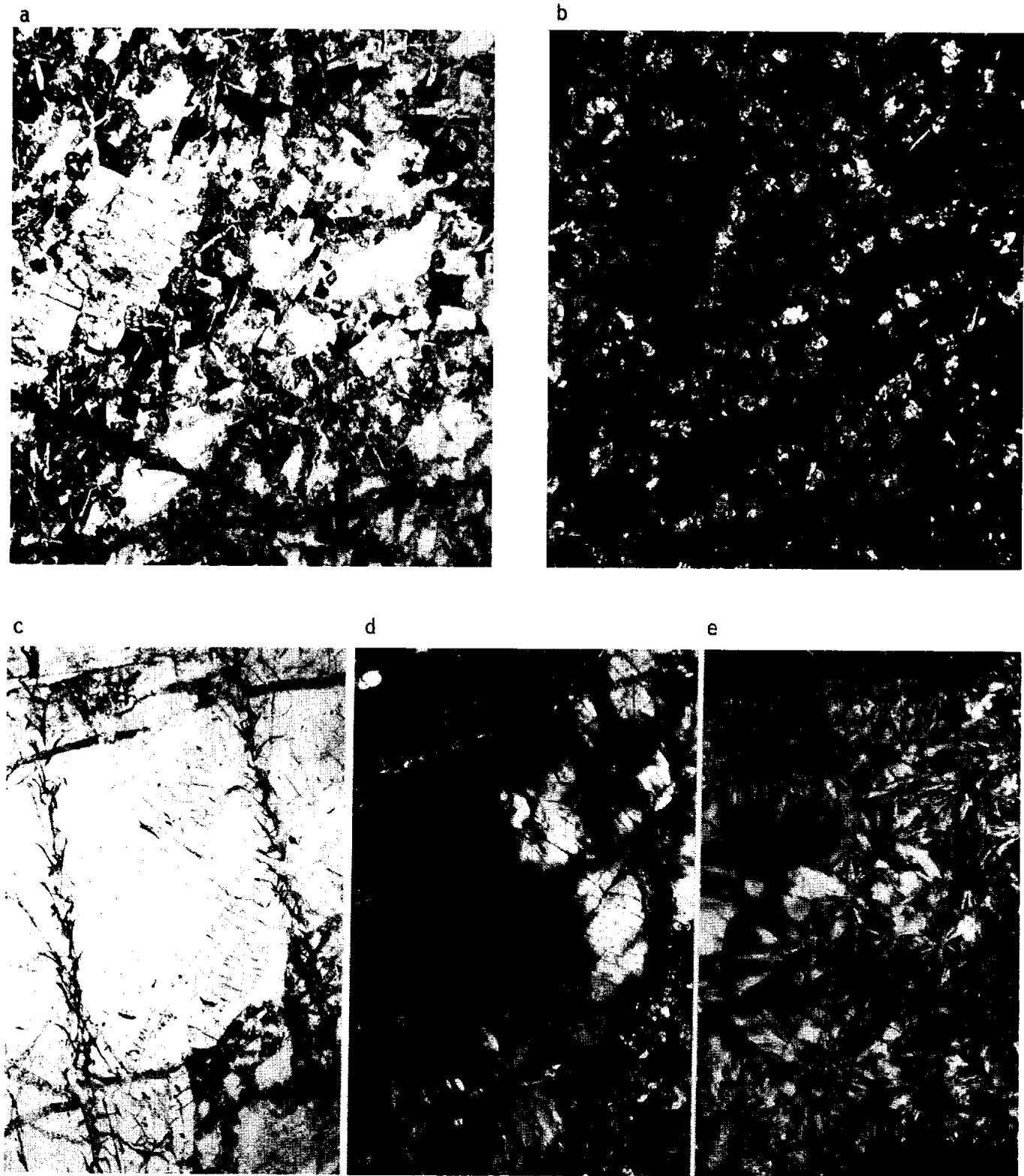


Figure 3. a) 61016,217, basaltic area, ppl. width 2 mm.
 b) 61016,217, basaltic area, xpl. width 2 mm.
 c) 61016,217, shock-melted anorthositic glass,
 ppl. width 1.5 mm.
 d) 61016,217, shock-melted anorthositic glass,
 xpl. width 1.5 mm.
 e) 61016,221, shocked anorthosite, xpl. width 1.5 mm.

PETROLOGY: 61016 consists of four lithologies (i) basaltic impact melt, (ii) shocked anorthosite, (iii) shock-melted anorthosite glass and (iv) glass coat (Figs. 1 and 3). A proper appreciation of the published petrographic descriptions requires an understanding of the location of the thin sections studied; these are shown in Figure 2, except for thin sections made from 2 chips of white anorthosite.

Stöffler *et al.* (1975) give an extensive description of the petrography and petrogenesis of 61016 with emphasis on the basaltic impact melt (referred to as "spinel troctolitic matrix") and the glass coat ("melt crust"). The paper provides microprobe analyses of minerals, metals, glasses, and xenoliths.

Drake (1974), McGee *et al.* (1979) and Juan *et al.* (1974) describe thin sections which are composed of the impact melt and the anorthosite glass vein (from ,25).

The basaltic impact melt (Fig. 3) consists of anhedral to subhedral olivine (43%), equant to lath-shaped anorthite transformed to diaplectic glass (42%), some tiny spinels, Fe-Ni metal (1.5%) and an opaque mesostasis (14%) consisting of ilmenite, submicroscopic phases and glass (Stöffler *et al.*, 1975). 16% of the basaltic lithology is xenolithic material. Olivine crystals are less than 200 μm and compositions range from Fo_{79-93} (Stöffler *et al.*, 1975; Drake, 1974). Plagioclases are An_{92-98} (Stöffler *et al.*, 1975). Fe-Ni metal (Fig. 4) has 4.24-7.48% Ni and 0.24-0.47% Co (Misra and Taylor, 1975; Stöffler *et al.*, 1975). The compositions of one metal-schreibersite pair indicates equilibrium at $\sim 650^\circ\text{C}$ (Misra and Taylor, 1975). Engelhardt (1979) notes that ilmenite occurs only in the mesostasis.

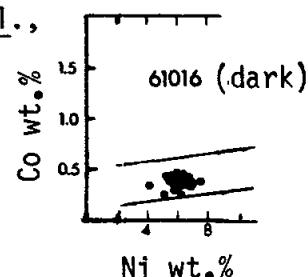


Figure 4. Metals, from Misra and Taylor (1975).

The chemically pristine shocked anorthosite is described by Steele and Smith (1973), Smith and Steele (1974), Stöffler *et al.* (1975), and Hansen *et al.* (1979a). It has a complex texture induced by shock metamorphism. Sub-rounded, fine-grained, polycrystalline anorthite "bodies" (Stöffler *et al.*, 1975) are embedded in a mass of spherulitically crystallized anorthite (Fig. 3). Some pyroxene aggregates are present. Plagioclases are An_{95-97} with low abundances of minor elements (Table 1) (Steele and Smith, 1973; Hansen *et al.*, 1979a).

Pyroxene blebs have two compositions, $\text{En}_{41}\text{Wo}_{44}$ and $\text{En}_{58}\text{Wo}_2$, lacking exsolution features on a 1 μm scale (Steele and Smith, 1973).

TABLE 1: Minor Elements in 61016 Anorthosite Plagioclases

Sample	(Hansen <i>et al.</i> , 1979a)			
	Mol % Ab	FeO wt%	MgO wt%	K ₂ O wt%
,15	3.5	0.11	0.07	0.006
,27 melted	3.8	0.231	0.17	0.022
,27 non-melted	3.8	0.121	0.051	0.023

The shock-melted anorthosite glass is described by Juan *et al.* (1974), Drake (1974) and Dixon and Papike (1975) where it is referred to as the anorthosite. The confusion arises because the relevant thin sections have basaltic impact melt, shock-melted anorthosite, and a large diaplectic plagioclase which is probably a xenocryst in the basaltic melt rather than the anorthosite. The shock-melted anorthosite has the composition of nearly pure plagioclase (verified by our own partial analysis) (An_{96} ; Drake, 1974; Dixon and Papike, 1975). Some low-Ca pyroxene grains are present with compositions $\sim En_{64}$ (Dixon and Papike, 1975) as well as high-Ca pyroxene and Cr-spinel. Ishii *et al.* (1976) use pyroxene data from Dixon and Papike (1975) to find an equilibrium temperature of 983°C.

The glass crust is described by Stöffler *et al.* (1975). It contains unshocked anorthite crystals and is connected to glass veins penetrating the rock. In places the glass coat has penetrated and annealed plagioclase in the basaltic impact melt. A temperature gradient of 600°C within about 2 mm is inferred (Stöffler *et al.*, 1975).

CHEMISTRY: Abundant chemical data for 61016 lithologies have been published. In a few cases the lithology analyzed has been erroneously or not specifically reported; Tables 2 and 3 list the references under the correct lithologies. In most cases the analyses are reported without specific comment.

The basaltic impact melt (Table 4) (61016 "dark") is aluminous and siderophile-rich. Ganapathy *et al.* (1974) place it in their meteorite Group 1. REEs are 45 (light)-20 (heavy) times chondrites i.e., a KREEP pattern (Fig. 5). Although roughly similar to local soils (Laul and Schmitt, 1973), in detail it differs significantly e.g., higher magnesium, lower nitrogen. The impact melt is volatile-enriched but when that enrichment occurred is not defined: Krähenbühl *et al.* (1973) note that both the impact melt and the anorthosite have similarly high Tl contents, suggesting post-formational enrichment. However, Cd and In are enriched in the impact melt as compared to the anorthosite (Krähenbühl *et al.*, 1973; Wasson *et al.*, 1975) suggesting pre-formational enrichment. While the impact melt has even higher contents of the volatiles Cl and Br than does 66095 (Jovanovic and Reed, 1973; and others), it has much lower abundances of Zn, even lower than local soils.

The anorthosite is almost pure plagioclase (Table 4) and is at least in part pristine (Krähenbühl *et al.*, 1973); some analyses have slightly higher siderophile contents and may be contaminated. This would not be surprising in view of the shock-melting, if some of the analyzed samples include shocked glass. (The Ir content of 1620 ppb given by Hughes *et al.* (1973) is completely anomalous; because it is 3 times higher than chondrites whereas the corresponding Au, Re contents are 5×10^{-4} times chondrites, it is probably erroneous). This pristine chemistry probably does not include volatiles, several of which (e.g., Tl, Cd) are enriched as compared with other ferroan anorthosites.

The glass coat (Table 4) has been analyzed only by the microprobe (Stöffler *et al.*, 1975), thus no trace element data exist. Its major element composition distinguishes it from both local soil and the 61016 basaltic impact melt. It is similar to Station 11 soil.

TABLE 2. Chemical work on 61016 basaltic impact melt

REFERENCE	SPLIT ANALYZED	ELEMENTS ANALYZED
S.R. Taylor <i>et al.</i> (1973)	,149	major and traces
Duncan <i>et al.</i> (1973)	,139	major and traces
Janghorbani <i>et al.</i> (1973)	,133	majors
Rose <i>et al.</i> (1973)	,150	major and traces
Brunfelt <i>et al.</i> (1973)	,145	majors and traces
Hubbard <i>et al.</i> (1973)	,143	majors and traces
Nyquist <i>et al.</i> (1973)		Rb, Sr
Lau and Schmitt (1973)	,152	major, traces, siderophiles
Nakamura <i>et al.</i> (1973)	,148	majors and traces
Wänke <i>et al.</i> (1973)	,151	majors, traces, siderophiles
Wänke <i>et al.</i> (1974)	,151	majors, traces, siderophiles
Wänke <i>et al.</i> (1977)	,151	V
Juan <i>et al.</i> (1974)	,146	majors and traces
Stettler <i>et al.</i> (1973)	,4	K, Ca
Jovanovic and Reed (1973)	,131*	F, Cl, Br, I, Li, U, Te
Allen <i>et al.</i> (1974, 1975)	,131*	²⁰⁴ Pb, Bi, Tl, Zn
Jovanovic and Reed (1976a)	,131	Ru, Os
Reed <i>et al.</i> (1977)	,131	Zn, Tl
Eldridge <i>et al.</i> (1973)	,120	K, U, Th
Ehmann and Chyi (1974)	,133	Zr, Hf
Miller <i>et al.</i> (1974)	,133	
Garg and Ehmann (1976)	,133	Zr, Hf, Fe, Co, Sc, Cr, REEs, Th
Des Marais (1978)	,323	N, S, C
Kerridge <i>et al.</i> (1975)	,159, 160	C, S
Goels <i>et al.</i> (1975)	,136	N
Gibson and Moore (1975)		Volatile gas compounds
Rees and Thode (1974)	,137*	S
Krähenbühl <i>et al.</i> (1973)	,132	Meteoritic siderophiles and volatiles
Ganapathy <i>et al.</i> (1974)		

* Erroneously referred to in paper as the anorthosite phase.

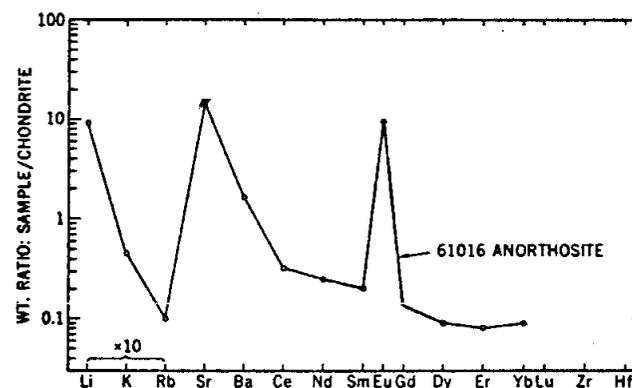


Figure 5. Incompatible elements, from Philpotts *et al.* (1973).

TABLE 4. Summary chemistry of lithologies in 61016

	Basaltic Impact Melt	Anorthosite	Glass Coat
SiO ₂	43.3	45.0	44.5
TiO ₂	0.76	0.02	0.17
Al ₂ O ₃	25.1	34.6	29.8
Cr ₂ O ₃	0.10	0.01	
FeO	5.1	0.3	3.7
MnO	0.05	<0.01	
MgO	10.7	0.2	4.9
CaO	14.3	19.6	15.6
Na ₂ O	0.33	0.40	0.66
K ₂ O	0.08	0.01	0.08
P ₂ O ₅	0.12	0.05	0.08
Sr	160	180	
La	15.3	0.1	
Lu	0.65	0.01	
Rb	2.0	0.1	
Sc	6.6	0.5	
Ni	443	~1.0	
Co	36	~1.0	
Ir ppb	13	0.01 ?	
Au ppb	12	0.02	
C	35	--	
N	19	--	
S	538	100	
Zn	~1	1.6	
Cu	4.4	--	

TABLE 3. Chemical work on 61016 anorthosite

REFERENCE	SPLIT ANALYZED	ELEMENTS ANALYZED
Nava (1974)	,184	Majors
Philpotts <i>et al.</i> (1973)	,184	REEs, Ba
Wrigley (1973)	,173	K, U, Th
Fruchter <i>et al.</i> (1974)	,180	Fe, Al, Co, Sc, Cr, REEs
Hubbard <i>et al.</i> (1974)	,79 ,84	Mg, REEs, other traces
Ganapathy <i>et al.</i> (1974)	,156	Siderophiles, volatiles
Wasson <i>et al.</i> (1975)	,161*	Siderophiles, volatiles
Baedecker <i>et al.</i> (1974b)		
Hughes <i>et al.</i> (1973)	,182	Ni, Ir, Au, Re
Tera <i>et al.</i> (1973)	,84	K, Rb, Sr
Nyquist <i>et al.</i> (1973)	,79 ,84	Rb, Sr
LSPET (1973)	,3**	Majors, traces

* ,161 in data pack is a dark chip. White chip intended for allocation to Wasson was ,183; the numbers evidently have become reversed.

** Mixed powder, severely contaminated with basaltic impact melt.

Oxides in wt%; others in ppm except as noted.

STABLE ISOTOPES: Stable isotope data are only available for the basaltic impact melt. These data serve to emphasize that the melt is not melted soil. Rees and Thode (1974) report S isotope data (erroneously referred to as for the anorthosite) showing that $\delta^{34}\text{S}$ is -0.1 ‰, much lower than soils (~ 8 ‰). Kerridge *et al.* (1975b) confirm the low value for $\delta^{34}\text{S}$ ($+1.9$, $+1.3$ ‰). These latter authors also report $\delta^{13}\text{C}$ results of -35.7 , -32.8 ‰ (soils $+10$ ‰ or higher). DesMarais (1978) reports $\delta^{34}\text{C}$ of -30.8 ‰. Allen *et al.* (1974) report total ^{204}Pb (considered stable because of its extremely long half-life) in the impact melt, and consider that non-leachable ^{204}Pb is partitioned into fine metallic grains.

GEOCHRONOLOGY AND RADIOGENIC ISOTOPES: No Rb-Sr or Sm-Nd internal isochrons exist for any lithologies in 61016, but whole-rock Rb-Sr data are available for both the basaltic impact melt (Table 5) and the anorthosite (Table 6). The anorthosite clearly was separated from high-Rb reservoirs very early in lunar history.

^{40}Ar - ^{39}Ar data are available for the basaltic impact melt (Stettler *et al.*, 1973) and the shocked anorthosite (Huneke *et al.*, 1977). A dark split, 4 gave an age of 3.65 ± 0.04 b.y. (Fig. 6) but a good plateau was not attained (Stettler *et al.*, 1973). Huneke *et al.* (1977) analyzed both clear and milky "diaplectic glasses" (Fig. 7). The age spectra are anomalous, and the clear glass is shifted to younger ages, with an apparent age for the milky glass clearly defined at 4.1 b.y. Huneke *et al.* (1977) suggest that shock melting can result in glass with distinctly different age plateaus. Neither glass records the true age of the anorthosite.

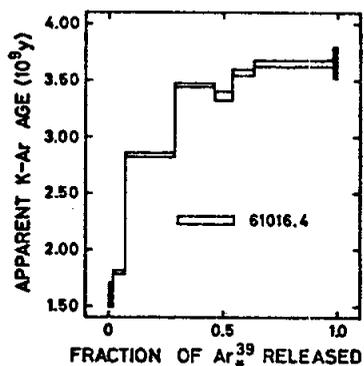


Figure 6. Ar releases of basaltic melt, from Stettler *et al.* (1973).

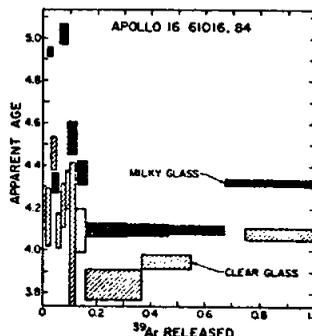


Figure 7. Ar releases of anorthositic glasses, from Huneke *et al.* (1977).

TABLE 5. Rb-Sr isotopic data for 61016 basaltic impact melt
(from Nyquist *et al.*, 1973)

Sample	Rb ppm	Sr ppm	$^{87}\text{Sr}/^{86}\text{Sr}$	T_{BABI} (b.y.)
,143 crystalline	2.04	164.4	0.70139±8	4.50±0.16
,79 black glassy	1.877	145.4	0.70151±10	4.49±0.33
,3 powder: mixed anorthosite & basalt	0.446	177.9	0.69960±9	4.8±0.1

TABLE 6. Rb-Sr isotopic data for 61016 anorthosite

Sample	Rb ppm	Sr ppm	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}^*$ calc. at 4.6 b.y.	Reference
,79 gray gray, repeat	0.017 ^a	179.0	0.69906±5 ^b 0.69906±5 ^b	0.69892±5 0.69892±5	Nyquist <i>et al.</i> (1973)
,79 white white, repeat white, repeat	0.0377	180.4	0.69924±40 0.69926±22 0.69906±4 ^{b,c}	- - 0.69890±4	Nyquist <i>et al.</i> (1973)
,79	0.0250	184.7	0.69907±3	0.69892±3	Nyquist <i>et al.</i> (1979)
,84	0.040	181.7	0.69907±5 ^b	0.69891±5	Nyquist <i>et al.</i> (1973)
,84	0.032 0.044	178 180	0.69900±3 0.69900±4	0.69897±3 0.69895±4	Tera <i>et al.</i> (1973)

*Corrected for interlaboratory bias to conform with CalTech data where applicable.
a) Misprinted as 0.167 in original paper.
b) Corrected according to Nyquist *et al.* (1974, p. 1519) for error caused by tracer.
c) Preferred value for this sample (Nyquist, pers. comm.).

RARE GAS, EXPOSURE AGES AND SURFACES: Stettler *et al.* (1973) calculate a ^{37}Ar - ^{38}Ar exposure age of <7 m.y. from a dark surface chip. This age is probably affected by ^{37}Cl because the Cl content of the rock is high and the exposure age is low. ^{38}Ar is produced from ^{37}Cl during pile irradiation and this effect is probably responsible for the unusual release curve observed (Stettler *et al.*, 1973).

Rao *et al.* (1979) use quantitative techniques to isolate the solar cosmic ray-produced Ne and Ar components in three sampling intervals from ,287 (which contains anorthosite and glass surface material). A solar cosmic ray age of 1.7 ± 0.2 m.y. is derived, as well as a galactic cosmic ray age of 3.7 ± 0.3 m.y. An erosion rate of 5 mm/m.y. is assumed.

Fleisher and Hart (1974) studied the particle track record (heavy cosmic ray nuclei). Two dark chips were too heavily shocked to reveal tracks. An anorthosite surface chip has an unusual track density/depth profile suggesting recent loss of a 1 mm chip. Assuming negligible erosion, an exposure age of 20 m.y. is calculated; assuming 0.6 A/year erosion, an exposure age of 40 m.y. is calculated. This is consistent with ^{26}Al data (Eldridge et al., 1973) which is saturated in the surface indicating exposure of more than a few million years. Bhattacharya and Bhandari (1975), evaluating erosional effects on the track record, derive an exposure age of 1.5 m.y. for the surface chip ,287. Bhandari et al. (1975) calculate an age of 1.2 ± 0.4 m.y. based on large craters, and 0.5 m.y. based on craters less than 80 μm in diameter. They suggest a simple one-stage exposure history. Bhandari et al. (1975, 1976) also measured ^{26}Al with depth and conclude that there has been little variation in the average solar flare proton production over the last 1.5 m.y.

MacDougall et al. (1973) found no solar flare tracks in either olivine or feldspar in an anorthosite sample.

Mandeville (1976) studied the size distribution of microcraters on a chip of impact melt (,23). The sample has fewer craters than the sample studied by Bhandari et al. (1975) which was on the lunar top of the sample (Fig. 8). Depth/pit diameters are also reported.

Gold et al. (1976a) report auger spectrometer analyses for Fe, Ti, Ca and Si (normalized to 60017 values) for a chip of basaltic impact melt. Fe is enriched in the surface.

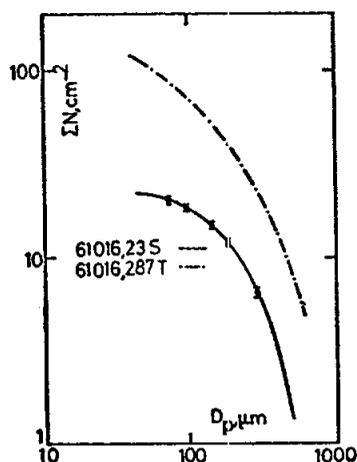


Figure 8. Microcraters, from Mandeville et al. (1976).

PHYSICAL PROPERTIES: Stephenson et al. (1977) tabulate, without comment, magnetic data for a glass chip from 61016. Housley et al. (1976) found that the ferromagnetic remanence (FMR) of a chip of basaltic impact melt (,27) was extremely weak.

Chung and Westphal (1973) provide dielectric constant, dielectric losses, and electrical conductivity data as a function of frequency and temperature. These data (Fig. 9) are for a chip of basaltic impact melt. The seismic data of Chung (1973) are for the same chip. Elastic wave (P-and S-) velocities were measured as a function of pressure as received and in both "dry" and "wet" modes (Table 7, Fig. 10). At low pressures, water increases velocities and drying the sample decreases velocities; this effect is greatest for P-waves. Warren and Trice (1975) use Chung's (1973) data to plot dynamic compressional modulus/density against pressure. They erroneously refer to the data as being for the anorthosite.

Dollfus and Geake (1975) report polarimetric and photometric characteristics of light reflected from a sample of dust-covered, surface basaltic impact melt (,23). The polarization curves resemble lunar fines.

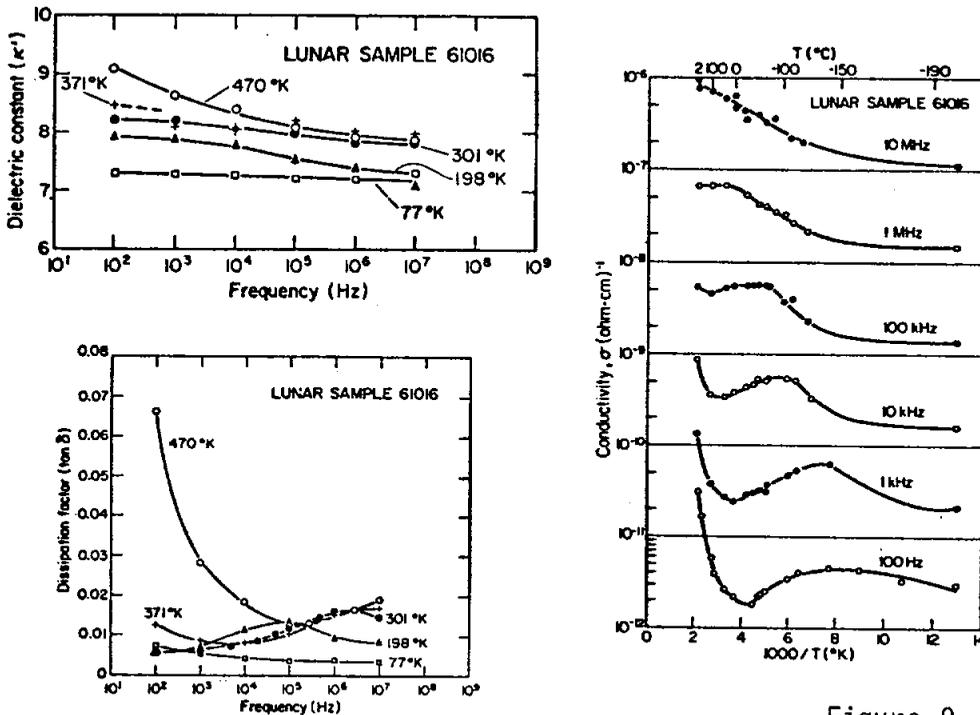


Figure 9. Electrical data, from Chung and Westphal (1973).

Condition of Sample	Mode	0.5	1.0	1.5	2	3	4	5	6	7	(10)*
As Received (from Table 2)	P	5.6	6.2	6.30	6.60	6.77	6.87	6.91	6.96	6.99	7.02
	S	2.4	3.1	3.22	3.36	3.58	3.69	3.74	3.86	3.88	3.90
	V _w /V _s	2.3	2.0	1.96	1.96	1.89	1.86	1.84	1.80	1.80	1.80
"dry" (1)	P	3.75	5.23	5.32	5.72	6.23	6.41	6.70	6.97	7.00	7.02
	S	2.23	3.04	3.09	3.25	3.52	3.64	3.72	3.86	3.88	3.90
	V _w /V _s	1.68	1.72	1.72	1.76	1.77	1.76	1.80	1.80	1.80	1.80
"wet" (2)	P	6.5	6.70	6.73	6.75	6.78	6.88	6.91	6.97	6.99	7.03
	S	2.4	3.10	3.23	3.36	3.58	3.69	3.74	3.86	3.88	3.90
	V _w /V _s	2.7	2.16	2.09	2.01	1.89	1.86	1.84	1.80	1.80	1.80

TABLE 7. Seismic data, from Chung (1973).

*Estimated by a linear extrapolation of high-pressure velocity data.
 (1) The term "dry" refers to the state of sample 61016 as it was heated in vacuum at 400°C for 10 hours and slowly cooled down to ambient temperature.
 (2) The term "wet" refers to a water-saturated sample 61016.

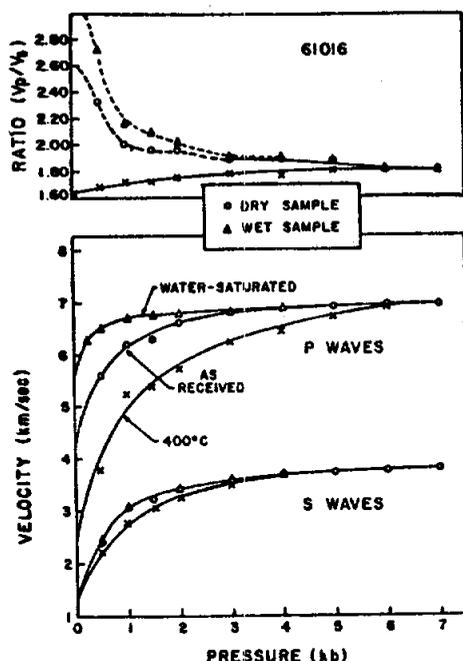


Figure 10. Seismic data, from Chung (1973).

PROCESSING AND SUBDIVISIONS: 61016 has been extensively subdivided. In 1972 a slab was cut from the rock producing two end pieces ,7 and ,8 (Figs. 1 and 11). ,7 remains essentially intact. The slab has been extensively dissected (Figs. 2 and 11) and ,8 has been totally subdivided into numerous daughters (not shown).

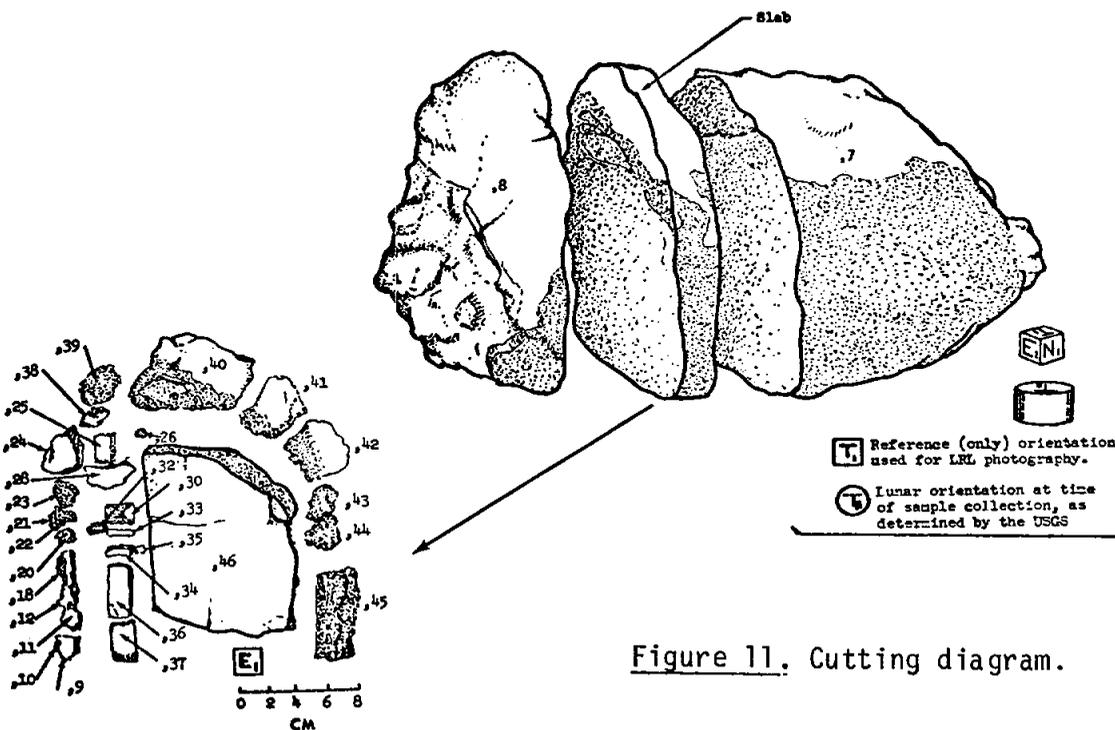


Figure 11. Cutting diagram.

INTRODUCTION: 61017 is a friable, fractured piece of cataclastic anorthosite (Fig. 1). It is almost pure white with rare black and yellow flecks. 61017 was a loose sample in the sample return container from the first extravehicular activity on the mission. Its lunar location is unknown and it could be from Station 1, 2, or from the ALSEP (Apollo Lunar Surface Experiments Package) site. At least one zap pit is present and part of the surface either has a patina or adhering soil.



Figure 1. 61017,0. Smallest scale division 0.5mm.

INTRODUCTION: 61135 is a friable, light gray breccia (Fig. 1) containing a diverse population of mineral and lithic fragments.

This sample was collected from the northeast rim of Plum Crater. Lunar orientation is known. A few zap pits are present on some surfaces.

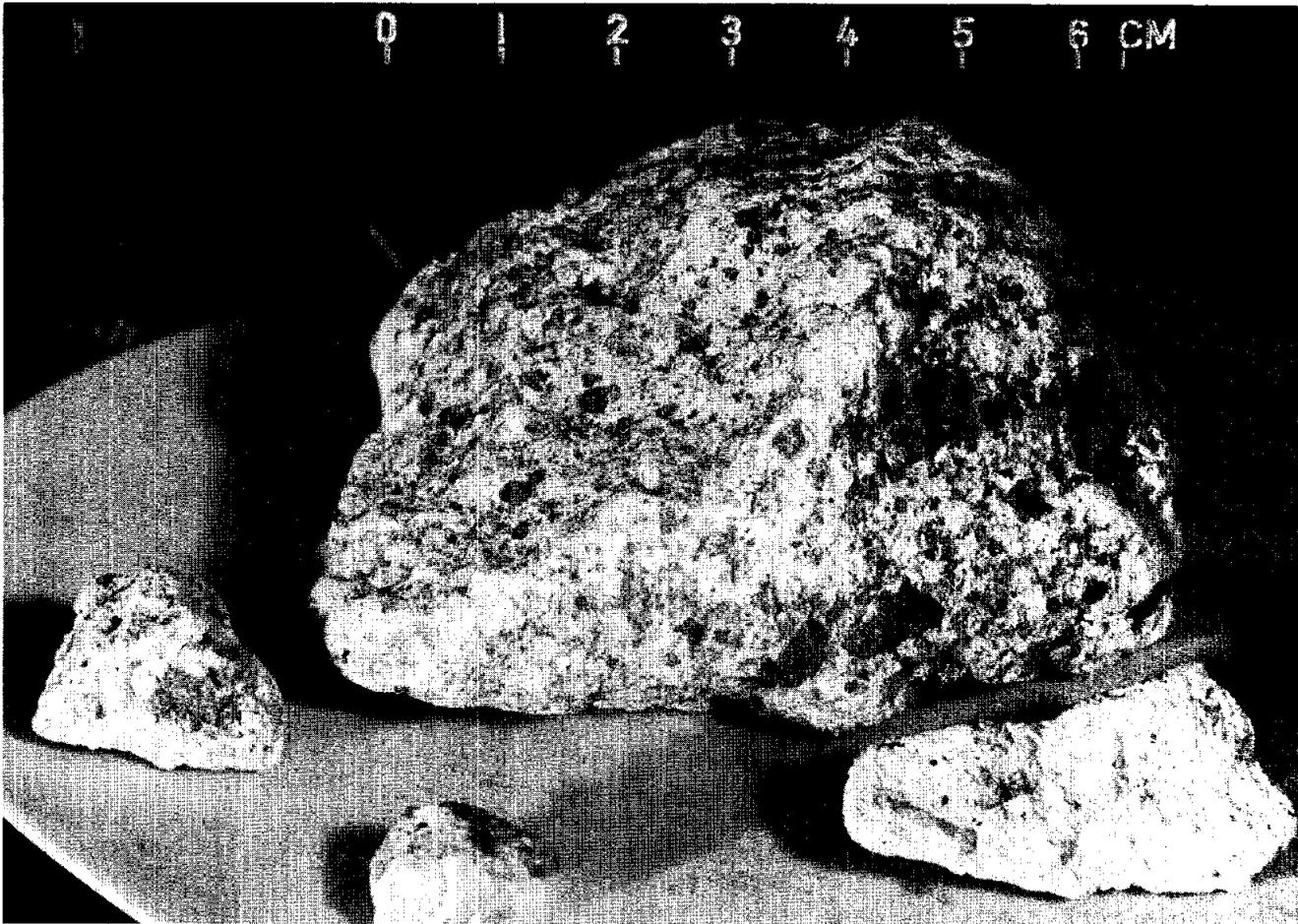


Figure 1. 61135,0. S-72-38316.

PETROLOGY: 61135 is a clastic, unrecrystallized breccia composed of various mineral and lithic fragments welded together by a small amount of glass (Fig.2). Angular grains of both shocked and unshocked plagioclase dominate the mineral fragment population. Mafic minerals, Fe-metal, troilite and ilmenite clasts are much less common. Lithic fragments include granoblastic anorthosite and noritic anorthosite (up to ~3 mm), basaltic and poikilitic impact melts, and clast-rich, glassy matrix breccia. Brown and clear glass beads and fragments are abundant and indicate a significant regolith component in this rock.

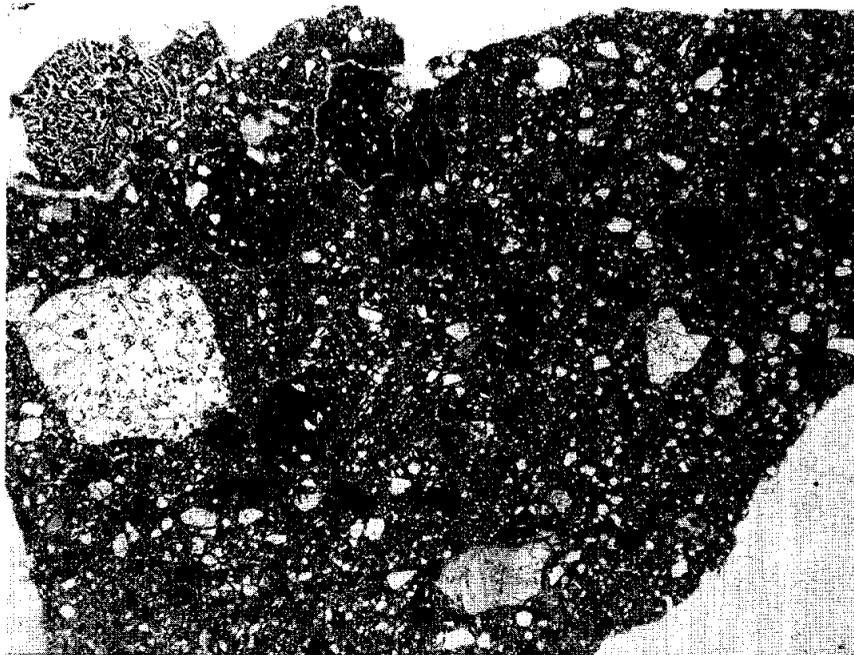


Figure 2. 61135,7, general view, ppl. width about 15mm.

CHEMISTRY: Eldridge et al. (1973) report whole rock K-U-Th and cosmogenic radionuclide abundances. Ca and K data for three splits are provided by Schaeffer and Schaeffer (1977) in a K-Ar geochronological study. Total N and C in a bulk sample are given by Moore and Lewis (1976).

The whole rock gamma ray data show 61135 to be poor in natural radionuclides (690 ppm K, 0.38 ppm U, 1.39 ppm Th). A randomly-picked sample and a split of fine powder analyzed by Schaeffer and Schaeffer (1977) show K abundances very similar to the whole rock value of Eldridge et al. (1973) and Ca levels indicative of nearly pure plagioclase (Table 1). The third split analysed by Schaeffer and Schaeffer (1977) was a single coherent fragment considerably enriched in K and depleted in Ca relative to the other samples (Table 1). No further information on the nature of these samples is available.

RADIOGENIC ISOTOPES/GEOCHRONOLOGY: Schaeffer and Schaeffer (1977) give K-Ar data for three splits. Two of the samples, a randomly-picked split and a split of fine powder, contain considerable amounts of trapped gas and did not give ^{40}Ar - ^{39}Ar plateaus. The third sample, a single coherent fragment, yielded a plateau age of 3.90 ± 0.10 b.y.

TABLE 1. Summary chemistry of 61135 lithologies

	<u>Bulk rock</u>	<u>K-rich fragment</u>
CaO	18.9	11.8
K ₂ O	0.088	0.58
C	54	
N	55	

Oxides in wt%; others in ppm.

RARE GAS/EXPOSURE AGES: ²⁶Al-²²Na whole rock data are provided by Eldridge et al. (1973). From these data Yokoyama et al. (1974) could not decide whether 61135 is saturated in ²⁶Al or not.

Ar data are given by Schaeffer and Schaeffer (1977) for three splits: a randomly picked sample, a split of fine powder, and a single coherent fragment. The first two samples contained considerable trapped gas, probably residing in the fine matrix of the rock. ³⁸Ar exposure ages of these two splits are given as 61 m.y. and 44 m.y. (Schaeffer and Schaeffer, 1977, Table 6). The third split gave an average ³⁸Ar exposure age of 28 m.y., but due to the extreme variability of the exposure age measured over the ⁴⁰Ar-³⁹Ar plateau temperature range (1800 m.y. at 400°C to 4 m.y. at 1150°C), the average age reported probably has little significance. A trapped ³⁸Ar component is also suggested by Schaeffer and Schaeffer (1977)

PROCESSING AND SUBDIVISIONS: 61135 was removed from its Documented Bag in 1972 as one large piece (,1) plus three smaller pieces (,2-,4) and some fine residue (,5). Schaeffer received 1 g of chips from ,5 in 1973. In 1975 ,2 and ,3 were subdivided for further allocations. The large piece ,1 (221.96 g) remains in stock at JSC.

INTRODUCTION: 61155 is a moderately coherent, medium gray, glassy impact melt with abundant white clasts (Fig. 1). At least two sets of perpendicular fractures and a series of thin, short (~ 5 mm) glass veins cut the rock. A slickenside is present on the B surface.

61155 was collected ~ 25 m northeast of Plum Crater. Zap pits are abundant on two surfaces, rare to absent on the other surfaces.

PETROLOGY: 61155 is a glassy impact melt that is very clast-rich (Fig. 2). In places the matrix texture approaches poikilitic. Oikocrysts (~ 0.3 mm) are separated from one another by a concentration of relatively large clasts of plagioclase. Glassy mesostasis is abundant. Clasts include fragments of basaltic impact melt and cataclastic anorthosite. Fe-metal, troilite and ilmenite are accessory phases.



Figure 1. 61155,0. Scale is cm. S-72-38371.

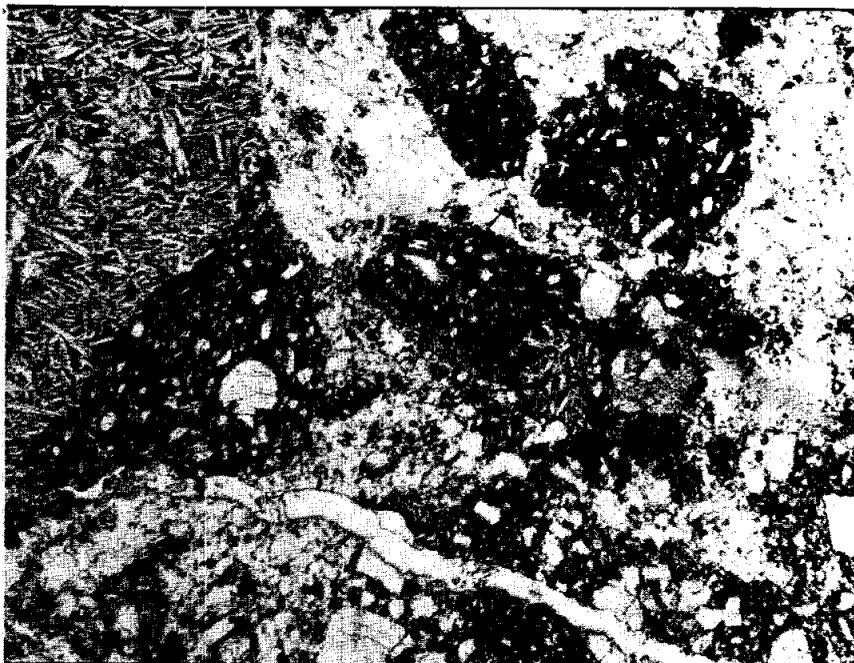


Figure 2. 61155,7, general view, ppl. width 3mm.

CHEMISTRY: Eldridge et al. (1973) provide whole rock K(445 ppm), U(0.31 ppm) and Th(1.12 ppm) abundances by gamma ray spectroscopy.

EXPOSURE AGE: Eldridge et al. (1973) provide ^{26}Al and ^{22}Na data. From these data Yokoyama et al. (1974) conclude that 61155 is saturated in ^{26}Al , indicating an exposure age of at least a few million years.

PROCESSING AND SUBDIVISIONS: In 1972 several chips were removed and one of these (,3) allocated for thin sections.

INTRODUCTION: 61156 is a tough, medium gray, poikilitic impact melt rock that has been thermally metamorphosed. Macroscopically the rock is blocky and angular; few clasts are apparent (Fig.1). Metal spherules and small vugs (<0.5 mm) are inhomogeneously distributed throughout the rock. There are many zap pits on the "lunar up" surface, few on other surfaces. This sample was collected 25 m north-east of Plum Crater.

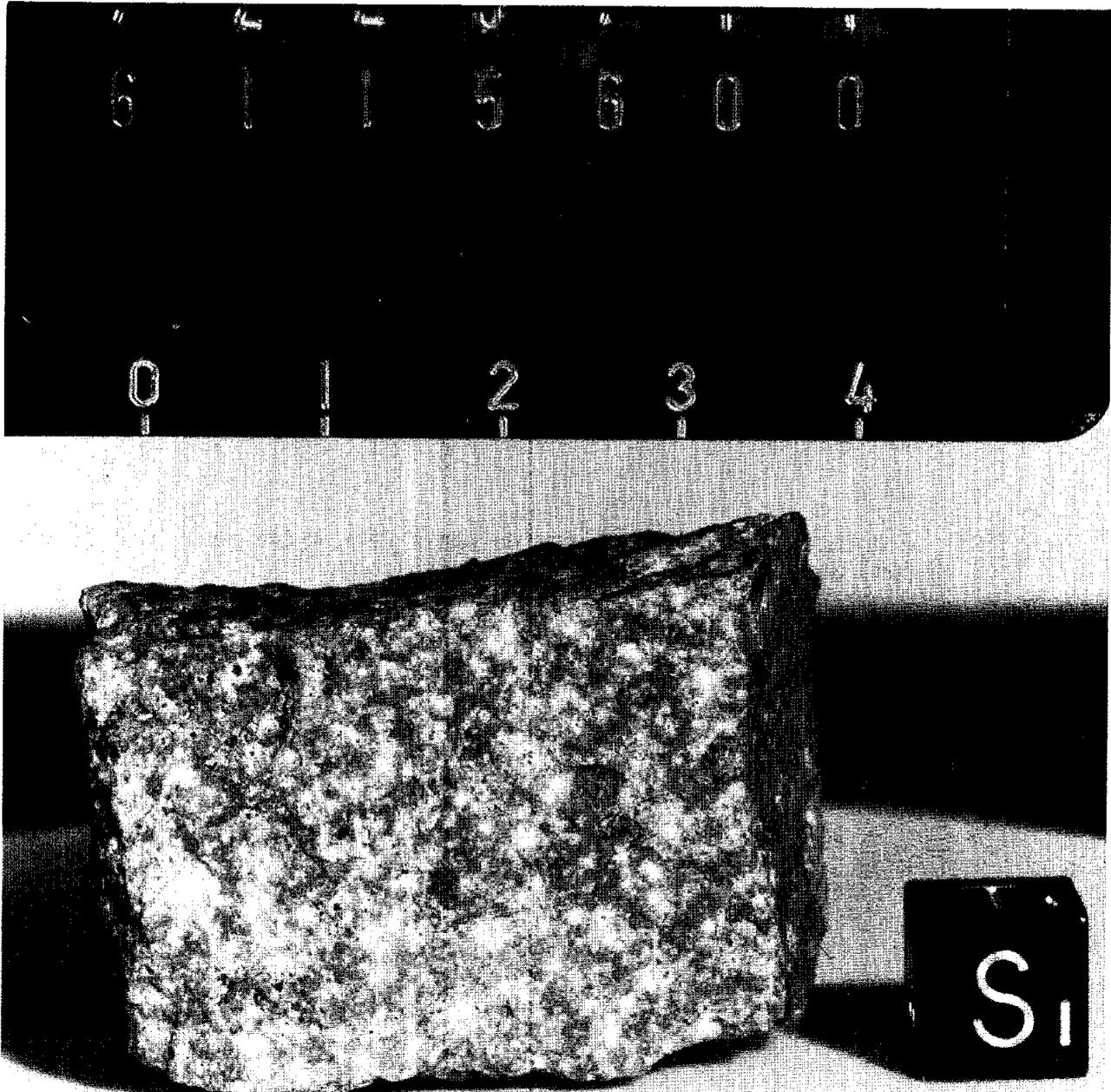
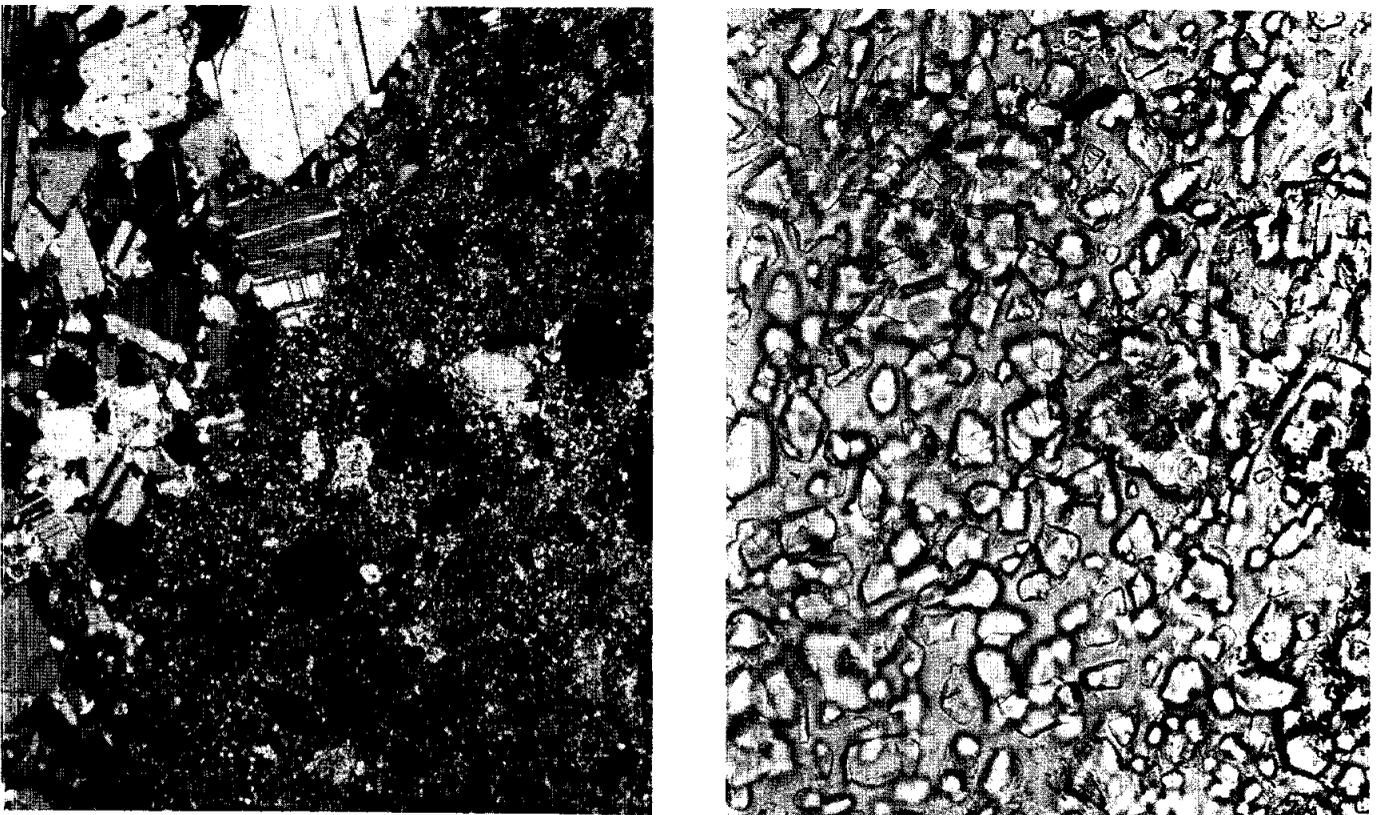


Figure 1. 61156,0. Scale is cm. S-72-38391.

PETROLOGY: Petrographic information is given by Albee *et al.* (1973), Simonds *et al.* (1973), and the Apollo 16 Lunar Sample Information Catalog (1972). Haggerty (1973) provides detailed microprobe analyses and descriptions of armalcolite and other oxides. Meyer *et al.* (1974) determined trace elements in plagioclase xenocrysts by ion microprobe. Metal compositions from an anorthositic clast and the poikilitic host are reported by Hewins and Goldstein (1975a)

61156 is a fine-grained, meta-poikilitic rock with several small (50-200 μm) plagioclase and pyroxene xenocrysts and at least one large (>10 mm) clast of anorthositic breccia. Modal data are presented by Albee *et al.* (1973) and the Apollo 16 Lunar Sample Information Catalog (1972) and reproduced here as Table 1. In the poikilitic host, mineral grains are anhedral and granular (Fig. 2) suggesting that the rock has undergone a period of extensive subsolidus annealing. Two types of poikilitic texture are randomly distributed throughout the rock. Most commonly, anhedral orthopyroxene oikocrysts (up to ~ 1 mm, averaging ~ 100 μm) enclose small, rounded, elongate to equant plagioclase crystals (20-50 μm). Pyroxene oikocrysts, however, are not as abundant in 61156 as in most of the other Apollo 16 poikilitic rocks. The second, less common poikilitic texture in this rock is characterized by an interlocking network of anhedral plagioclase grains (usually <50 μm) intergrown with small, equant grains of olivine and (rarely) high-Ca pyroxene (up to ~ 50 μm). Many of these mafic grains are optically continuous over an area generally <0.5 mm. Olivine and high-Ca pyroxene are not included within the orthopyroxene oikocrysts. K-rich patches are scattered throughout the rock but are never found within oikocrysts. Minerals are homogeneous and largely equilibrated (Fig. 3). Ridley and Adams (1976) calculate a temperature of equilibration of 1010°C for coexisting olivine and augite.



a

Figure 2. 61156,30. a) general view, xpl. width 2mm.
b) poikilitic area, ppl. width 0.2mm.

b

TABLE 1

Modal data for 61156

	61156,5	61156,31	
	(1300 pts; Apollo 16 Lunar Sample Information Catalog, 1972)	(1990 pts; Albee <i>et al.</i> , 1973) vol%	wt%
<u>orthopyroxene</u>	25.9	20.6	23.0
oikocryst	18.4		
xenocryst	7.5		
<u>plagioclase</u>	59.5	62.1	55.4
in oikocrysts	15.0		
surrounding olivine	38.0		
xenocryst	6.5		
<u>olivine</u>	11.7	10.2	12.9
<u>high-Ca pyroxene</u>		5.1	5.6
<u>metal</u>	1.0	0.3	0.9
<u>other opaques</u>	1.9	0.6	1.2
<u>phosphates</u>		0.3	0.3
<u>K-rich interstices</u>		0.6	0.5

A wide variety of opaque and other accessory phases occur within the poikilitic portions of 61156, including ilmenite, armalcolite, Cr-spinel, rutile, baddelyite, metal, troilite and schreibersite. Oxides often form complex associations, probably representing the decomposition of some pre-existing oxide phase (Albee *et al.*, 1973; Haggerty, 1973). Ilmenite plates are apparently not related to the development of oikocrysts. Metal occurs principally as 100-400 μm globules and is very homogeneous in composition (Fig.4).

Xenocrysts of plagioclase and low-Ca pyroxene account for $\sim 15\%$ of the rock. Many of these plagioclase clasts have calcic cores (An_{95-97}) rimmed by overgrowths of the same composition as in the poikilitic host (An_{87-93}). Trace elements in plagioclase clasts as determined by ion microprobe (Meyer *et al.*, 1974) are presented in Table 2. Ba in these clasts is significantly below the initial Ba expected by in situ crystallization.

TABLE 2

Trace elements in plagioclase xenocrysts in 61156

Na_2O	0.39 wt%
Li	5
Mg	400
K	760
Ti	110
Sr	150
Ba	18

All data in ppm except as noted (from Meyer *et al.*, 1974)

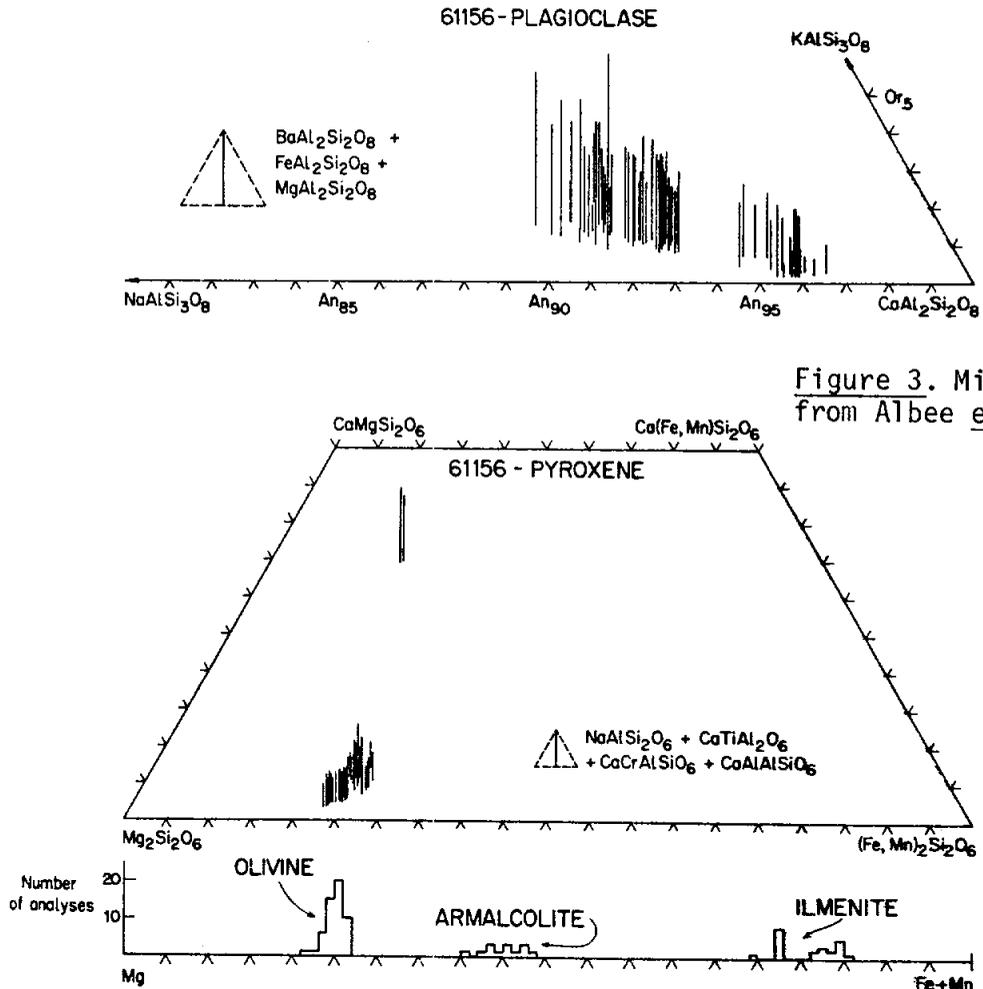


Figure 3. Mineral compositions, from Albee et al. (1973).

At least one large (>10 mm) clast of anorthositic breccia is also found in 61156. It consists of angular, well-twinned plagioclase (An₉₅; up to 1 mm) which has been coarsely crushed. Interstitial mafics are rare but, where present, tend to show a poikilitic texture around smaller plagioclase grains within the clast. The clast-matrix boundary is irregular with matrix sometimes penetrating along grain boundaries of the clast. Metal in the clast is of the same composition as that in the poikilitic host (Fig.4) (Hewins and Goldstein, 1975a).

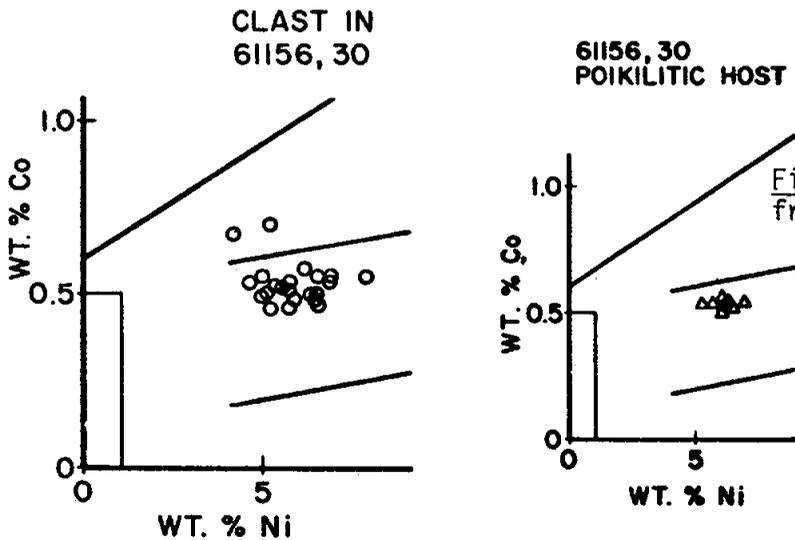


Figure 4. Metal compositions, from Hewins and Goldstein (1975a).

CHEMISTRY: Major and trace element analyses are given by Hubbard *et al.* (1973), Wänke *et al.* (1974) and LSPET (1973). Albee *et al.* (1973) calculate a major element bulk composition based on a mode and mineral analyses. Eldridge *et al.* (1973) provide data on natural and cosmogenic radionuclides. Rb, Sr and U, Th, Pb data are presented by Nyquist *et al.* (1973) and Tera *et al.* (1974) respectively.

Compositionally, 61156 is more similar to Apollo 16 basaltic melt rocks than to the other poikilitic melt rocks. It is more aluminous than most other poikilitic rocks (Table 3), plotting on the plagioclase-spinel cotectic in the system olivine-anorthite-silica (Fig. 5). Rare earth elements (Fig. 6) are moderately enriched over local soils but are significantly less than in the KREEP-rich poikilitic rocks such as 62235 and 60315. Siderophiles indicate a significant, though variable, meteoritic content (Table 3). This variation in levels of siderophiles is almost certainly due to the inhomogeneous distribution of metal.

TABLE 3. Summary chemistry of 61156

SiO ₂	45.0
TiO ₂	0.64
Al ₂ O ₃	23.0
Cr ₂ O ₃	0.13
FeO	7.8
MnO	0.11
MgO	9.7
CaO	13.5
Na ₂ O	0.40
K ₂ O	0.108
P ₂ O ₅	0.22
Sr	154
La	21.5
Lu	0.90
Rb	2.43
Sc	9.36
Ni	184-1190 (?)
Co	59.4
Ir ppb	23
Au ppb	22
C	
N	
S	1200
Zn	5.0
Cu	6.6

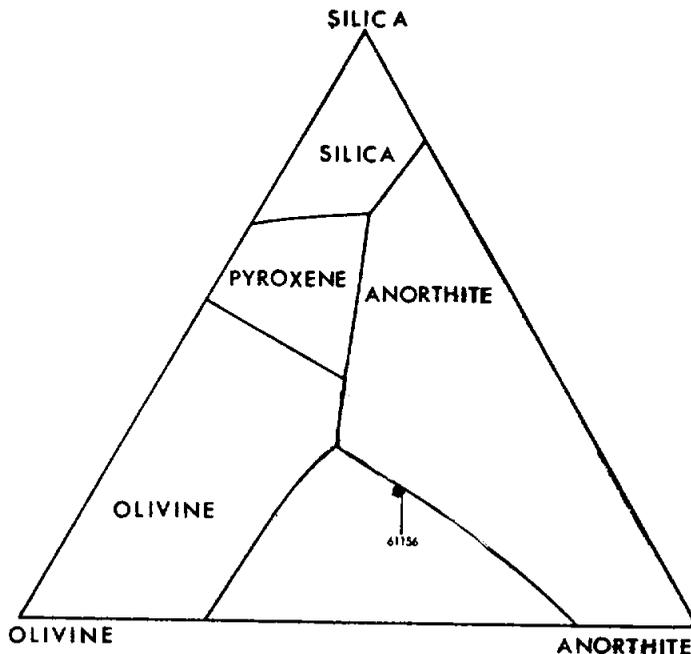


Figure 5. From Simonds *et al.* (1973).

Oxides in wt%; others in ppm except as noted.

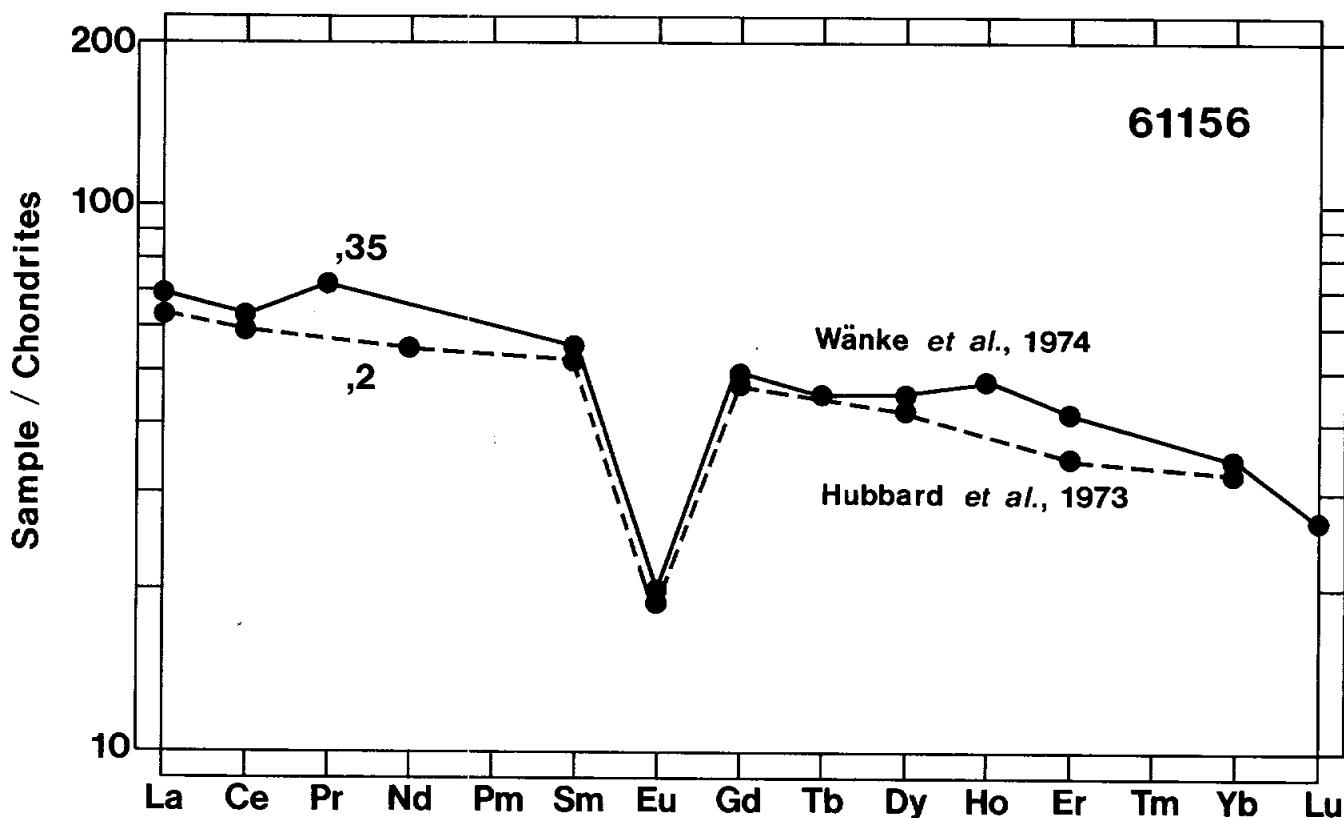


Figure 6. Rare earths.

TABLE 4. Summary of isotopic data on 61156

$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$ measured	$^{87}\text{Sr}/^{86}\text{Sr}$ at 4.6 b.y.*	T_{BABI} (b.y.)	T_{LUNI} (b.y.)	Reference
0.0451	0.70202 \pm 8	0.69949	4.66 \pm .12		Tera <i>et al.</i> (1974)
0.0462 \pm 4	0.70217 \pm 5	0.69948	4.63 \pm .11	4.77 \pm .11	Nyquist <i>et al.</i> (1973)
*extrapolated from 3.9 to 4.6 b.y. and corrected for interlaboratory bias by Nyquist (1977)					
U-Th-Pb model ages (b.y.)					
$^{207}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{238}\text{U}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{208}\text{Pb}/^{232}\text{Th}$	Reference	
4.24	4.21	4.23	3.88	Tera <i>et al.</i> (1974)	

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Nyquist et al. (1973) report whole rock Rb-Sr isotopic data. Tera et al. (1974) provide whole rock Rb-Sr and U-Th-Pb isotopic data.

The data are summarized in Table 4. Notable are the old model ages calculated from Rb-Sr systematics. U-Pb isotopes do not show such old model ages. The whole rock analysis of Tera et al. (1974) is within error of concordia at 4.24 b.y.

MICROCRATERS: Neukum et al. (1973) provide size-frequency data (Fig.7). They conclude that the surface of 61156 is in production.

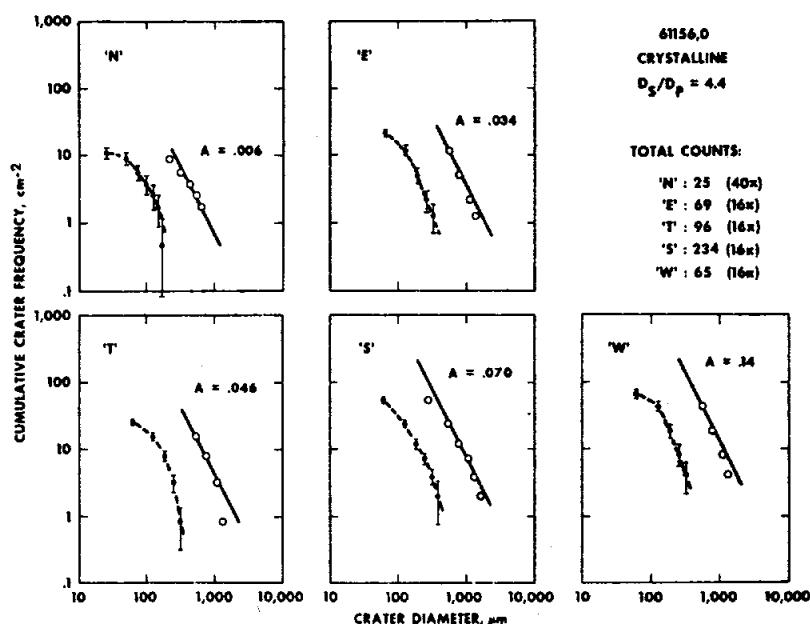


Figure 7. Microcraters, from Neukum et al. (1973).

PHYSICAL PROPERTIES: Intrinsic and remanent magnetic parameters were measured on two splits of 61156 by Nagata et al. (1974) using hysteresis and AF-demagnetization techniques. They find no significant residue of NRM after 150 Oe-rms demagnetization. Greater than 90% of the metal in 61156 is kamacite with 4-6% Ni. Schwerer and Nagata (1976) determined size distribution data for metallic particles in the 0.003-0.15 μm (30-150 Å) size range using magnetic granulometry. The mean grain size of fine-grained metal in this rock is 37 Å.

Huffman et al. (1974) present Mossbauer and magnetic analyses of the same two splits studied by Nagata et al. (1974) These results are summarized in Table 5.

TABLE 5

Distribution of Fe in the mineral phases of 61156* (Huffman et al., 1974)

Sample	pyroxene	olivine	ilmenite	troilite	metal	wt% metal
61156,11	57.9	34.2	2.8	2.8	2.2	0.70
61156,12	49.3	43.9	2.0	1.8	2.9	1.76

*percentage of total Fe

PROCESSING OF SUBDIVISIONS: In 1972, 61156,0 was chipped to produce ,1 ,2 and ,4 from the N surface. In 1973, the largest piece remaining (61156,0) was entirely subdivided to produce ,3 and ,9-,13 (Fig.7). ,9-,12 came from the W half of ,0. ,13 is the E end of ,0 and is now the largest single piece remaining (43.4 g). Other splits have since been made from the chips.

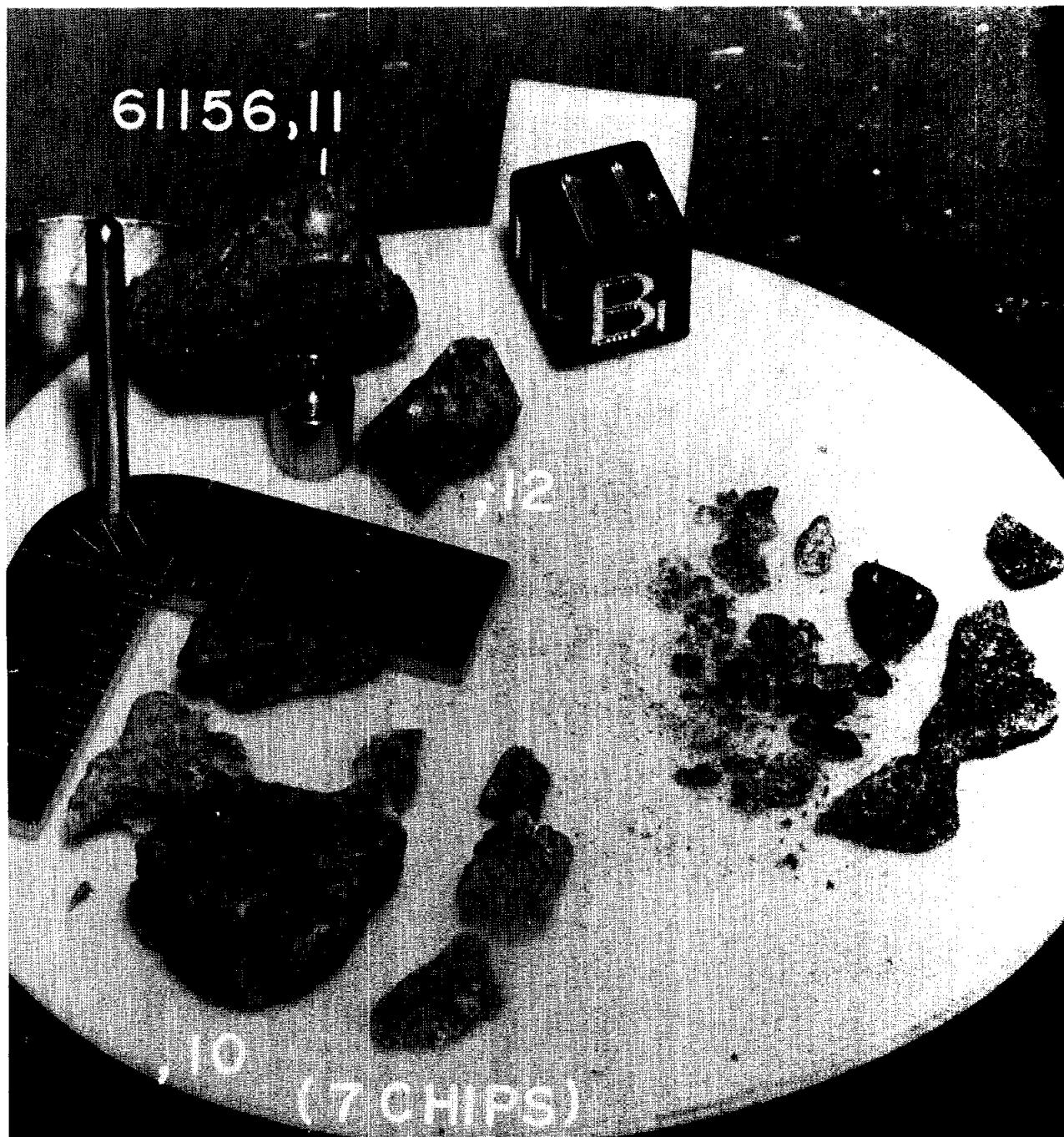


Figure 8. S-72-53534.

INTRODUCTION: 61157 is an irregularly shaped fragment of pale medium gray, fragmental breccia (Fig. 1). It is fairly coherent and fractured with some planar surfaces. It contains dark and light colored angular clasts, all of which are small. 61157 was taken from the regolith 25 m northeast of Flag Crater. Its surfaces have some patina and zap pits.



Figure 1. 61157,0. Smallest scale subdivision 0.5mm

INTRODUCTION: 61158 is a pale gray, friable, polymict breccia (Fig. 1). It contains small dark and light-colored fragments. The sample was taken from the regolith 25 m northeast of Flag Crater. It has rare zap pits.

PROCESSING AND SUBDIVISIONS: A part of 61158 has been numbered separately as ,1 (4.00 g).

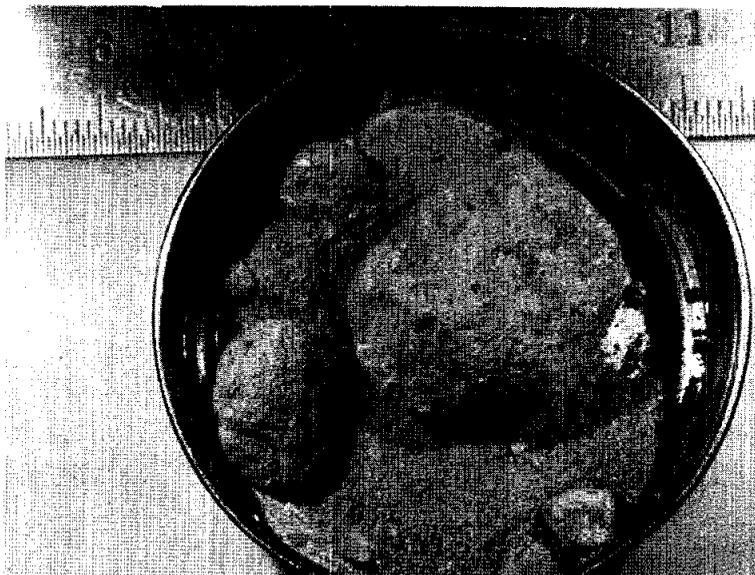


Figure 1. 61158,0



61158,1. Smallest
scale subdivision
0.5mm.

INTRODUCTION: 61175 is a friable, gray matrix breccia (Fig. 1) with a wide variety of clast types. It is subrounded in shape, and homogeneous in color and texture.

61175 was collected near the northeast rim of Plum Crater, and its orientation is known. Zap pits are abundant on the "lunar up" surface and rare to absent on other surfaces.

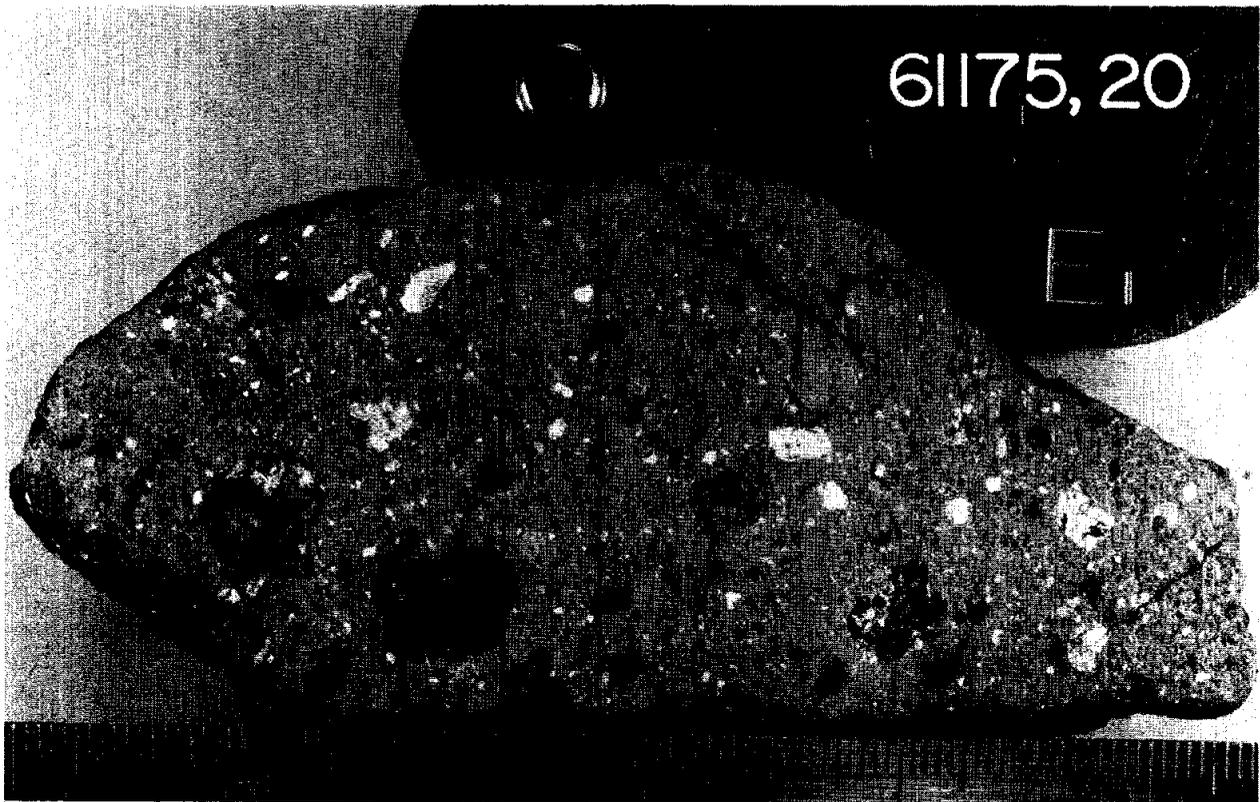


Figure 1. S-78-31342, mm scale.

PETROLOGY: Winzer et al. (1977) provide detailed petrographic information.

A variety of mineral and lithic clasts rest in a friable, clastic matrix sintered by a small amount of alkali-rich glass (Fig. 2). Modal data are presented by Winzer et al. (1977) and reproduced here as Table 1. Grain size of the matrix is seriate from several millimeters down to a few microns. A significant regolith component is suggested by the several types of glass beads and fragments present in the matrix. Glass compositions are plotted in Figure 3. A mare component is present in the glasses and as a glassy breccia clast (Winzer et al. 1977; Delano, 1975). Coarse spinel fragments (up to several mm) are scattered through the matrix but are not present in any of the lithic clasts, suggesting that at least one rock type not present as clasts has contributed to the matrix (Winzer et al., 1977).

Lithic clasts include, in approximately decreasing order of abundance, basaltic melt rocks (clast-free and clast-bearing), coarse-grained annealed rock (granulite), fine-grained annealed rocks (hornfels), and cataclastic anorthosites.

Basaltic melt rock clasts (Fig. 2) have textures ranging from vitrophyric to diabasic. Most are holocrystalline with plagioclase, clinopyroxene, orthopyroxene, olivine, ilmenite and a complex mesostasis as the principal constituents. Minerals are zoned and compositions from all textural varieties overlap. Olivine and pyroxene compositions are shown in Figures 4 and 5. Plagioclase is An_{95-83} . Some of the basaltic clasts carry xenocrysts of olivine and plagioclase and rare lithic fragments. Accessory minerals, normally associated with the mesostasis but also occurring as xenocrysts, include Mg-spinel, chromite, troilite, metal (up to 9% Ni), schreibersite, ilmenite, armalcolite, rutile and a Zr-mineral.

Coarse-grained granoblastic clasts (granulites of Winzer et al., 1977) include anorthositic, noritic and troctolitic lithologies with the anhedral minerals, smooth grain boundaries and triple junctions indicative of extensive subsolidus annealing (Fig. 2). Mafic minerals are unzoned and largely equilibrated within any single clast (Fig. 6). Some large plagioclase grains have calcic cores (An_{95-97}) and narrow, more sodic rims. Some of the noritic clasts have anhedral orthopyroxene poikiloblasts (up to ~ 1 mm) which enclose anhedral plagioclase and rare ilmenite. Several of the poikiloblasts show exsolution lamellae (up to 0.1 mm) of high-Ca pyroxene. Anhedral, magnesian ilmenites are found in some granoblastic clasts.

Fine-grained granoblastic clasts (hornfels of Winzer et al., 1977) are characterized by an interlocking mass of anhedral plagioclase plus olivine and/or pyroxene with smooth grain boundaries and triple junctions. Grain size is typically $\sim 50\mu\text{m}$ or less. Many of these clasts are rich in xenocrysts. Minerals are unzoned and largely equilibrated (Fig. 5); glass is absent. Xenocrysts of plagioclase often have calcic cores (An_{95}) and thin rims of the same composition as the groundmass plagioclase (down to An_{88}). Metal (4.5-9% Ni), troilite, ilmenite, apatite and schreibersite occur as accessory minerals. Several of the fine-grained annealed clasts have a poikiloblastic texture that ranges from poorly to well developed (Fig. 2). These poikiloblastic clasts are texturally distinct from the typical Apollo 16 poikilitic rocks (such as 60315) which usually show a melt texture characterized by euhedral crystallites of plagioclase enclosed by anhedral pyroxene oikocrysts.

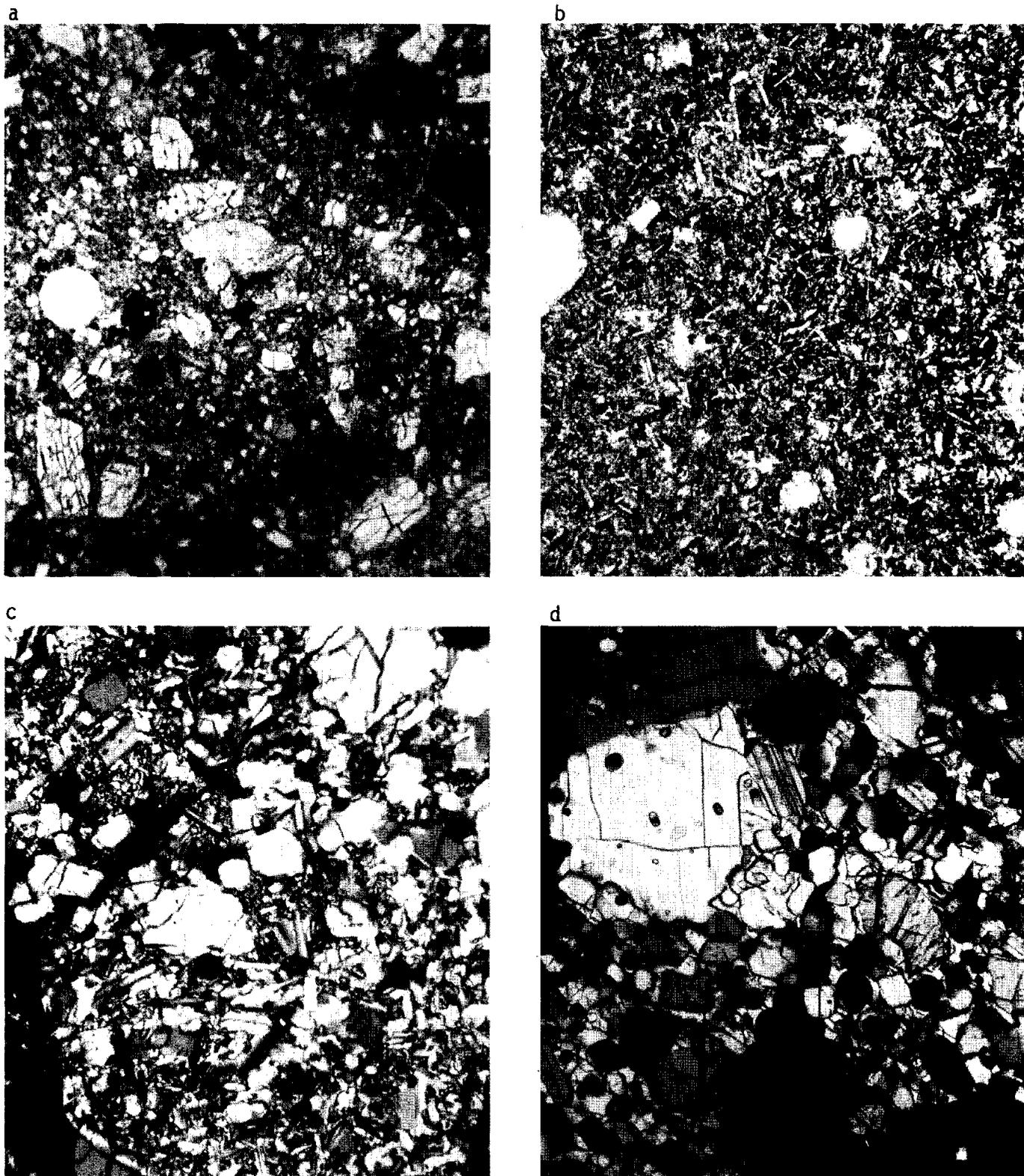


Figure 2. a) 61175, 108, general view, ppl. width 2mm.
 b) 61175, 97, basaltic clast, ppl. width 1mm.
 c) 61175, 108, fine-grained granoblastic clast, xpl. width 2mm.
 d) 61175, 97, coarse-grained granoblastic clast, xpl. width 2mm.

Cataclastic anorthosites occur as larger clasts (up to 2 cm) which have been moderately to severely shocked and brecciated. Maskelynite is abundant and melting has occurred in some clasts. Original grain size of the plagioclase (An_{95-100}) was several millimeters. Minor phases include olivine, orthopyroxene, and rare ilmenite and spinel.

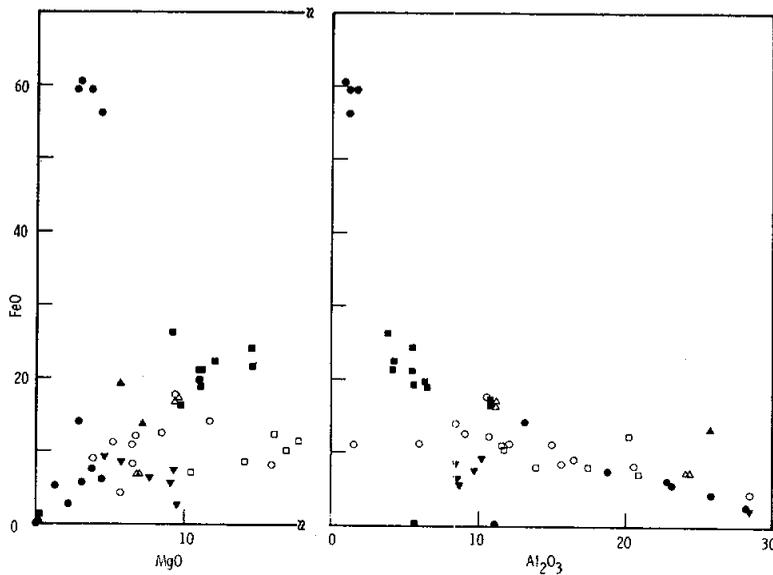


Figure 3. Glass compositions, from Winzer et al. (1977).

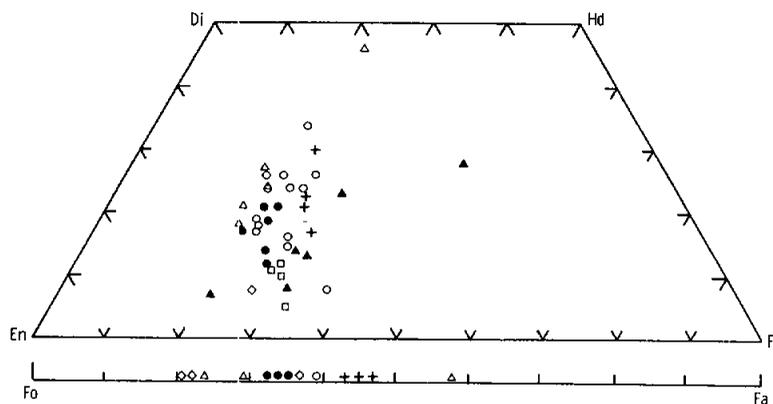


Figure 4. Pyroxene, olivine compositions in clast-free basaltic clasts, from Winzer et al. (1977).

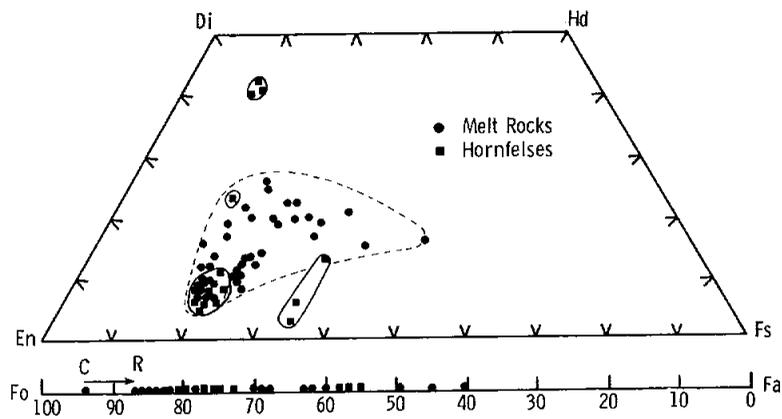


Figure 5. Pyroxene, olivine compositions in clast-bearing melt clasts and fine-grained granoblastic clasts, from Winzer et al. (1977).

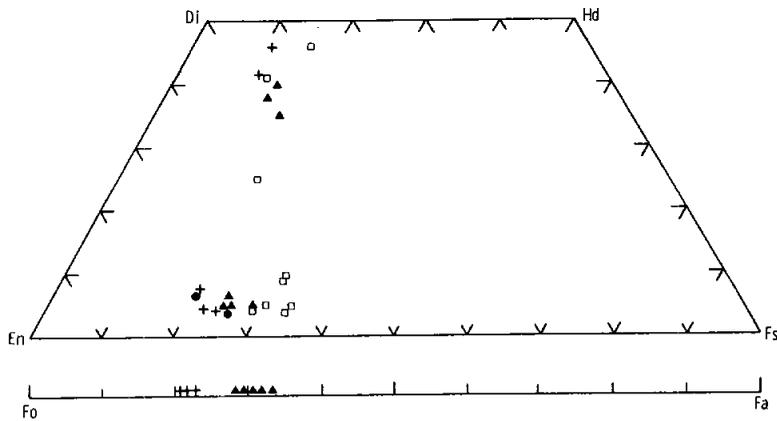


Figure 6. Pyroxene, olivine compositions in coarse-grained granoblastic clasts, from Winzer et al. (1977).

CHEMISTRY: Winzer *et al.* (1977) provide major and trace element data for matrix and various clast samples. S.R. Taylor *et al.* (1974) report major and trace element analyses on a plagioclase-rich separate of a whole rock sample. Cripe and Moore (1974) report bulk sulfur and Moore and Lewis (1976) give bulk carbon and nitrogen data. Eldridge *et al.* (1973) determined K, U, and Th by gamma-ray spectroscopy.

Analyses by Winzer *et al.* (1977) show the matrix of 61175 to be somewhat more mafic than its clasts (Table 2). Compared to the local soils, the 61175 matrix has the same Fe/Mg but is depleted in absolute abundances of ferromagnesian elements and REEs.

None of the rock types classified on the basis of texture can be singled out as chemically distinct. Figure 7 shows that the major element chemistry of all of the clast types overlap although some clustering is apparent. Coarse-grained clasts tend to plot near the anorthite apex while the fine-grained annealed rocks have compositions similar to other Apollo 16 poikilitic melt rocks and plot near the olivine-plagioclase-spinel peritectic. Basaltic textured clasts cluster between these two groups.

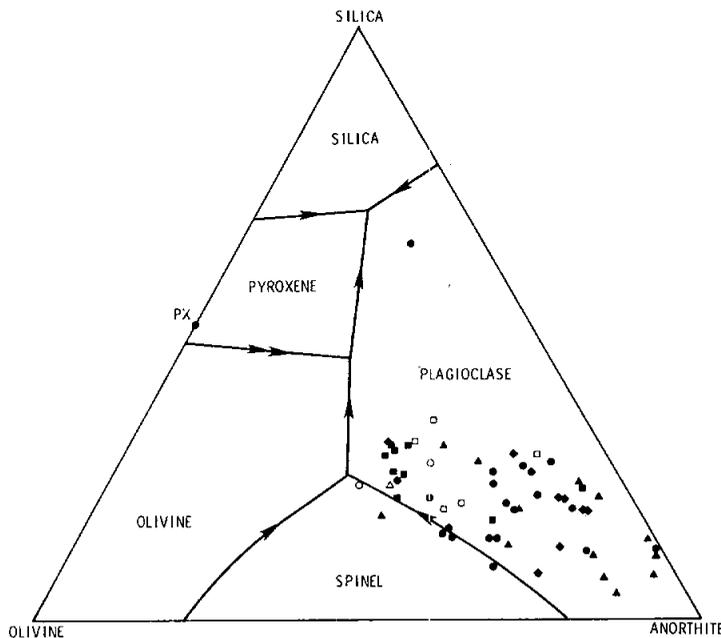


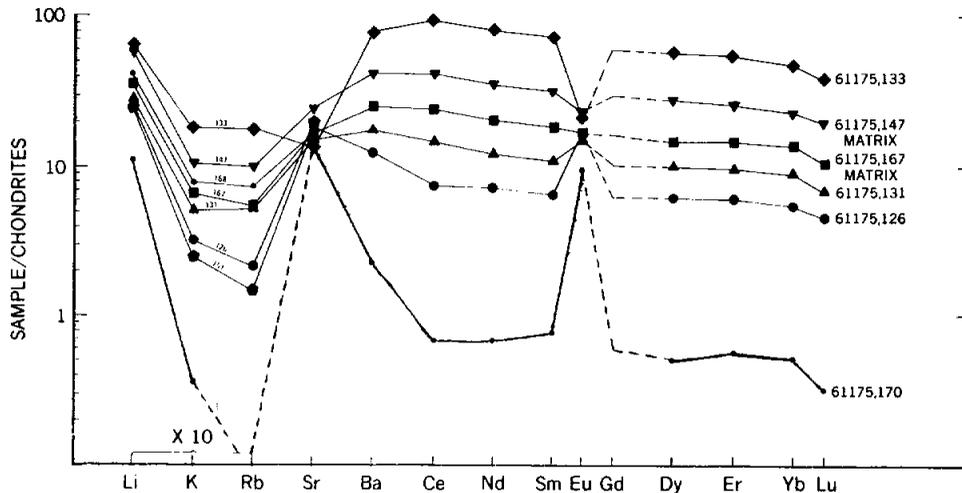
Figure 7. From Winzer *et al.* (1977).

▲—ANT, ■—hornfels, ●—impact melts, and ◆—basalts. Unfilled symbols mark clasts whose classification is uncertain.

TABLE 1. Summary chemistry of 61175

SiO ₂	45.5
TiO ₂	0.53
Al ₂ O ₃	27.8
Cr ₂ O ₃	0.06
FeO	4.3
MnO	0.06
CaO	16.2
Na ₂ O	0.51
K ₂ O	0.10
P ₂ O ₅	
Sr	201
La	
Lu	0.5
Rb	2.3
Sc	
Ni	
Co	
Ir ppb	
Au ppb	
C	69
N	91
S	570
Zn	
Cu	

Oxides in wt%; others in ppm except as noted.



Lithophile trace element abundances from clasts and matrix of 61175. 61175,133 and ,126 are dark clasts and are probably melt rocks. 61175,131 and ,170 are white clasts, and are moderately shocked anorthosites.

Figure 8. From Winzer *et al.* (1977).

Rare earth elements (Fig. 8) also show the diversity of clast compositions although too few clasts have been analyzed to show definite trends. Apparently the clasts have a range of REE abundances which bracket that of the matrix. Of particular interest is split 61175, 170 which sampled a small anorthosite clast. This clast has very low REE abundances and may represent a pristine lithology although no siderophile data are available. Other anorthositic clasts from this rock have significantly higher REEs (,131 on Fig. 8) and have probably been contaminated with KREEP. Basaltic clasts may be either poor or rich in a KREEP component (e.g. ,126 and ,133 respectively, Fig. 8).

STABLE ISOTOPES: Clayton *et al.* (1973) determined a whole rock δO^{18} value of 5.78‰ , typical of Apollo 16 breccias.

EXPOSURE AGE: A maximum track exposure age of 10 m.y. is reported by Crozaz et al. (1974, reference to Fleisher and Hart, 1974, unpublished). Crozaz et al. (1974) also calculate a surface exposure age of > 1.5 m.y. from the cosmogenic radio-nuclide data of Eldridge et al. (1973).

MICROCRATERS: Morrison et al. (1973) and Neukum et al. (1973) report size-frequency data for microcraters on 61175 (Fig. 9). From the subrounded shape of the rock and its crater distribution, both authors conclude that 61175 is probably in equilibrium.

Schaal et al. (1976) provide detailed petrography and microprobe analyses of a thin section cut through a 3.6 mm, glass-lined microcrater as an example of an impact into a complex, polymict host. Preferential assimilation of plagioclase over pyroxene and small scale flow and mixing was observed. The glass lining is inhomogeneous (30-37% Al_2O_3) and significantly enriched in a plagioclase component relative to the host matrix. Shock effects in the host progressively diminish away from the crater through a zone ~ 1.5 mm into the rock.

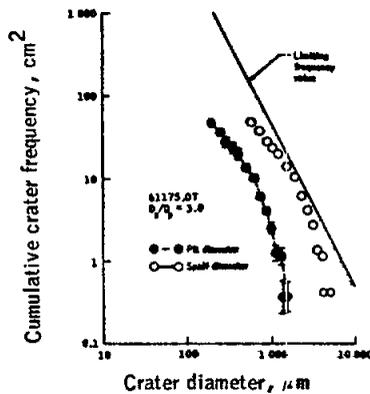


Figure 9. Microcraters, from Morrison et al. (1973).

PHYSICAL PROPERTIES: Compressional and shear wave velocities at pressures up to 10 kb were measured by Mizutani and Osako (1974) (Fig.10). The porous nature of 61175 results in velocities significantly less than those determined for the lunar crust.

PROCESSING AND SUBDIVISIONS: In 1972, 61175 was chipped into six main pieces (,0-,5). In 1973 the largest of these (,0) was cut into three pieces (,16 ,19 and ,20) one of which was a slab (,19). The slab was subsequently divided for allocations (Fig. 11). All of the Winzer et al. (1977) allocations came from the slab with most of them being taken from ,21 and ,30. The large white clast shown in ,30 is a moderately shocked anorthosite and was analyzed as ,151 (see CHEMISTRY). The anorthosite clast with very low REEs (,170) was a small clast from ,21. It was not the large white clast seen in ,21 in Figure 14. S.R. Taylor et al. (1974) received several whole rock chips from butt end ,16 but the analysis (,80) is unlike any of the other matrix analyses and looks more like a plagioclase-rich separate.

Figure 10. Wave velocity profile, from Mizutani and Osako (1974).

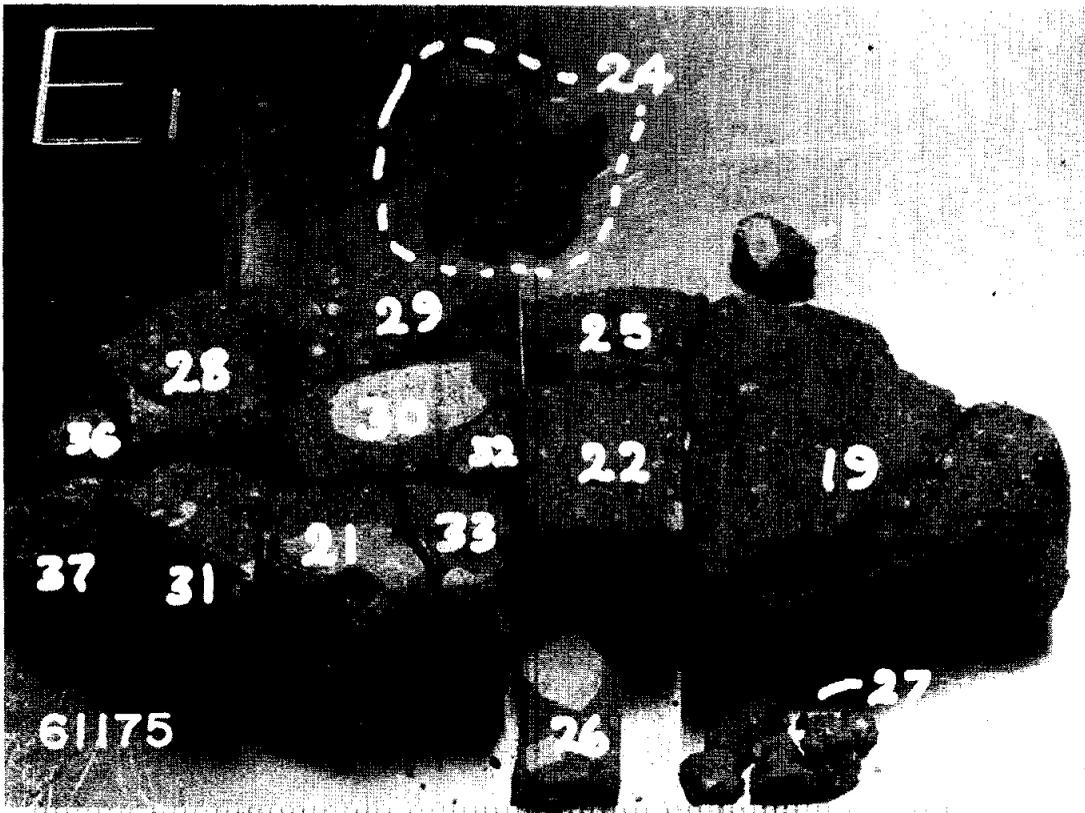
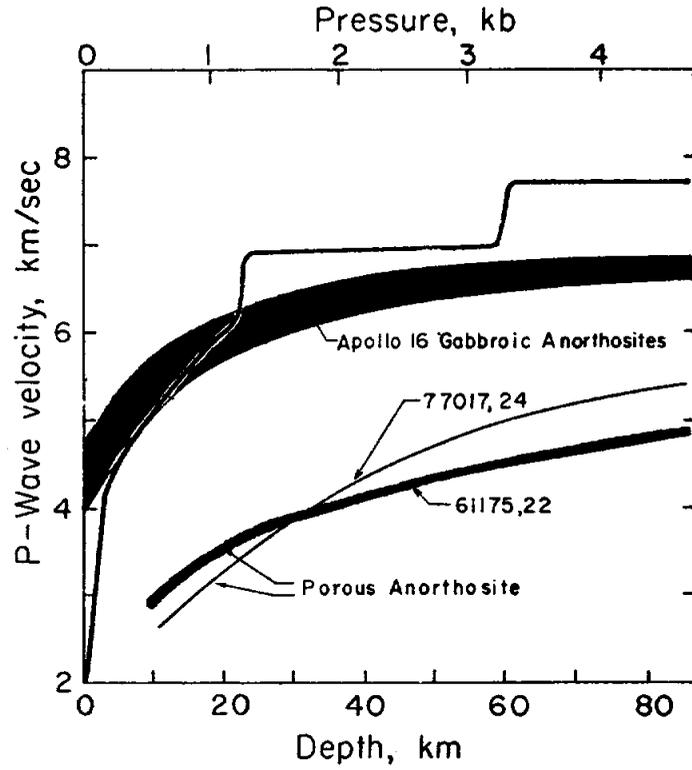


Figure 11. Slab subdivisions, mm scale. S-73-25605.

INTRODUCTION: 61195 is a coherent, medium gray breccia with a glassy matrix and abundant clasts (Fig. 1). A significant regolith component is indicated by the petrography and chemistry. A dark, vesicular glass coats 80-90% of the exterior surface and intrudes the rock as small veins.

This sample was collected from the northeast rim of Plum Crater, where it was about $\frac{1}{4}$ buried. Its orientation is known. Zap pits are common on the "lunar up" surface, rare to absent on other surfaces.

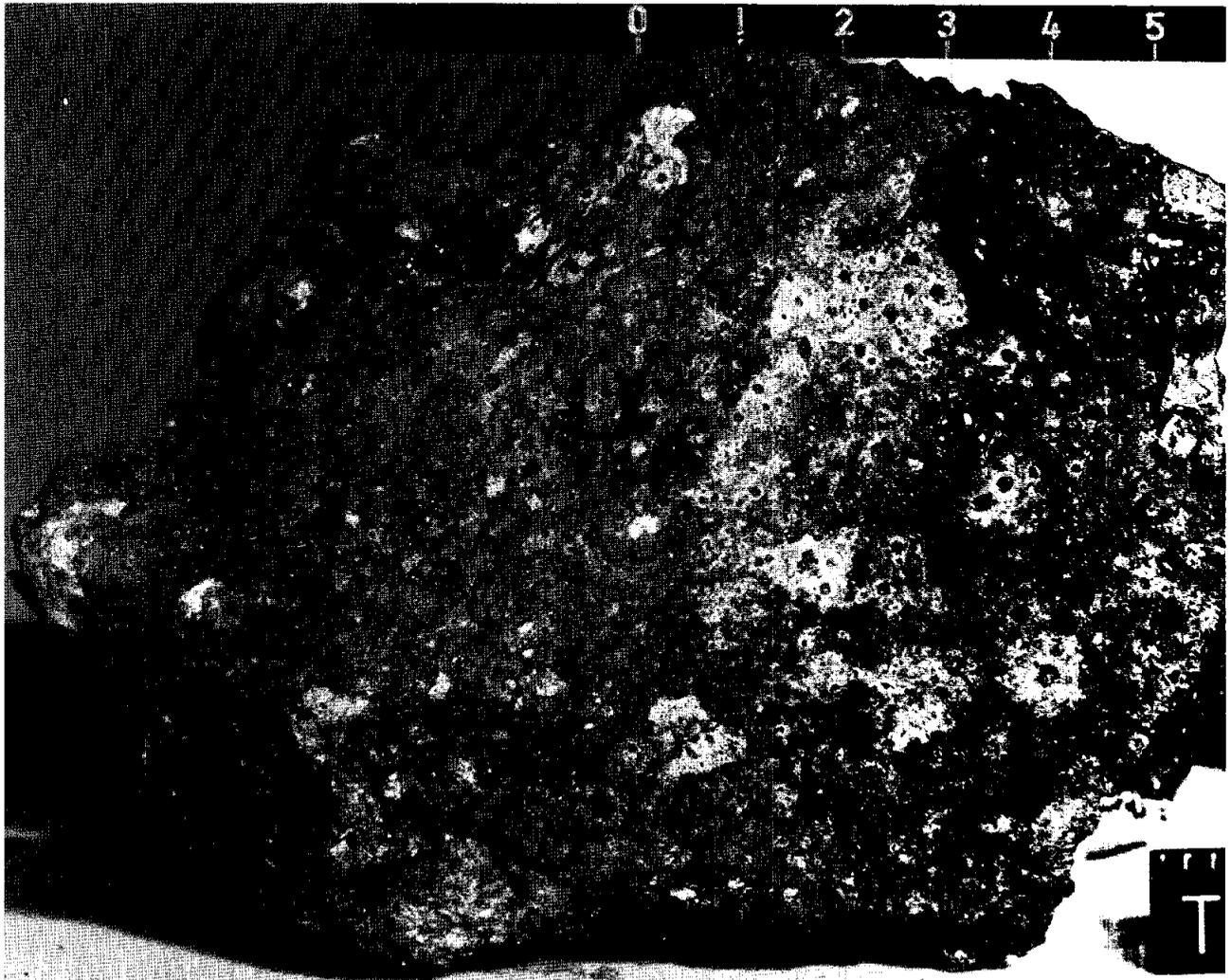


Figure 1. S-72-37972, cm scale.

PETROLOGY: 61195 is a glassy matrix breccia with an abundant and diverse clast population (<0.1-3 mm) (Fig. 2) and a low porosity. Two sets of nearly perpendicular fractures cut the rock and cross clast-matrix boundaries.

Homogeneous and partly crystalline glass beads and fragments are common, and indicate a regolith component. Mineral clasts include plagioclase, pyroxene and olivine, nearly all of which have been shocked or recrystallized. Lithic clasts include rounded to angular fragments of granoblastic anorthosite and anorthositic norite, cataclastic anorthosite, spinel- and clast-bearing basaltic impact melt, fine-grained poikilitic impact melt, clast-rich vitric matrix breccia, and plagioclase vitrophyre. Fe-metal, troilite, schreibersite and rare ilmenite are accessory phases in both the matrix and some clasts.



Figure 2. 61195,36, general view, ppl. width 2mm.

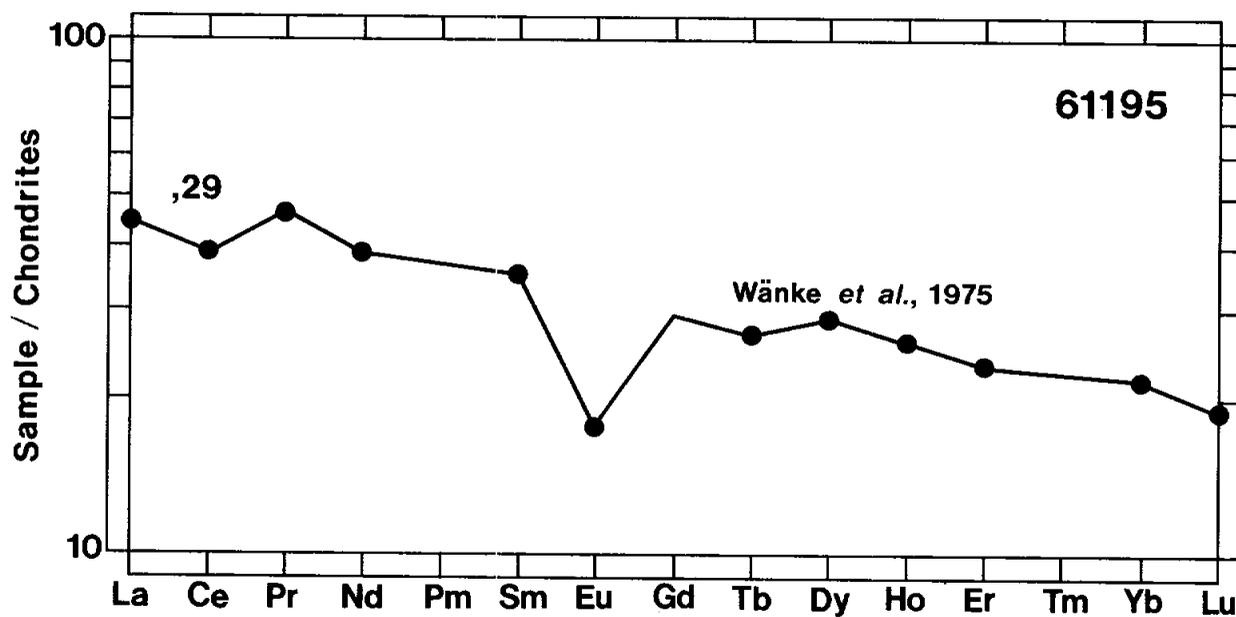
CHEMISTRY: Wänke et al. (1975) provide bulk major and trace element data. Eldridge et al. (1973) report whole rock data for K, U, and Th determined by gamma-ray spectroscopy. The major and lithophile element abundances (Table 1, Fig. 3) are identical to those of local mature soils. Siderophile element abundances in the rock are slightly lower than in the soils.

TABLE 1. Summary chemistry of 61195

SiO ₂	45.5
TiO ₂	0.50
Al ₂ O ₃	26.8
Cr ₂ O ₃	0.099
FeO	5.13
MnO	0.06
MgO	5.56
CaO	15.4
Na ₂ O	0.46
K ₂ O	0.088
P ₂ O ₅	0.17
Sr	166
La	14.6
Lu	0.64
Rb	3.86
Sc	8.53
Ni	410
Co	27.1
Ir ppb	11.3
Au ppb	6.1
C	-
N	-
S	660
Zn	9.71
Cu	3.76

Oxides in wt%; others in ppm
except as noted.

Figure 3. Rare earths.



EXPOSURE AGE: Eldridge et al. (1973) report cosmogenic radionuclide data and conclude that the rock is unsaturated in ^{26}Al . The very low $^{26}\text{Al}/^{22}\text{Na}$ indicates a surface exposure age of <1 m.y.

PROCESSING AND SUBDIVISIONS: In 1973, 61195 was cut into three main pieces including a slab. The slab was entirely subdivided into smaller chips (Fig. 4). Allocations for thin sections were made from two chips of the slab (,7 and ,9). Wänke et al. (1975) analyzed a collection of small chips (,29) for chemistry. Other chips were also taken from butt end ,4.

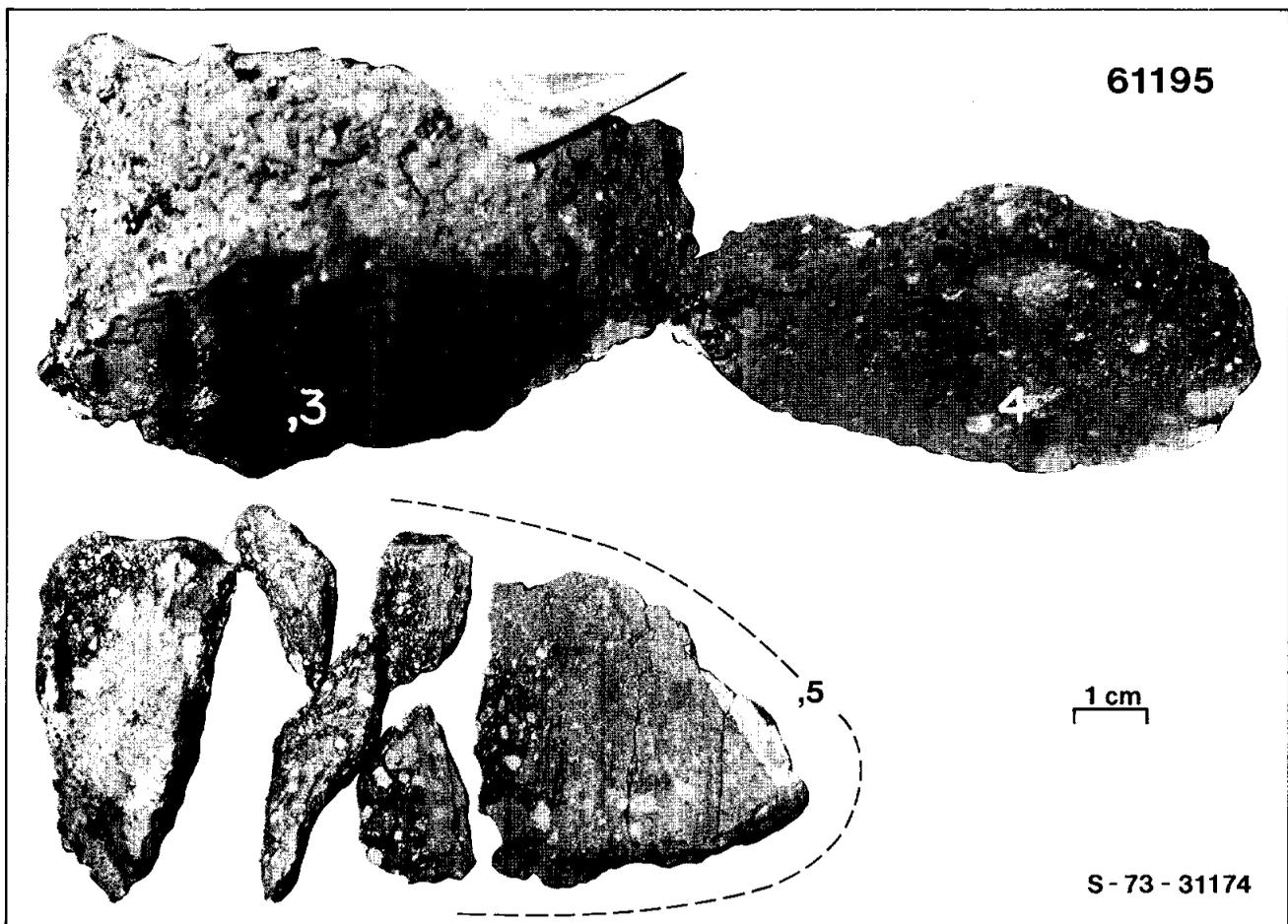


Figure 4.

INTRODUCTION: 61225 is a coherent, medium gray, crystalline rock that is probably an impact melt (Fig. 1). Vugs and vesicles are heterogeneously distributed and all but one of the surfaces are covered with thick, white dust. The N surface is clean and appears to be fresh. This rock was taken from the soil sample from the bottom of the trench on the east rim of Plum Crater. Zap pits are absent.

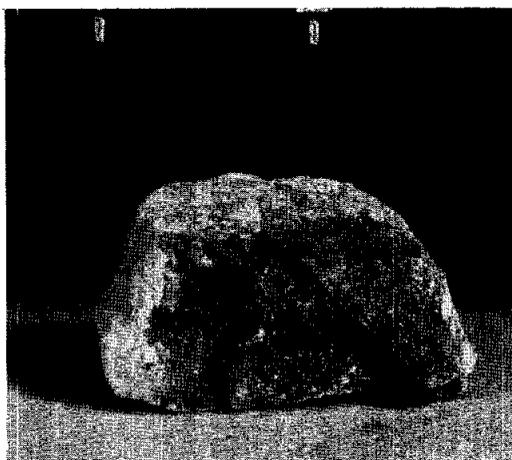


Figure 1. S-72-41306, cm scale.

INTRODUCTION: 61226 consists of coherent, white anorthosite separated by a zone of crushed, pale gray breccia (Fig. 1). The latter may be a crushed version of the anorthosite, although it contains small black specks. A thin (~ 1 mm) black glass coats part of the surface.

61226 was taken from a soil sample collected from the bottom of a trench dug on the east rim of Plum Crater. It lacks zap pits.



Figure 1. Smallest scale subdivision 0.5mm.

INTRODUCTION: 61245 is a fine-grained or glassy, dark gray, crystalline rock (Fig. 1). It contains vesicles, both round (up to 2 mm across) and elongate (up to 1 cm long). It contains a few percent rounded white clasts. 61245 was taken from a soil sample collected from the top of a trench dug on the east rim of Plum Crater. It lacks zap pits.



Figure 1. Smallest scale subdivision 0.5mm.

INTRODUCTION: Most of 61246 is a fine-grained or glassy, gray or greenish impact melt. It contains rare vesicles, some of which are soil filled, and is angular and coherent (Fig. 1). One side has a rind of fragmental (though coherent) breccia which is firmly attached and may have been welded on while the melt was still hot. This fragmental rind consists of tiny black fragments in a pale-colored matrix.

61246 was taken from a soil sample collected from the top of a trench dug on the east rim of Plum Crater. It lacks zap pits.

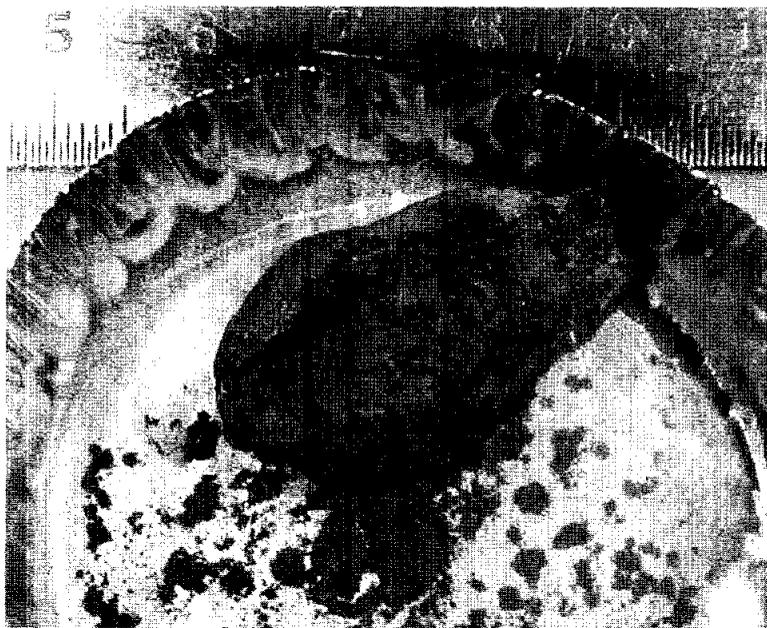


Figure 1. Smallest scale subdivision 0.5mm.

INTRODUCTION: 61247 is a coherent, angular sample (Fig. 1). It is macroscopically similar to the poikilitic impact melt 65015, with pale-colored pyroxene oikocrysts (?) about 1 mm across enclosing gray (plagioclase?) grains. Some of the plagioclases are quite lath-shaped but most very angular. Between these areas are distinctive dark chains. The sample contains a few vugs.

61247 was taken from a soil sample collected from the top of a trench dug on the east rim of Plum Crater. It lacks zap pits.

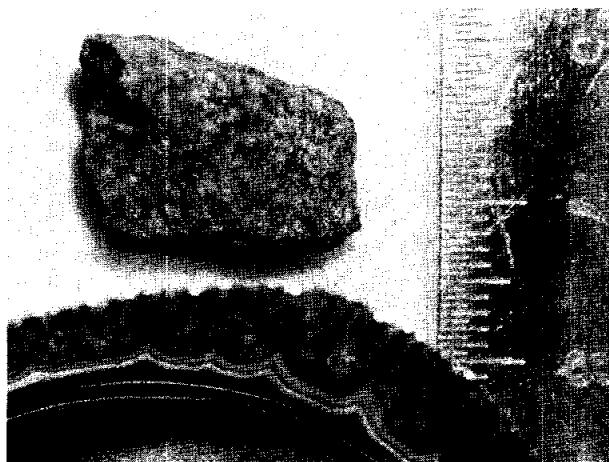


Figure 1. Smallest scale subdivision 0.5mm.

INTRODUCTION: 61248 is an extremely friable, polymict breccia (Fig. 1). It is pale-colored with several small, dark, coherent clasts. 61248 was taken from a soil sample collected from the top of a trench dug on the east rim of Plum Crater. It is far too friable to have retained zap pits.



Figure 1. mm scale.

INTRODUCTION: 61249 is a slabby coherent sample (Fig. 1). It is crystalline with yellowish/gray and white minerals, and ilmenite forms distinct laths. A basaltic texture is not well-developed, although the plagioclases appear to be ~ 1 mm long. The sample lacks vugs or vesicles.

61249 was taken from a soil sample collected from the top of a trench dug on the east rim of Plum Crater. It has several zap pits.

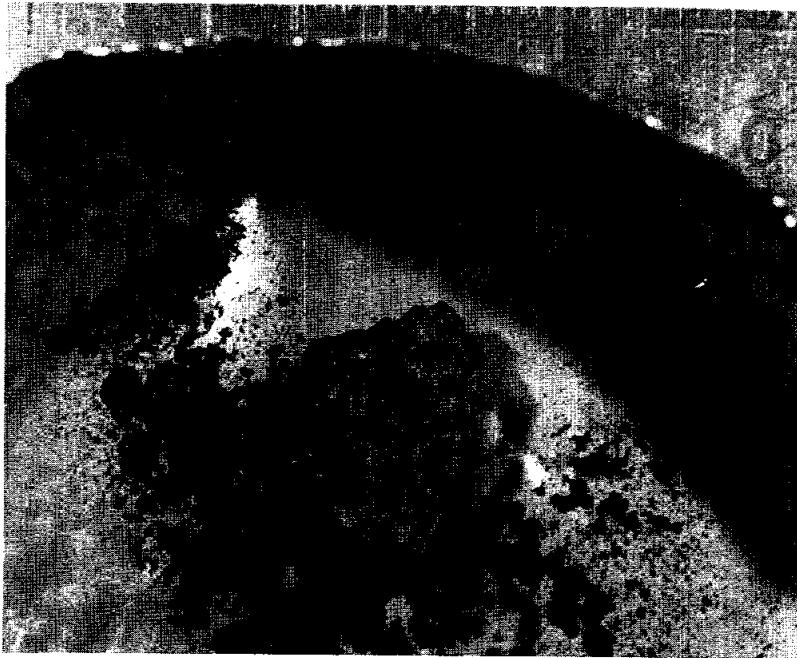


Figure 1. mm scale.

INTRODUCTION: 61255 is a vesicular, cindery black glass (Fig. 1), containing one prominent pure white clast. The glass has several broken surfaces. 61255 was taken from a soil sample collected from the top of a trench dug on the east rim of Plum Crater. It lacks zap pits.



Figure 1. Smallest scale subdivision 0.5mm.

INTRODUCTION: 61295 is a moderately coherent polymict breccia (Fig. 1) containing a wide variety of clasts. Glass shards, glass beads, and agglutinates are present; some of the glasses appear to be of mare derivation. Only about 10% of the clasts are larger than 1 mm, and most are angular.

61295 was removed from an unburied portion of a 2 m boulder on the southwest rim of Plum Crater, and its orientation is known. Its exposed surface is rounded and has many zap pits.



PETROLOGY: LSPET (1973) depicts 61295 as typical of those polymict, light-gray, moderately friable breccias which have essentially glass-free matrices.

Thin sections are of a polymict breccia containing abundant lithic clasts (Fig. 2). 25% of the rock consists of fragments larger than 200 μm . The matrix is extremely porous and most fragments, including the smallest, are angular (Fig. 2). The lithic clasts include feldspathic impact basalts, feldspathic granulites, aphanitic breccias, and poikilitic impact melts. Plagioclase and mafic mineral fragments are common. Regolith-derived materials--orange glass shards, clasts and pale green glass balls, and agglutinate fragments--are common. Some of the glasses are evidently of mare origin: Delano (1975) refers to mare components in 61295 but does not detail specific analyses.

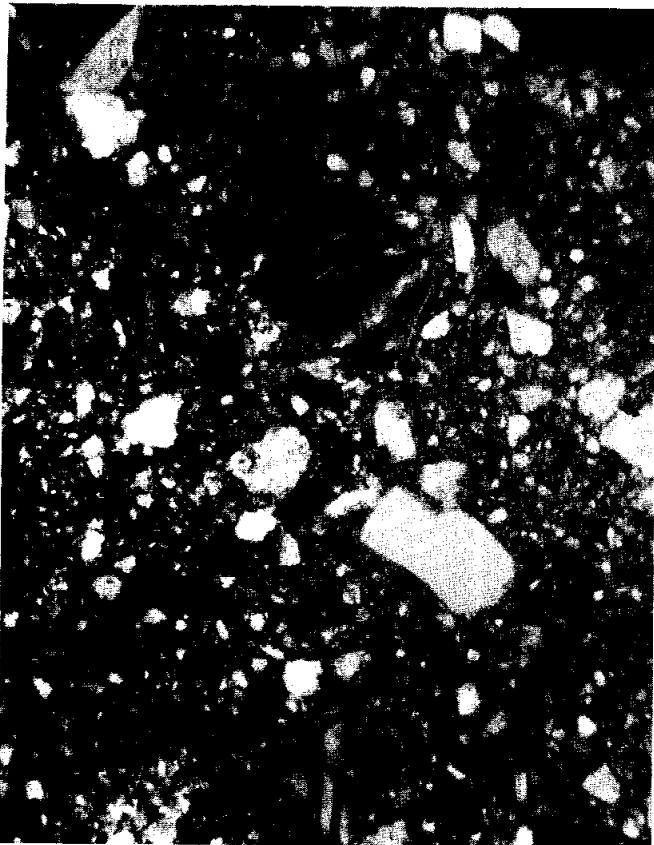


Figure 2. 61295,37, general view,pppl. width 2mm.

CHEMISTRY: For bulk rock samples, LSPET (1973) presents major and some trace element abundances. Hubbard et al. (1974) present abundances of trace elements including rare-earths. Eldridge et al. (1973) present K, U, Th, and radio-nuclide data, and Moore et al. (1973) present carbon contents. Nyquist et al. (1974) present Rb, Sr abundances. Little specific comment is made by these authors.

The chemistry is summarized in Table 1 and Figure 3. Although the rock contains regolith-derived fragments, it differs from local soils in its high Al_2O_3 , and its C content (55 ppm) is significantly lower than most soils (100+ ppm).

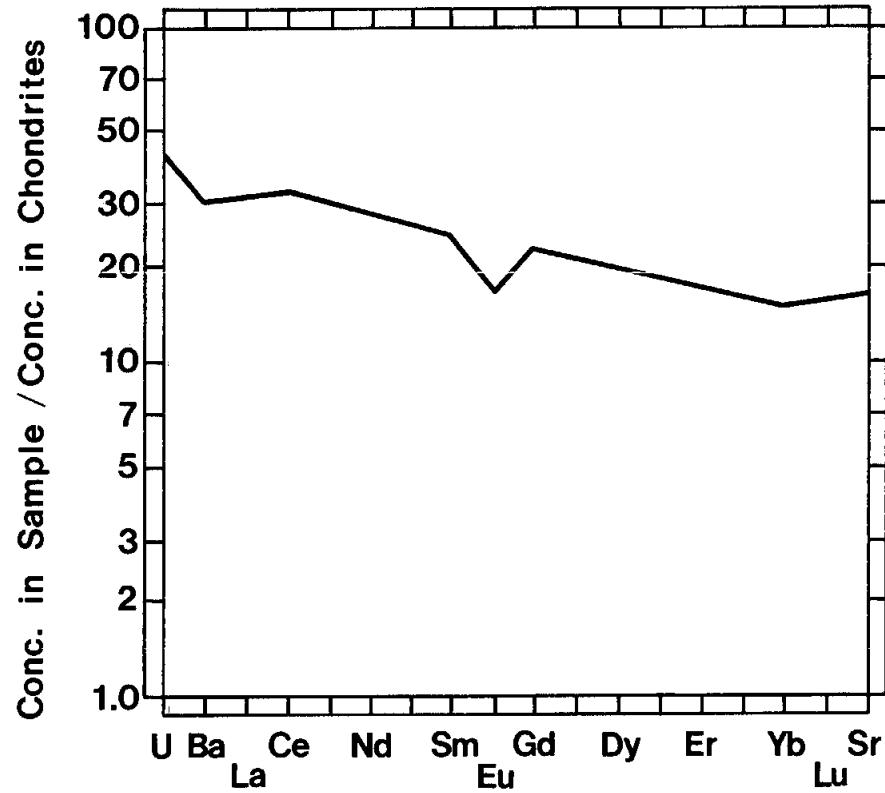


Figure 3. Rare earths, from Hubbard et al. (1974).

TABLE 1. Summary chemistry of 61295 bulk rock

SiO ₂	45.2
TiO ₂	0.56
Al ₂ O ₃	28.3
Cr ₂ O ₃	0.08
FeO	4.5
MnO	0.06
MgO	4.7
CaO	16.2
Na ₂ O	0.46
K ₂ O	0.09
P ₂ O ₅	0.10
Sr	186
La	10.4
Lu	
Rb	2.3
Sc	
Ni	114
Co	
Ir ppb	
Au ppb	
C	55
N	
S	600
Zn	
Cu	

Oxides in wt%; others in ppm except as noted.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: The only radiogenic isotope data published on 61295 are Rb-Sr whole rock data by Nyquist et al. (1974), summarized in Table 2.

TABLE 2. Whole rock Rb-Sr isotopic data (Nyquist et al., 1974)

Rb ppm	Sr ppm	$^{87}\text{Sr}/^{86}\text{Sr}$	T_{BABI}^* b.y.	T_{LUNI}^* b.y.
2.308	186.0	0.70130 \pm 6	4.28 \pm .15	4.41 \pm .15

*BABI and LUNI adjusted for interlaboratory bias.

EXPOSURE AGES: Yokoyama et al. (1974) assess the radionuclide data of Eldridge et al. (1973) as indicating that 61295 is saturated with ^{26}Al . Thus the exposure age of 61295 is long in relation to the half-life of ^{26}Al .

PROCESSING AND SUBDIVISIONS: 61295 has main subdivisions as shown in Figure 1, but many small pieces also exist. A poikilitic impact melt clast was removed from ,12 and part made into a potted butt for thin sections. Bulk matrix ,3 (not shown) was also made into thin sections.

INTRODUCTION: 61505 is a medium dark gray, angular fragment (Fig. 1) which is fine-grained and coherent. It lacks obvious clasts or vesicles. It is probably a fine-grained or glassy impact melt. It was taken from a regolith sample collected 30 m east of Flag Crater. Zap pits are common on most surfaces and have white or colorless glass linings.

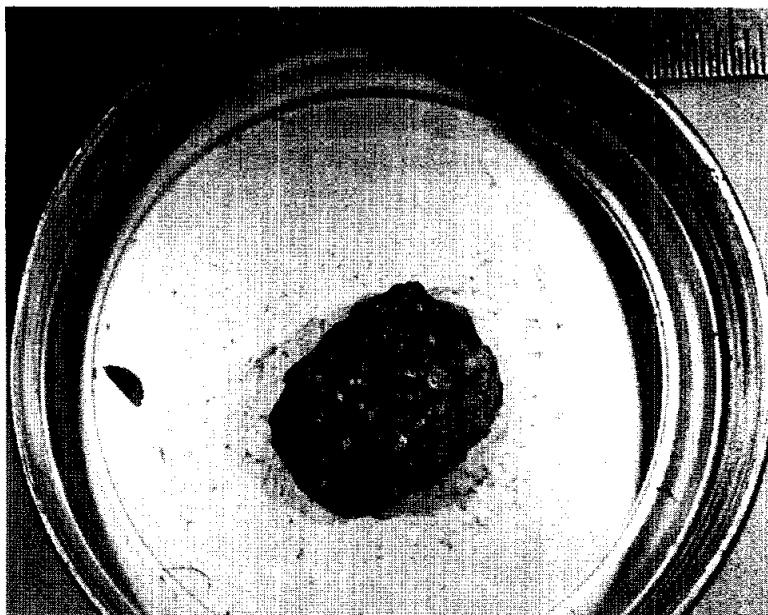


Figure 1. Smallest scale subdivision 0.5mm.

INTRODUCTION: 61515 is a friable, light gray clastic breccia with many small, white to gray clasts (Fig. 1). It is a rake sample collected about 45 m north-east of Plum Crater. Zap pits are rare.



Figure 1. S-72-43347.

INTRODUCTION: 61516 is a friable, light gray, clastic breccia (Fig. 1). It is a rake sample collected ~45 m northeast of Plum Crater. Zap pits are present.

PETROLOGY: Warner et al. (1973) include 61516 in a general petrographic discussion of Apollo 16 rake samples and provide a photomicrograph. Phinney et al. (1976) studied the matrix characteristics using SEM techniques.

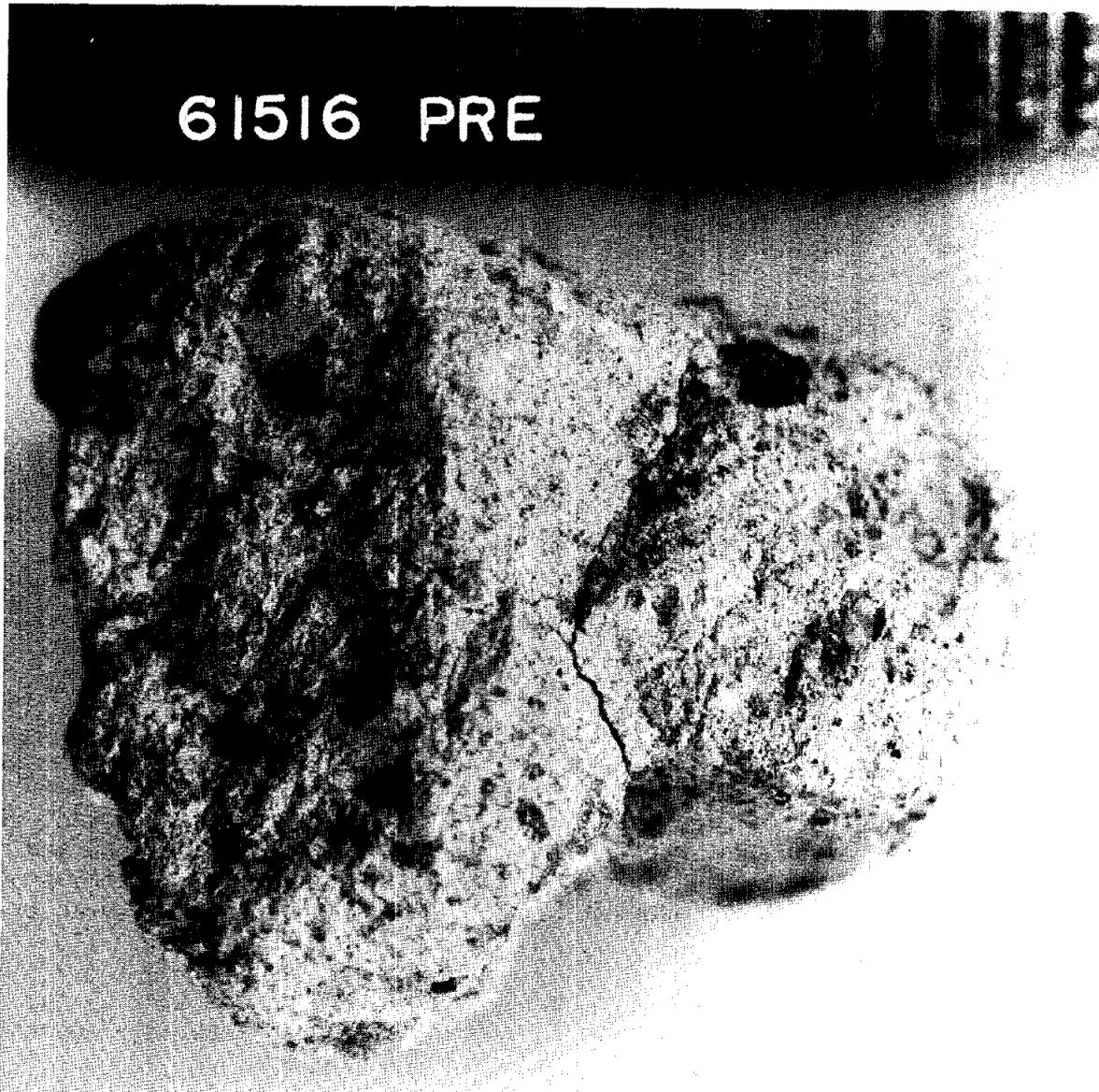


Figure 1. S-72-55331, mm scale.

Abundant mineral and lithic clasts rest in a porous, unequilibrated matrix (Fig. 2). Plagioclase fragments are the dominant clast type. A few large (up to ~ 0.5 mm) grains of mafic silicate are present. Lithic clasts include granoblastic anorthosite, basaltic impact melt, coarse-grained poikilitic impact melt, and recrystallized, granoblastic breccia. Phinney *et al.* (1976) find that the matrix contains 2-3% glass with traces of sintering and $\sim 35\%$ porosity.



Figure 2. 61516,4, general view, ppl. width 1mm.

CHEMISTRY: Floran *et al.* (1976) present major element data obtained by electron microprobe analysis of natural rock powder fused to a glass (except FeO and Na₂O, by instrumental neutron activation). Blanchard (unpublished data) provides a trace element analysis and the FeO and Na₂O data quoted by Floran *et al.* (1976).

These data show that 61516 is similar in its major element chemistry to the local mature soils, but contains slightly lower levels of rare earth elements as compared to the soils (Table 1, Fig. 3).

TABLE 1. Summary chemistry of 61516

SiO ₂	45.58
TiO ₂	0.42
Al ₂ O ₃	27.24
Cr ₂ O ₃	0.102
FeO	4.61
MnO	
MgO	6.05
CaO	15.35
Na ₂ O	0.538
K ₂ O	0.12
P ₂ O ₅	
Sr	
La	10.4
Lu	0.52
Rb	
Sc	7.16
Ni	195
Co	18.1
Ir ppb	
Au ppb	
C	
N	
S	
Zn	29
Cu	

Oxides in wt%; others in ppm except as noted.

PHYSICAL PROPERTIES: Pearce and Simonds (1974) report the results of a room temperature hysteresis curve determination on 61516. The very small saturation remanence to saturation magnetization ratio ($J_{RS}/J_S = 0.005$) indicates that virtually all of the ferromagnetic phases in this sample are multidomain particles. Fe^0/Fe^{2+} is 0.0949 and total Fe^0 is 0.24 wt%.

PROCESSING AND SUBDIVISIONS: During processing in 1972 the rock broke into many pieces. One of these (,1) was allocated to Phinney for thin sectioning and petrography. In 1975 a set of eleven small chips (,2) was allocated for chemistry; the analyses of Floran et al. (1976) and Blanchard (unpublished) are both of portions of this split. The magnetic studies were done on the potted butt of ,1. The rest of the rock remains at JSC as ,0 (2.09 g).

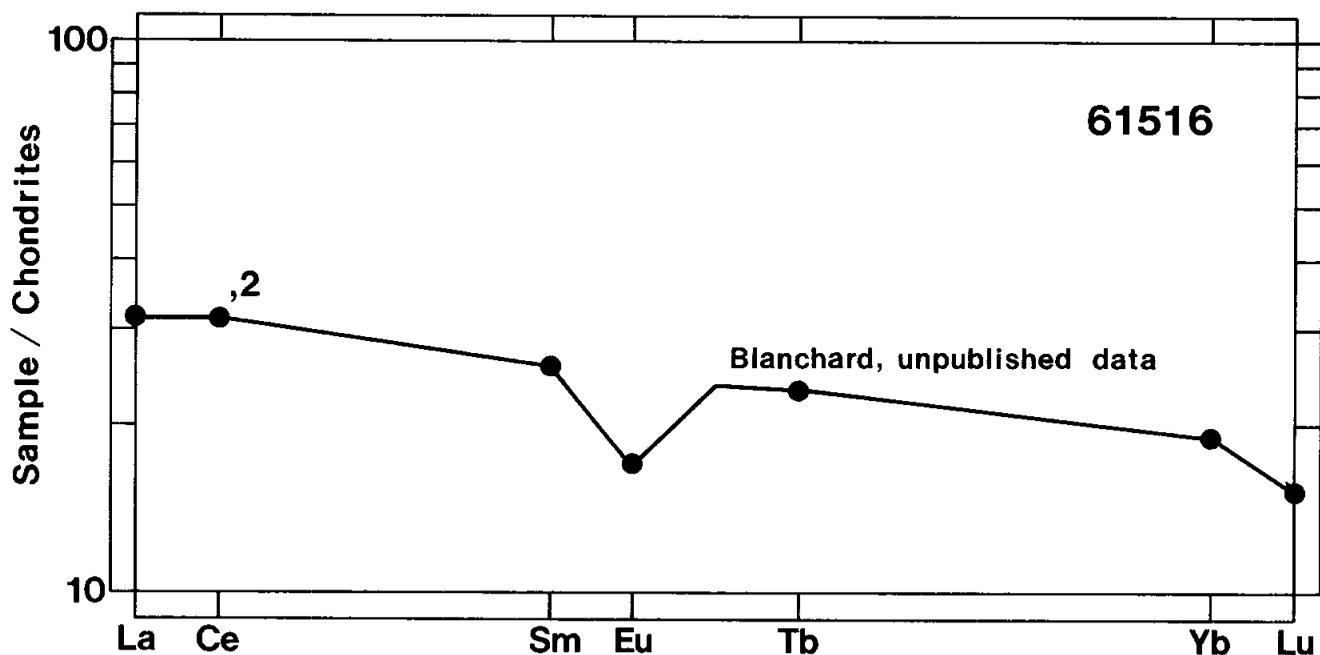


Figure 3. Rare earths.

INTRODUCTION: 61517 is a friable, light gray, clastic breccia with several white to gray clasts (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.



Figure 1. S-72-43349.

INTRODUCTION: 61518 is a friable, light gray, clastic breccia with several white to gray clasts (Fig. 1). It is a rake sample collected about 45 m north-east of Plum Crater. Zap pits are rare or absent.



Figure 1. S-72-43349.

INTRODUCTION: 61519 is a friable, light gray, clastic breccia with several small, white to gray clasts (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare to absent.

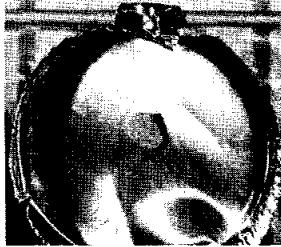


Figure 1. S-72-43349.

INTRODUCTION: 61525 is a moderately friable, medium gray, polymict breccia with considerable glass in the matrix (Fig. 1). It is a rake sample collected ~45 m northeast of Plum Crater. Zap pits are abundant on one surface, absent on others.

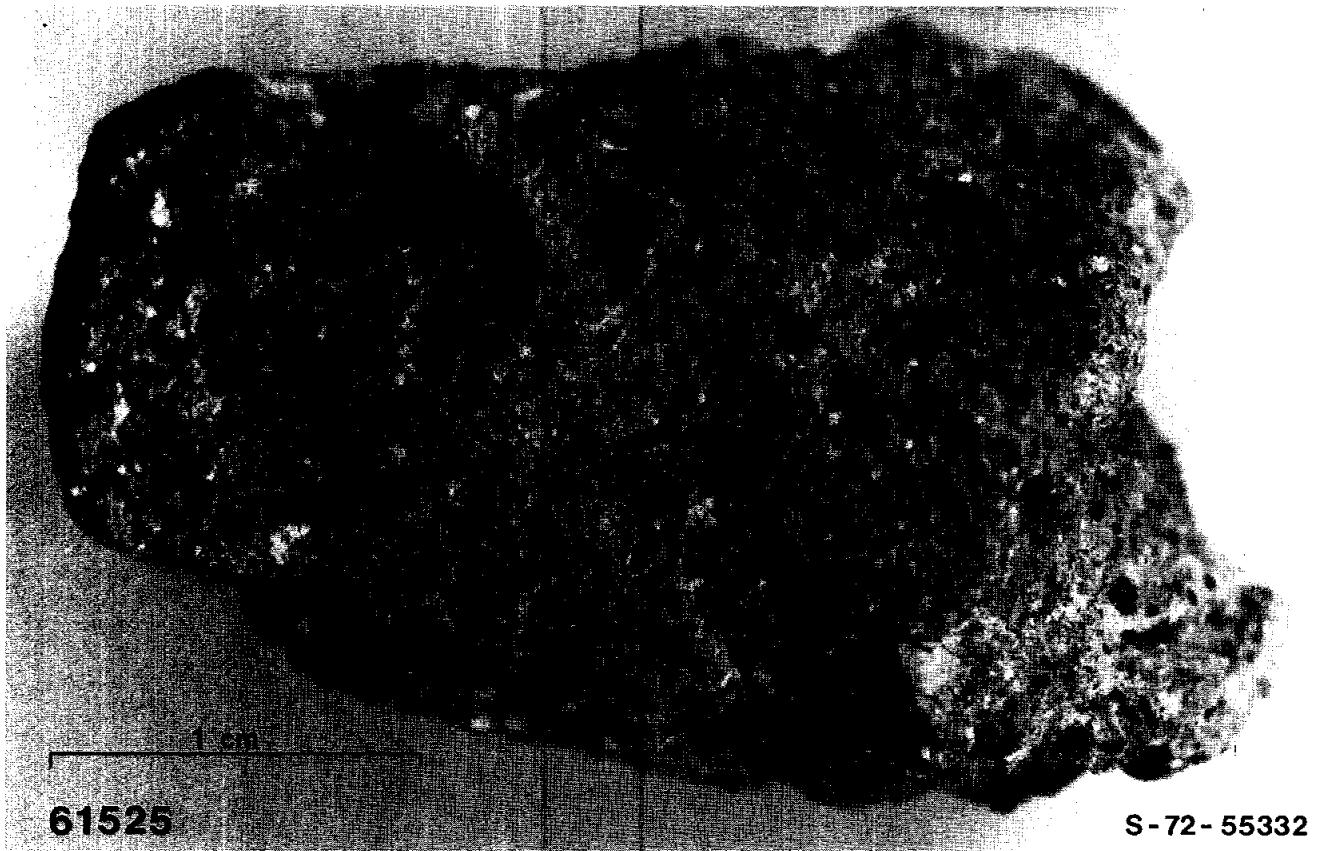


Figure 1.

PETROLOGY: Warner *et al.* (1973) include 61525 in a general petrographic discussion of Apollo 16 rake samples and classify it as a "glassy breccia". Phinney *et al.* (1976) studied the matrix characteristics using SEM techniques.

61525 consists of shocked mineral and lithic clasts, and occasional beads and fragments of clear glass, in a chaotic, glassy matrix (Fig. 2). Phinney *et al.* (1976) report that the matrix contains ~25% glass and variable (1-10%) porosity. Fe-metal compositions are provided by Gooley *et al.* (1973) and reproduced here as Table 1.

TABLE 1. Metal Compositions of 61525 (wt %)

Metal	Ni	Co	P	S
	5.6-6.6	0.5	0.0-0.2	0.02

CHEMISTRY: Floran et al. (1976) report major element data obtained by electron microprobe analysis of natural rock powder fused to a glass (except FeO and Na₂O, by instrumental neutron activation). Blanchard (unpublished data) provides a trace element analysis and the FeO and Na₂O data quoted by Floran et al. (1976)

These data show that 61525 is similar to the local mature soils in major element composition, but is somewhat enriched in rare earth elements compared to the soils (Table 2, Fig. 3).

TABLE 2. Summary Chemistry of 61525

SiO ₂	45.85
TiO ₂	0.55
Al ₂ O ₃	26.19
Cr ₂ O ₃	0.120
FeO	5.27
MnO	
MgO	5.57
CaO	15.12
Na ₂ O	0.591
K ₂ O	0.23
P ₂ O ₅	
Sr	
La	17.6
Lu	0.776
Rb	
Sc	9.24
Ni	190
Co	17.8
Ir ppb	
Au ppb	
C	
N	
S	
Zn	50
Cu	

Oxides in wt %; others in ppm except as noted.

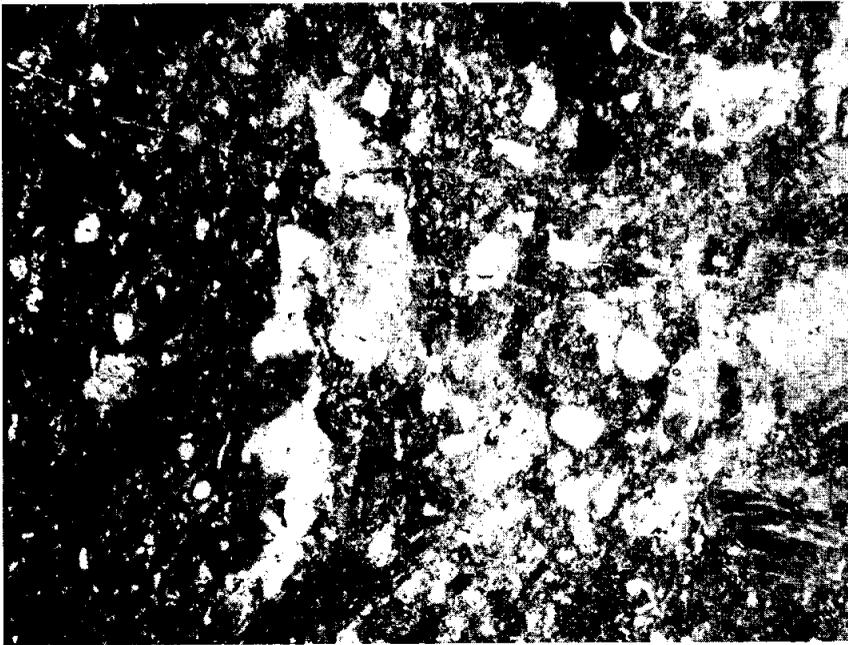


Figure 2. 61525,4, general view, ppl. width 2mm.

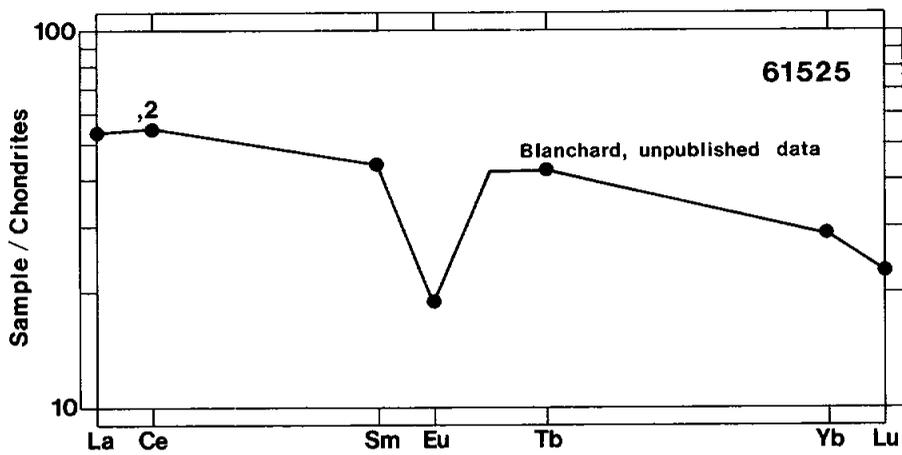


Figure 3. Rare earths.

PHYSICAL PROPERTIES: Pearce and Simonds (1974) report the results of a room temperature hysteresis curve determination on 61525. The saturation remanence to saturation magnetization ratio ($J_{RS}/J_S = 0.014$) indicates that 3-6% of the ferromagnetic phases in this sample are single domain particles and the rest are multidomain. Fe^0/Fe^{2+} is 0.0654 and total FeO is 0.25 wt%.

PROCESSING AND SUBDIVISIONS: In 1972 a single chip (,1) was removed and allocated to Phinney for thin sectioning and petrography. In 1975 a set of three small chips (,3) were allocated for chemistry; the analyses of Floran et al. (1976) and Blanchard (unpublished) are both portions of this split. The magnetic studies were done on the potted butt of ,1.

INTRODUCTION: 61526 is a moderately coherent, light gray, clastic breccia with many small white to gray clasts (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.



Figure 1. S-72-43349.

INTRODUCTION: 61527 is a moderately coherent, medium gray, clastic breccia with many small white to gray clasts (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.

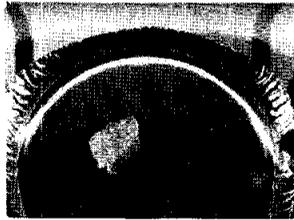


Figure 1. S-72-43349.

INTRODUCTION: 61528 is a moderately coherent, medium gray, clastic breccia with many small, white to gray clasts and a small patch of glass coat (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.



Figure 1. S-72-43349.

INTRODUCTION: 61529 is a moderately coherent, medium gray, clastic breccia with many small white to gray clasts (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.

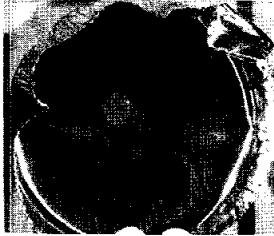


Figure 1. S-72-43349.

INTRODUCTION: 61535 is a moderately coherent, light gray, clastic breccia with a thin coat of dark glass on one surface (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.

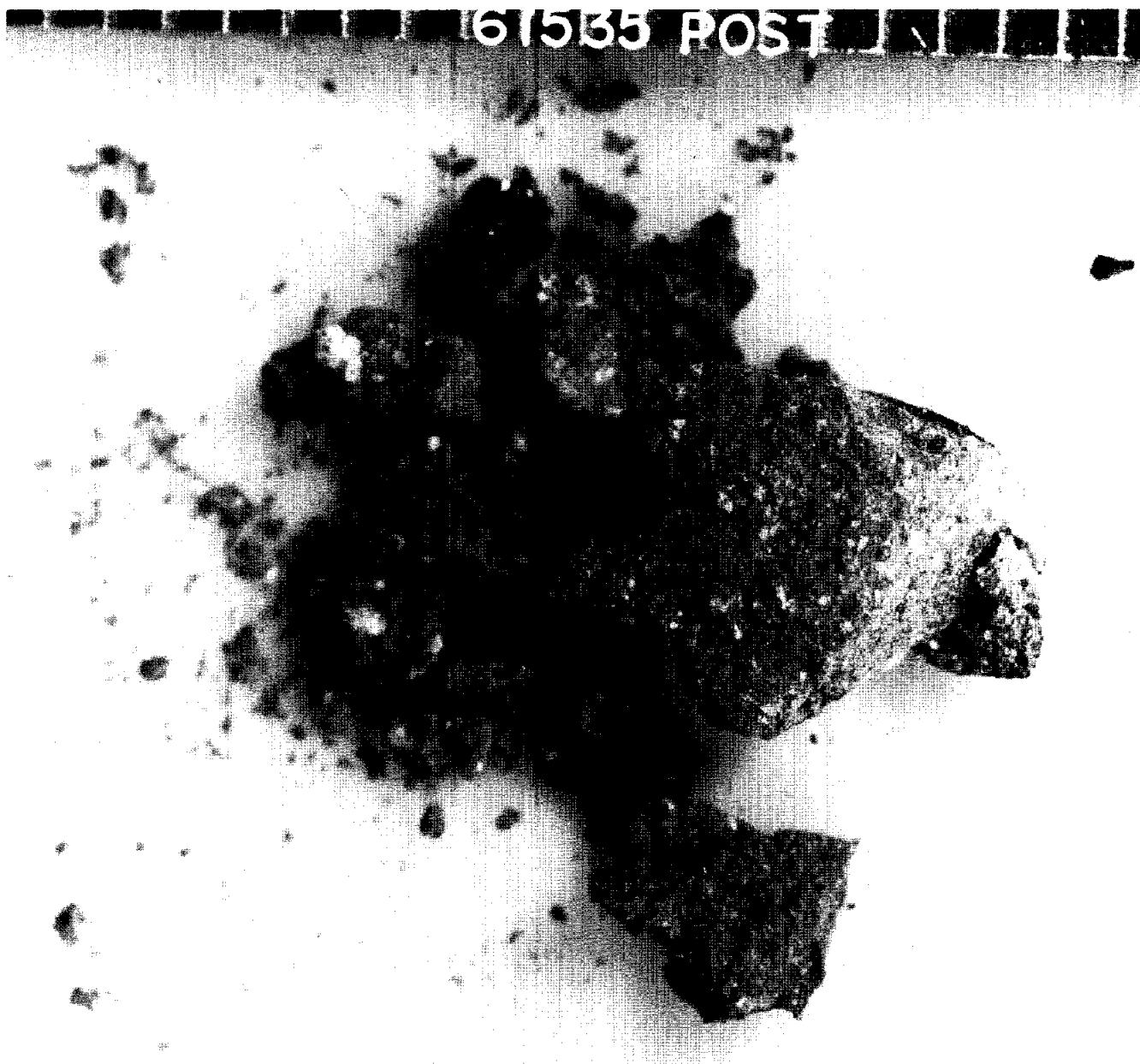


Figure 1. S-72-55318, mm scale.

PETROLOGY: The thin section of 61535 is entirely of a highly vesicular and clast-laden, glassy impact melt, presumably the glass coat (Fig. 2). This lead Warner et al. (1973) to classify this rock as a "glassy breccia".

PROCESSING AND SUBDIVISIONS: During processing in 1972 the rock crumbled to many pieces. Two of these (,1) were allocated to Phinney for thin sectioning and petrography. From data pack photos these pieces appear to have been representative of the bulk rock although photo documentation is not complete. Apparently only the glass coat made it into the thin section.



Figure 2. 61535,4, general view,
ppt. width 2mm.

INTRODUCTION: 61536 is a coherent, glassy breccia with light-colored clasts (Fig. 1). A vesicular, debris-filled green glass coats portions of the surface. The large white clast in Figure 1 is a granoblastic troctolitic(?) anorthosite. 61536 is a rake sample collected from the rim of Flag Crater.

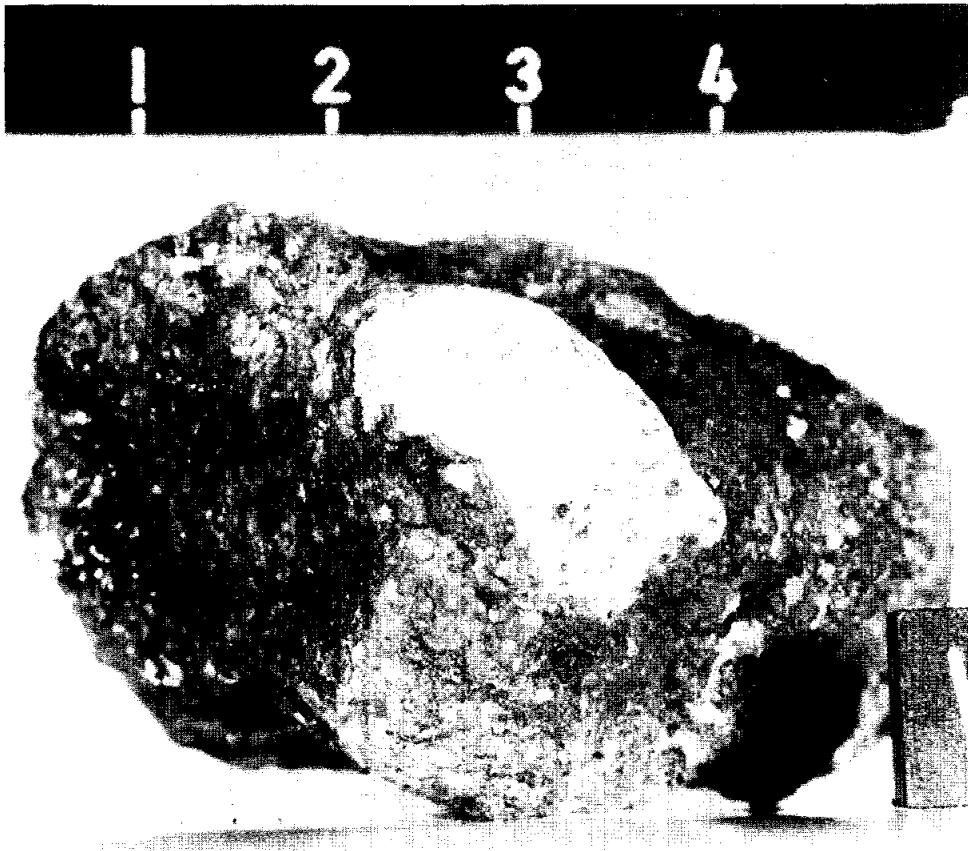


Figure 1. S-72-43398, cm scale.

PETROLOGY: Thin sections cut for this study show that the matrix of 61536 is glassy to cryptocrystalline. Angular clasts of mildly shocked plagioclase, mafic minerals, basaltic and poikilitic impact melts, brown glassy breccia or devitrified glass, and orange-brown glass shards are common (Fig. 2). Many of the clasts exhibit reaction rims with the matrix. Metal, troilite, and glass beads are also present but not common. Several of the metal particles are rusty.

The large white clast seen in Figure 1 is a granoblastic troctolitic (?) anorthosite (Fig. 2), composed of anhedral to elongate plagioclase (~85%) and rounded mafic minerals (~15%). Many grains meet in triple junctions. Plagioclases are much larger (200-400 μm) than the mafic minerals (25-50 μm). Trace amounts of ilmenite, troilite and metal are scattered through the clast. The clast in thin section ,7 is cut by a brown glassy vein containing lithic clasts. The vein is more uniform and contains fewer clasts than the general breccia matrix and is clearly intrusive.

PROCESSING AND SUBDIVISIONS: Thin section ,5 was made from a chip of matrix. The large white clast was designated ,2 most of which remains part of ,0. Two chips (,3 and ,4) were taken from ,2 and thin sections ,6 and ,7, respectively, cut from them. ,3 was entirely used up.

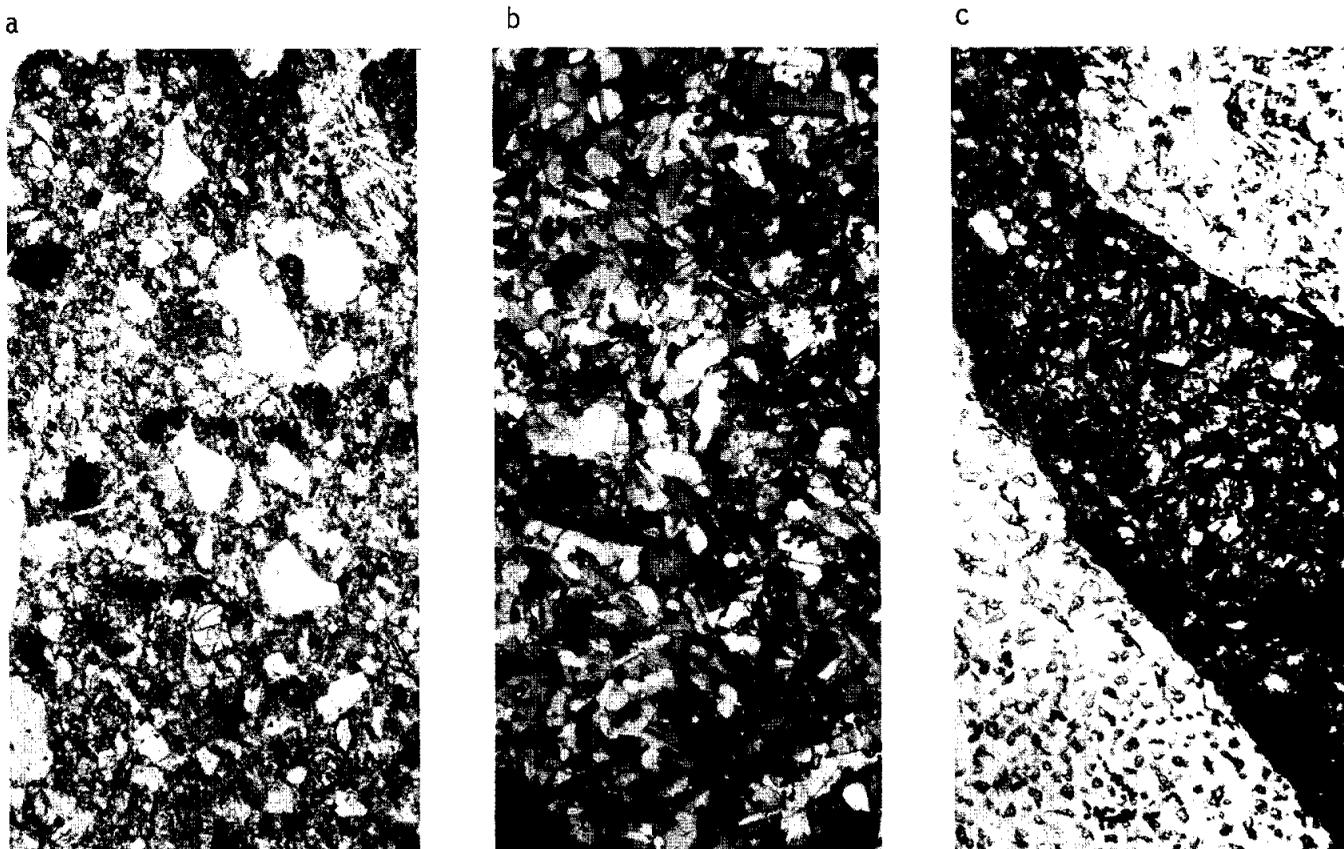


Figure 2. a) 61536,5, matrix, ppl. width 2mm.
 b) 61536,6, granoblastic clast, xpl. width 2mm.
 c) 61536,7, granoblastic clast, ppl. width 2mm.

INTRODUCTION: 61537 is a moderately coherent, medium gray breccia with a few small white clasts and coated by a dark vesicular glass (Fig. 1). Several cracks penetrate the breccia but the rock is held together by the glass coating. This is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.

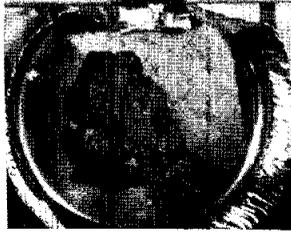


Figure 1. S-72-43349.

INTRODUCTION: 61538 is a light gray, moderately coherent breccia with a few small white clasts and coated with highly vesicular glass (Fig. 1). Many of the vesicles in the glass coat are filled with soil. This is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.



Figure 1. S-73-17119, mm scale.

PETROLOGY: The only thin section of this rock shows a glassy, vesicular impact melt with abundant fragments of plagioclase and anorthositic breccia (Fig. 2). Portions of the glass have crystallized to clusters of elongate tablets and needles of plagioclase separated by a fine-grained mesostasis.

PROCESSING AND SUBDIVISIONS: In 1973 a single chip of glass with some adhering breccia (,1) was allocated to Phinney for thin sectioning and petrography.

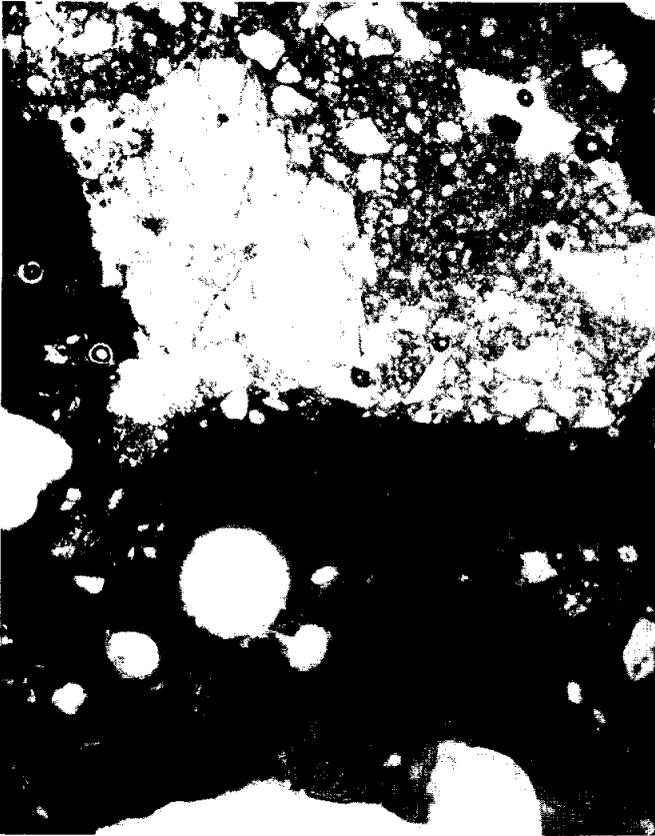


Figure 2. 61538,4, general view, ppl. width 2mm.

INTRODUCTION: 61539 is an aggregate of several fragments of moderately coherent, medium gray breccia welded together by dark, vesicular glass (Fig. 1). Considerable dust adheres to the glass. This is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.



Figure 1. S-72-43349.

INTRODUCTION: 61545 is a moderately coherent, medium gray breccia coated with dark glass (Fig. 1). Several light clasts are present in the breccia and many smaller fragments of breccia are adhering to the glass. This is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare or absent.



Figure 1. S-72-43349.

INTRODUCTION: 61546 is a coherent, dark gray, glassy impact melt with several large white clasts (Fig. 1). Vesicles account for ~25% of the dark matrix. This is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are abundant on one surface; absent on other surfaces.



Figure 1. S-72-43422, cm scale.

PETROLOGY: The texture of the matrix varies from aphanitic to nearly basaltic, often over short distances (Fig. 2). Glass or very fine-grained mesostasis is abundant throughout the rock. Clasts of plagioclase, mafic minerals and cataclastic anorthosite are abundant and often show diffuse boundaries with the matrix. Spherules of Fe-metal, often intergrown with troilite and schreibersite, are scattered through the matrix.

PROCESSING AND SUBDIVISIONS: In 1973 two small chips (,1) were allocated to Phinney for thin sectioning and petrography.



Figure 2. 61546,4, general view, ppl. width 1mm.

INTRODUCTION: 61547 is a coherent, medium gray, crystalline impact melt with a few large vesicles (Fig. 1). It is angular and may be coated by dark glass. It was collected as a rake sample about 45 m northeast of Plum Crater. Zap pits are rare or absent.

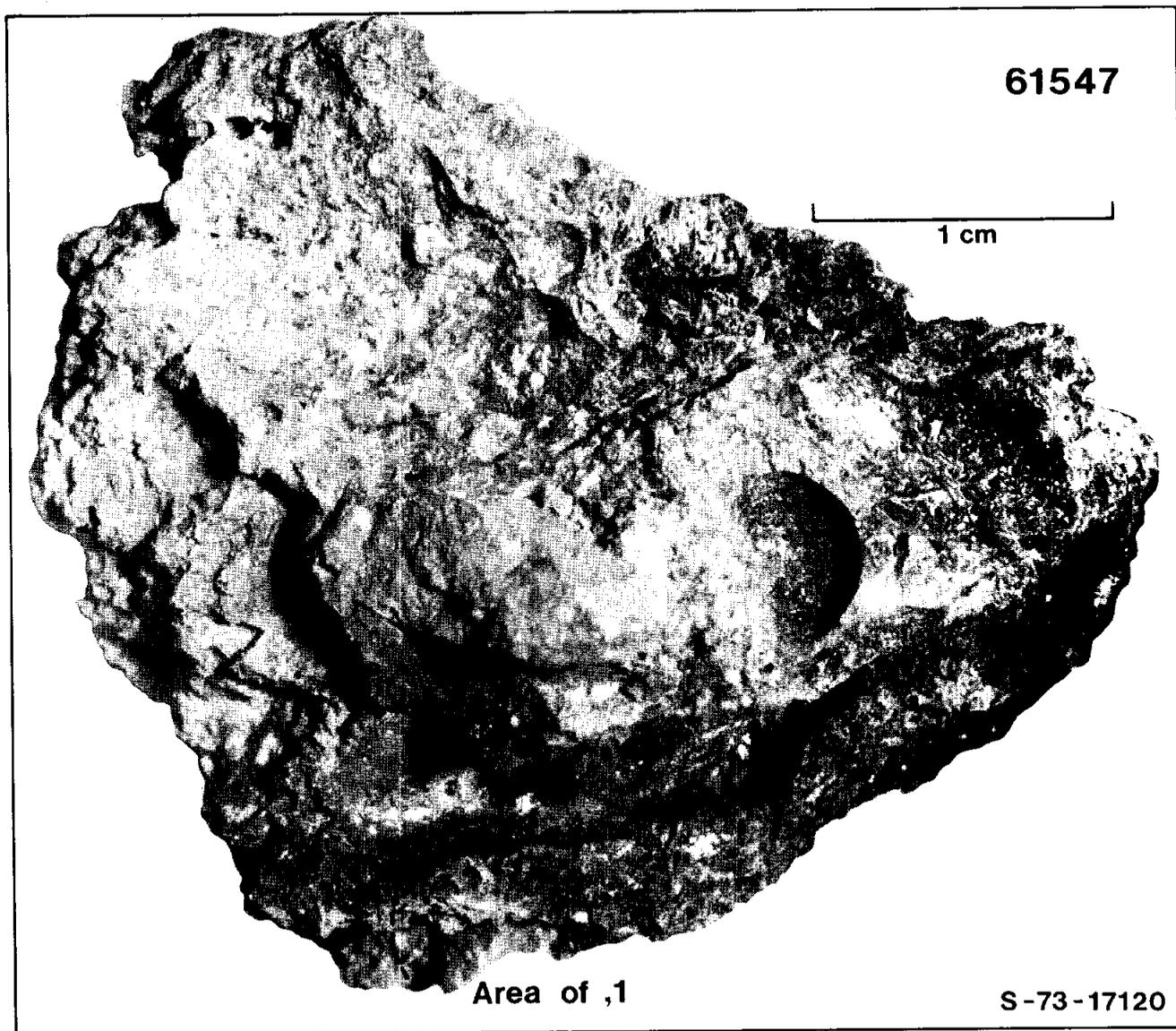


Figure 1.

PETROLOGY: The thin section of 61547 is dilithologic, showing a fine-grained, basaltic impact melt in sharp contact with a cryptocrystalline to glassy impact melt (Fig. 2). Clasts of the basalts are present in the glassy material indicating that the latter is probably a coat or vein.

PROCESSING AND SUBDIVISIONS: In 1973 four small chips (,1) were removed and allocated to Phinney for petrography.

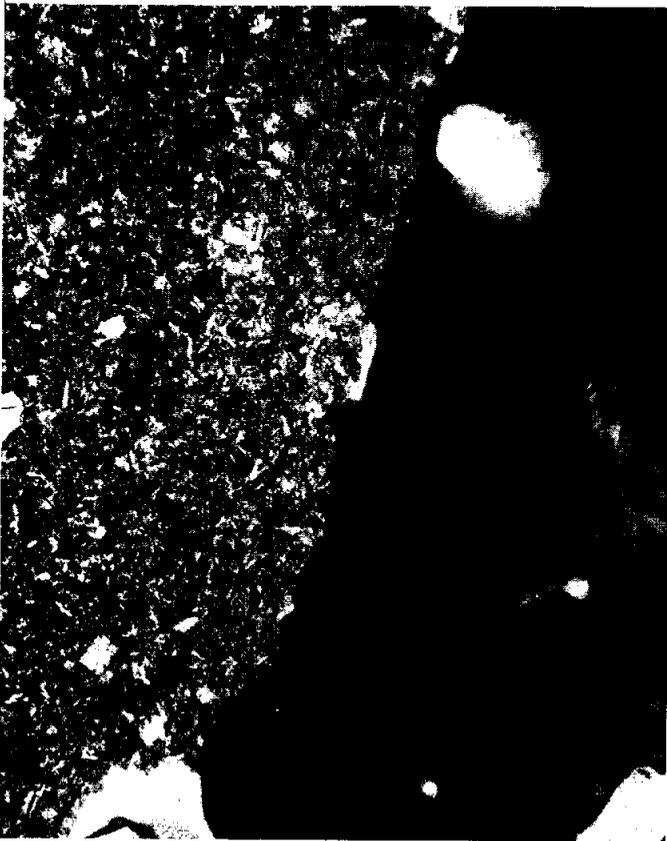


Figure 2. 61547,4, general view, ppl. width 1mm.

INTRODUCTION: 61548 is a coherent, medium gray, glassy impact melt with abundant clasts and vesicles (Fig. 1). It is subrounded and was collected as a rake sample about 45 m northeast of Plum Crater. Zap pits are rare.



Figure 1. S-72-55319, mm scale.

PETROLOGY: Warner et al. (1973) include this rock in a general discussion of Apollo 16 rake samples and provide a photomicrograph. Abundant monomineralic clasts of plagioclase, mafic minerals and spherules of Fe-metal rest in a chaotic, glassy matrix that approaches a basaltic texture in places (Fig. 2).

PHYSICAL PROPERTIES: Pearce and Simonds (1974) report the results of a room temperature hysteresis curve determination on 61548. The very small saturation remanence to saturation magnetization ratio ($J_{RS}/J_S = 0.0015$) shows that most of the ferromagnetic phases in this rock occur as relatively large ($>300\text{\AA}$), multidomain particles. The magnetically-determined $\text{Fe}^0/\text{Fe}^{2+}$ (0.0659) and total Fe^0 (0.024 wt%) are also given by Pearce and Simonds (1974).

PROCESSING AND SUBDIVISIONS: In 1972 a small piece (,1) was removed and allocated to Phinney for thin sectioning and petrography. The potted butt was used for the magnetic determinations.



Figure 2. 61548,4, general view, ppl. width 1mm.

INTRODUCTION: 61549 is a coherent, medium gray, crystalline impact melt with several large clasts (Fig. 1). It is subangular and was collected as a rake sample about 45 m northeast of Plum Crater. Zap pits are absent.



Figure 1. S-72-55347, mm scale.

PETROLOGY: Warner *et al.* (1973) provide a petrographic description and mineral compositions. 61549 is texturally intermediate between a basalt and a fine-grained poikilitic impact melt. Skeletal olivine phenocrysts and laths of plagioclase rest in a fine-grained, faintly poikilitic matrix of plagioclase and pyroxene (Fig. 2). Abundant clasts of plagioclase and lesser amounts of relict spinel and granoblastic norite are present. Mineral compositions are very homogeneous (Fig. 3) suggesting equilibration. Warner *et al.* (1973) classify this rock as a metamorphosed basalt.

PROCESSING AND SUBDIVISIONS: In 1972 three pieces were broken from the rock and one of these (,1) allocated to Phinney for thin sectioning and petrography.



Figure 2. 61549,4, general view, ppl. width 1mm.

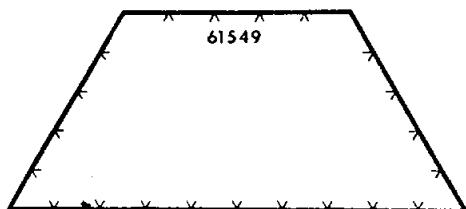


Figure 3. Mafic mineral compositions, olivine plotted along base, from Warner *et al.* (1973).

INTRODUCTION: 61555 is a coherent, dark gray, glassy impact melt with several white clasts and vesicles (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are rare.



Figure 1. S-72-43350.

INTRODUCTION: 61556 is a coherent, medium gray fragment of devitrified (?) impact glass (Fig. 1). It is angular and somewhat vesicular. Clasts are relatively rare. It is a rake sample collected about 45 m northeast of Plum Crater.



Figure 1. S-72-55349, smallest scale subdivision 0.5mm.

PETROLOGY: Warner et al. (1973) include this rock in a general petrographic study of Apollo 16 rake samples. 61556 is characterized texturally by sets of closely packed plagioclase tablets separated by thin regions of olivine and/or mesostasis (Fig. 2, and photomicrograph in Warner et al., 1973). The rock is virtually entirely crystalline; very little, if any, clean glass remains. Mineral compositions of 61556 presumably fall within the range cited by Warner et al. (1973) for devitrified glass samples, i.e. plagioclase An_{94-97} , olivine FO_{75-79} , with high-Ca pigeonite ($\sim Wo_{15}En_{65}$), Fe-Ti oxide and Fe-metal as accessory phases. Fe-metal is 4.9-5.5% Ni, 0.5% Co, 0.4-0.6% P and 0.02% S (Gooley et al., 1973) and occurs as large (up to ~ 0.5 mm), rounded grains (Fig. 2, and photomicrographs in Gooley et al., 1973) and as small spherules disseminated throughout the rock. Metal-troilite intergrowths are common.

PROCESSING AND SUBDIVISIONS: In 1972 a small piece (,1) was removed and allocated to Phinney for thin sectioning and petrography.



Figure 2. 61556,4, general view, ppl. width 2mm.

INTRODUCTION: 61557 is a coherent, dark gray, glassy impact melt with a few clasts and vesicles (Fig. 1). It is a rake sample collected about 45 m north-east of Plum Crater. Zap pits are rare or absent.



Figure 1. S-72-43350.

INTRODUCTION: 61558 is a coherent, medium gray, impact melt with abundant clasts and vesicles (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater.

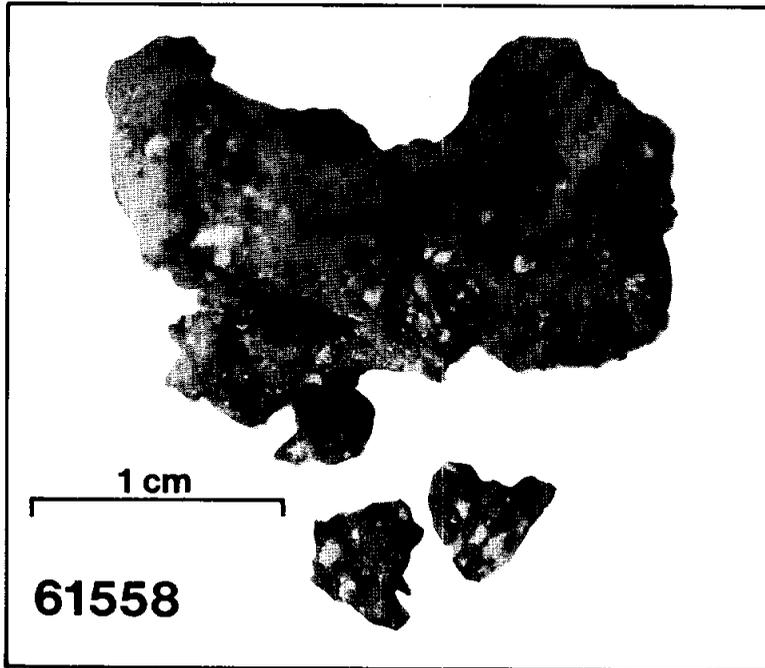


Figure 1.

PETROLOGY: Warner et al. (1973) include this rock in a general petrographic discussion of Apollo 16 rake samples. Although 61558 may have been very glassy at one time, it is now almost completely crystalline. "Quench" crystals surround clasts, but the texture away from the clasts is dominated by a series of interlocking spherulites (Fig. 2, and photomicrograph in Warner et al., 1973). Fragments of plagioclase and cataclastic anorthosite and spherules of Fe-metal, often intergrown with troilite and schreibersite, are scattered through the rock. Compositions of coexisting metal and metal/phosphide intergrowths are given by Gooley et al. (1973) and are reproduced here as Table 1.

TABLE 1. Coexisting metal and metal/phosphide intergrowth compositions (wt%)

	Ni	Co	Fe	P	S
a) Metal	18.9	1.0	77.4	1.0	0.05
Eutectic intergrowth	28.8	0.8	56.2	12.2	0.4
b) Metal	22.4	1.0	74.0	1.0	0.02
Eutectic intergrowth	29.2	0.9	56.5	12.1	0.5



Figure 2. 61558,4, general view,
ppl. width 2mm.

PHYSICAL PROPERTIES: Pearce and Simonds (1974) report the results of a room temperature hysteresis curve determination on 61558. The very small saturation remanence to saturation magnetization ratio ($J_{RS}/J_S = 0.009$) indicates that most of the ferromagnetic phases in this rock occur as relatively large ($>300 \text{ \AA}$), multidomain particles. Total Fe^0 is 0.037 wt% and $\text{Fe}^0/\text{Fe}^{2+}$ is 0.0858 (Pearce and Simonds, 1974).

PROCESSING AND SUBDIVISIONS: In 1972 three small chips were removed and one of these (.1) was allocated to Phinney for thin sectioning and petrography. The magnetic studies were done on the potted butt made from .1.

INTRODUCTION: 61559 is composed of several fragments of gray breccia and abundant dust welded together by dark, vesicular glass (Fig. 1). It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are absent.

PETROLOGY: Abundant clasts of plagioclase, mafic minerals, cataclastic anorthosite and basaltic impact melt rest in a matrix of dark, vesicular glass (Fig. 2).

PROCESSING AND SUBDIVISIONS: In 1973 three small pieces (,1) were allocated to Phinney for thin sectioning and petrography.

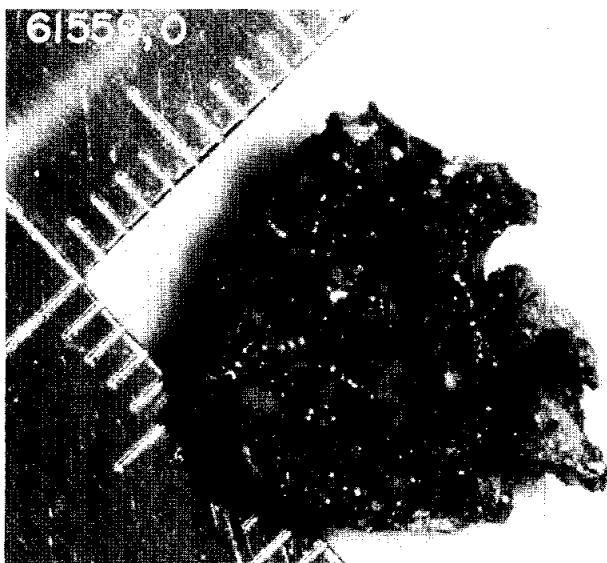


Figure 1. S- 73-17115, mm scale.

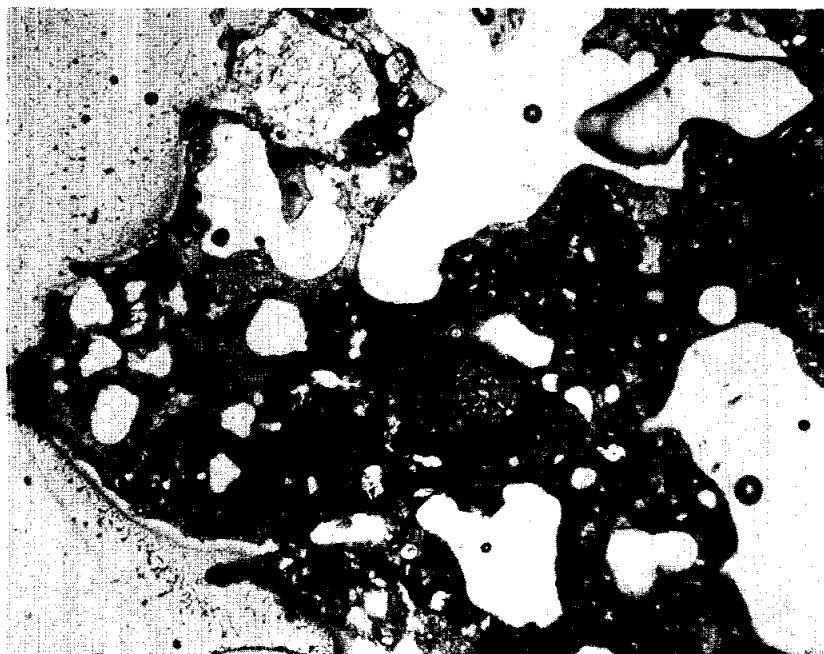


Figure 2. 61559,4, general view, ppl. width 2mm.

INTRODUCTION: 61565 is an aggregate of several fragments of gray breccia welded together by dark, vesicular glass (Fig. 1). Some dust adheres to the smooth surfaces of the glass. It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are absent.



Figure 1. S-72-43350.

INTRODUCTION: 61566 is a coherent, dark gray, glassy impact melt (Fig. 1). It is angular with several clasts and many vesicles and was collected as a rake sample about 45 m northeast of Plum Crater. Zap pits are absent.



Figure 1. S-72-43350.

INTRODUCTION: 61567 is a coherent, dark gray, glassy impact melt (Fig. 1). Some white clasts and vesicles are present. It is a rake sample collected about 45 m northeast of Plum Crater. Zap pits are absent.



Figure 1. S-72-43350.

INTRODUCTION: 61568 is a coherent, medium gray, crystalline impact melt with few vesicles (Fig. 1). It is a rake sample collected ~45 m northeast of Plum Crater. Zap pits are abundant.

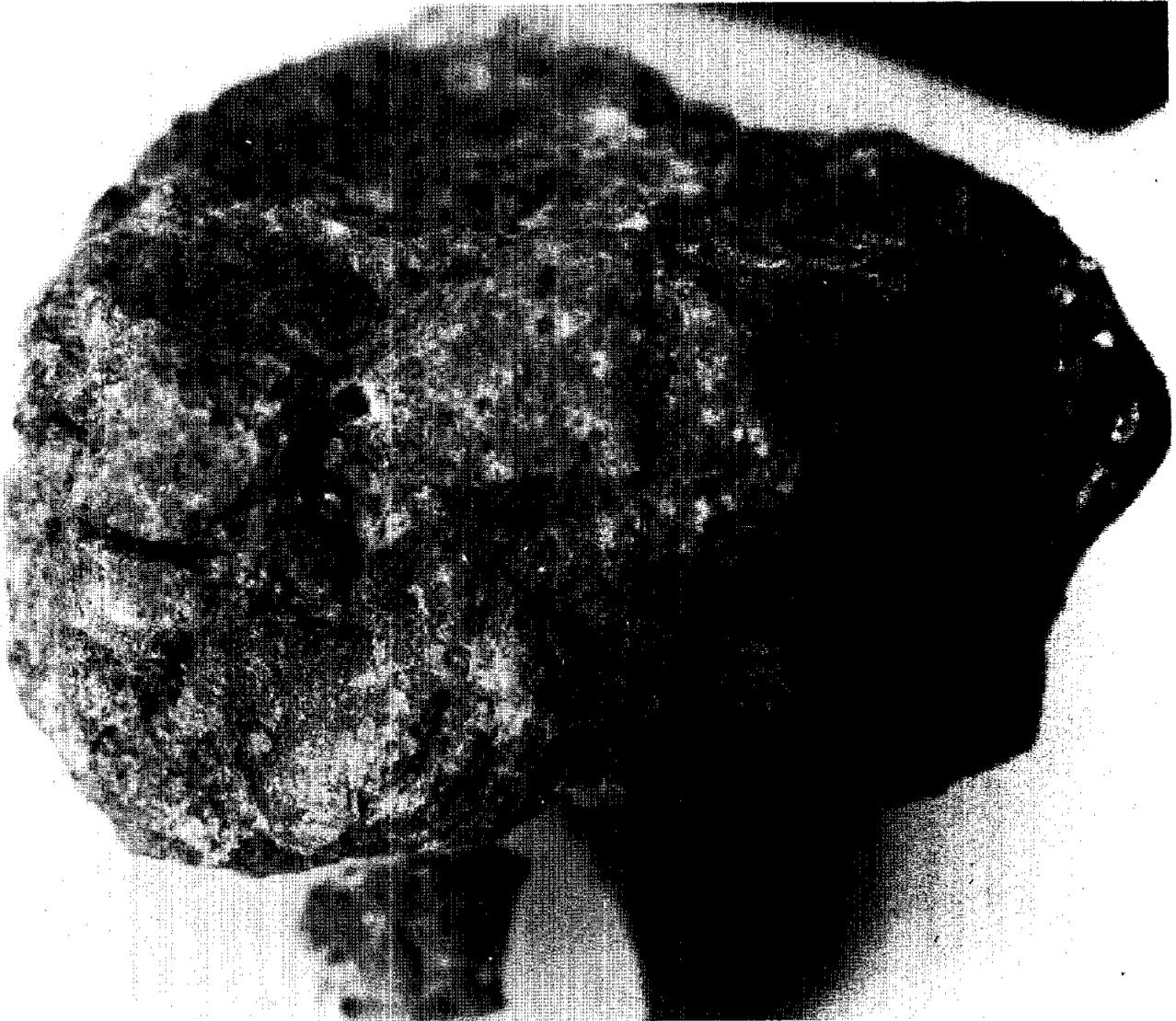


Figure 1. S-72-55324.

PETROLOGY: The only thin section of this rock is dilithologic, showing a fine-grained basaltic impact melt in sharp contact with a poikilitic lithology (Fig. 2). Warner et al. (1973) include 61568 in a general petrographic discussion of Apollo 16 rake samples and provide mineral compositions for the basaltic lithology. Simonds et al. (1973) give a brief petrographic description and mineral compositions of the poikilitic material. Clast/matrix relations cannot be determined from this thin section.

The basaltic lithology is fine-grained with grains of olivine and pyroxene filling interstices between plagioclase laths. Relatively large and angular clasts of plagioclase are abundant (Fig. 2). Mineral compositions are shown in Figure 3.

The poikilitic lithology is composed of pigeonite oikocrysts surrounding chadacrysts and clasts of plagioclase, olivine and opaques. Mineral compositions are shown in Figure 3. Coexisting Fe-metal and schreibersite compositions are given by Gooley et al. (1973) and are reproduced here as Table 1.

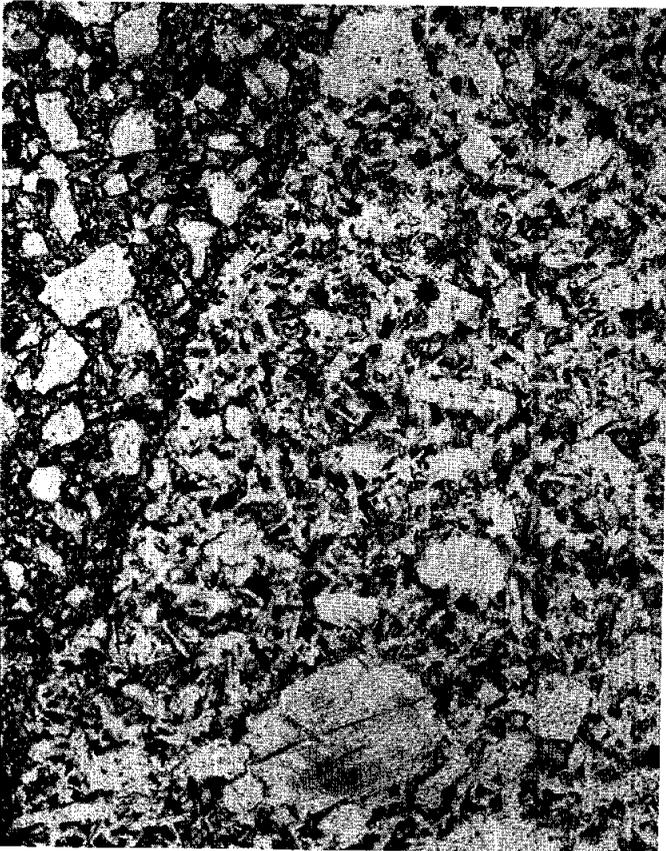


Figure 2. 61568,4, general view, ppl. width 2mm.

TABLE 1. Coexisting metal and schreibersite compositions (wt%)

	Ni	Co	Fe	P	S
a) Metal	6.9	0.4	92.4	0.01	0.02
Schreibersite	47.3	0.05	38.1	15.2	0.07
b) Metal	4.1	0.5	95.8	0.04	0.02
Schreibersite	32.7	0.1	50.9	15.4	0.06

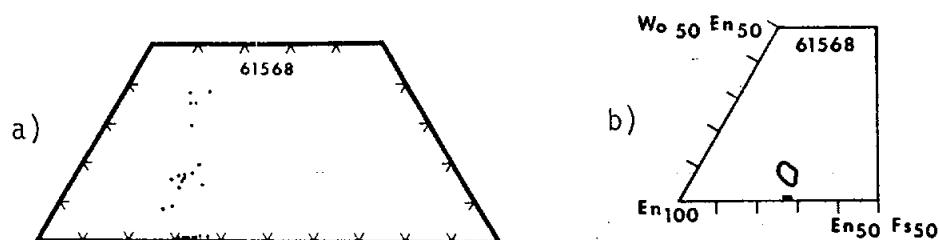


Figure 3. Mafic mineral compositions, olivine plotted along base; a) basaltic melt, from Warner *et al.* (1973); b) poikilitic melt, from Simonds *et al.* (1973).

PHYSICAL PROPERTIES: Pearce and Simonds (1974) report the results of a room temperature hysteresis curve determination on 61568. The very low saturation remanence to saturation magnetization ratio ($J_{RS}/J_S = 0.0021$) indicates that most of the ferromagnetic phases in 61568 occur as $>300 \text{ \AA}$ multidomain particles. The total Fe^0 is 0.26 wt% and $\text{Fe}^0/\text{Fe}^{2+}$ is 0.0921 (Pearce and Simonds, 1974).

PROCESSING AND SUBDIVISIONS: In 1972 a small chip (,1) was allocated to Phinney for thin sectioning and petrography. The magnetic studies were done on the potted butt made from ,1.

INTRODUCTION: 61569 is a medium gray, coherent, poikilitic impact melt (Fig. 1). It is angular with ~5% vesicles, and was collected ~45 m northeast of Plum Crater. Zap pits are absent.



Figure 1. S-72-55317, smallest scale subdivision 0.5mm.

PETROLOGY: A petrographic description is given by Simonds et al. (1973). 61569 differs from most other Apollo 16 poikilitic rocks in that olivine is the major oikocryst phase. Rounded olivine oikocrysts (up to 1.5 mm across) enclose equant to tabular plagioclase chadacrysts and rare augite chadacrysts (Fig. 2). Plagioclase clasts are concentrated between the olivines and are surrounded by oikocrysts of pigeonite. Simonds et al. (1973) give a mode of 68% plagioclase + mesostasis, 22% olivine, 6% pigeonite, 2% augite and 2% opaques. Mineral compositions are shown in Figure 3.

CHEMISTRY: Major and trace element data are given by Wasson et al. (1977) and summarized here as Table 1.

PROCESSING AND SUBDIVISIONS: In 1972 a small chip (,1) was removed and allocated to Phinney for thin sectioning and petrography. In 1977 another small piece (,5) was allocated to Wasson for chemistry.



Figure 2. 61569,4, general view, xpl. width 2mm.

TABLE 1. Summary chemistry of 61569

SiO ₂	
TiO ₂	1.00
Al ₂ O ₃	21.9
Cr ₂ O ₃	0.16
FeO	7.4
MnO	0.09
MgO	10.0
CaO	12.9
Na ₂ O	0.467
K ₂ O	0.186
P ₂ O ₅	
Sr	
La	18.1
Lu	0.82
Rb	
Sc	12.4
Ni	1000
Co	54
Ir ppb	20
Au ppb	18
C	
N	
S	
Zn	
Cu	

Oxides in wt%; others in ppm except as noted.

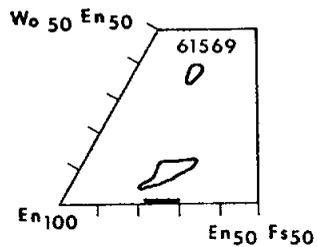


Figure 3. Mafic mineral compositions, olivine plotted along base, from Simonds *et al.* (1973).

INTRODUCTION: 61575 is a coherent, medium gray, crystalline rock with several large white clasts (Fig. 1). It is a rake sample collected ~45 m northeast of Plum Crater.

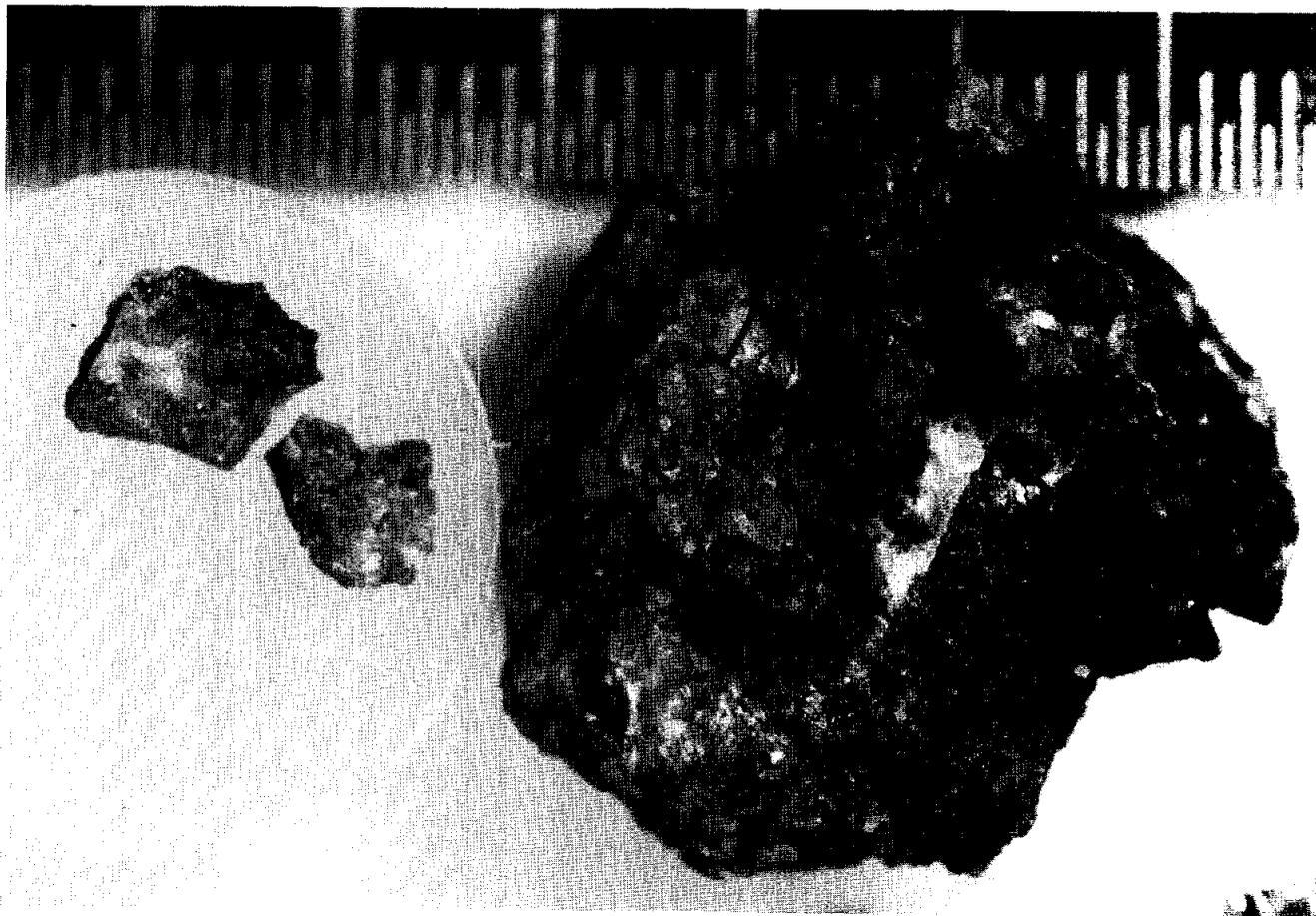


Figure 1. S-72-55323, smallest scale subdivision 0.5mm.

PETROLOGY: Warner et al. (1973) include this rock in a general petrographic discussion of Apollo 16 rake samples. The only thin section consists entirely of a single grain of severely shocked plagioclase (~8 mm) with a few small, rounded inclusions of a mafic mineral (Fig. 2). Phinney and Lofgren (1973, p. 19) state that this rock is "probably ... a coarse-grained plagioclase rock that has been partially melted and shocked ..." Warner et al. (1973) classify it as "devitrified glass (?) with large clear plagioclase clasts".

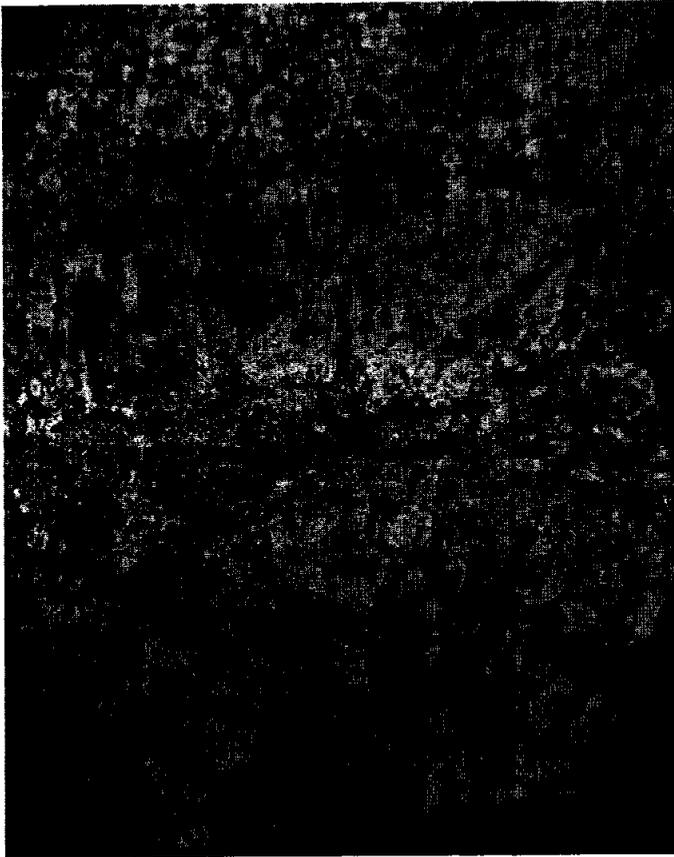


Figure 2. 61575,4, plagioclase grain, xpl. width 4mm.

PROCESSING AND SUBDIVISIONS: In 1972 two small pieces were removed from the rock and one of them (,1) allocated to Phinney for thin sectioning and petrography.

INTRODUCTION: 61576 is a coherent, white fragment composed almost entirely of plagioclase (Fig. 1). The continuous cleavage suggests that it is a single crystal. A dark, vesicular, glassy coating occurs on one surface. It is a rake sample collected ~45 m northeast of Plum Crater. Zap pits are present on one surface.

PETROLOGY: Bell and Mao (1975) report that 61576 is very homogeneous in composition and contains abundant inclusions. No analyses are given.

PROCESSING AND SUBDIVISIONS: In 1975 three small chips (.1) were removed and allocated to Bell.

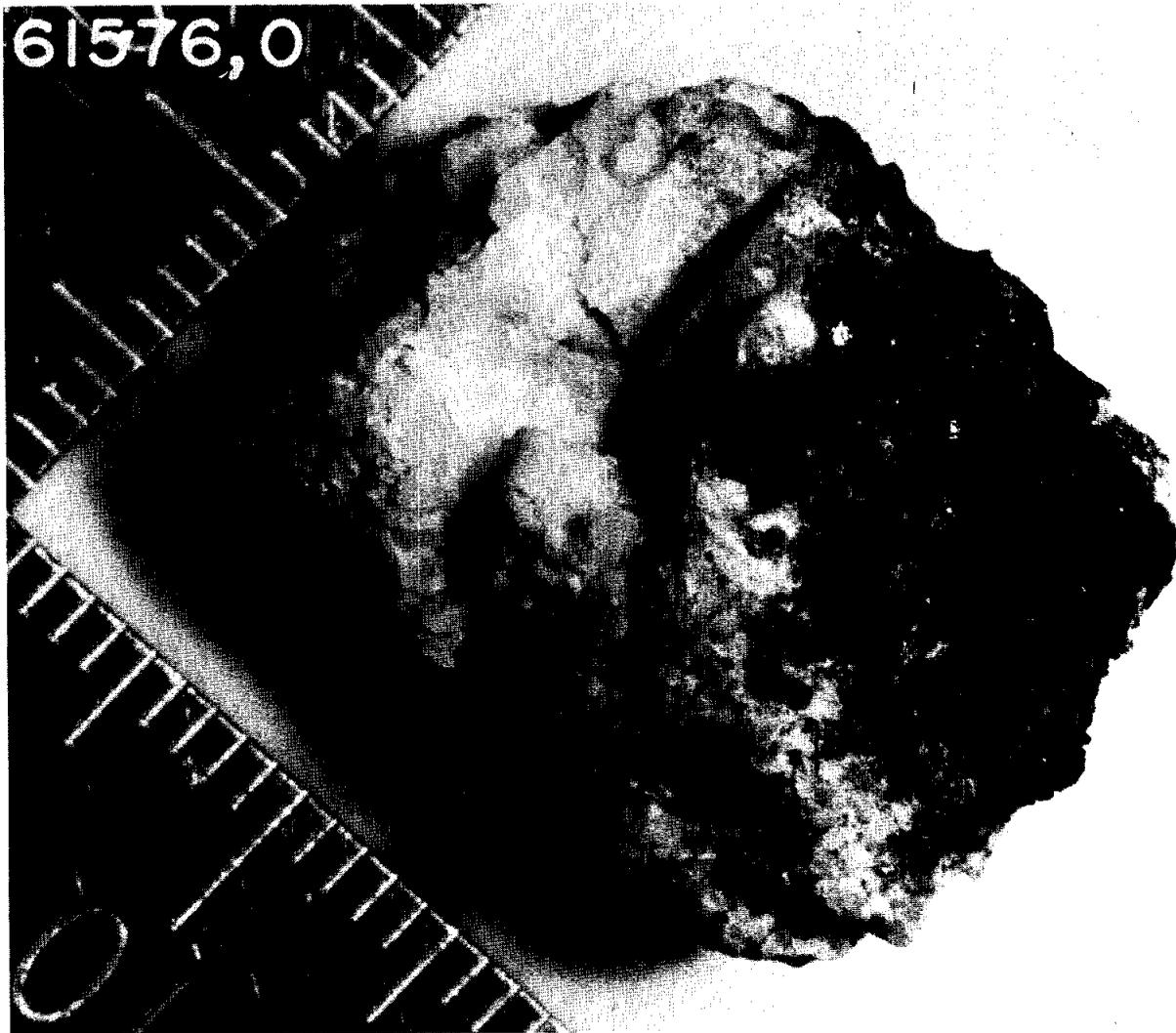


Figure 1. S-73-17117, mm scale.

INTRODUCTION: 61577 is a friable, white anorthositic rock with a partial coating of dark glass (Fig. 1). It is a rake sample collected ~45 m northeast of Plum Crater. Zap pits are abundant on all surfaces.

PETROLOGY: Tiny, anhedral mafic minerals are interstitial to blocky, anhedral plagioclase grains (Fig. 2). A crust of clast-rich, glassy breccia is present.

PROCESSING AND SUBDIVISIONS: In 1973 four small chips (,1) were removed and allocated to Phinney for petrography.

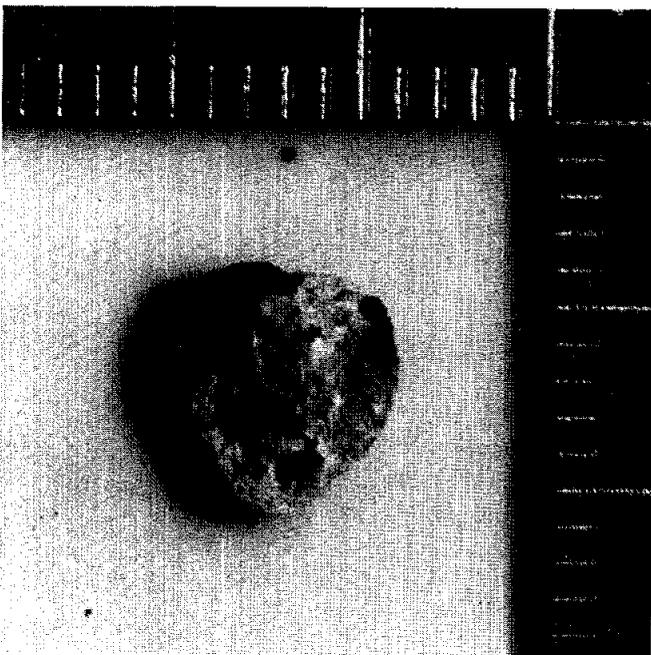


Figure 1. S-73-17118, mm scale.



Figure 2. 61577,4, general view
ppl. width 2mm.

INTRODUCTION: 62235 is a homogeneous, coherent block (Fig. 1) composed of poikilitic, KREEP-rich melt with a few clasts and small vesicles. It was collected from the rim of Buster Crater where it was perched and its orientation documented. Zap pits are irregularly distributed with many on one side and few on the others.

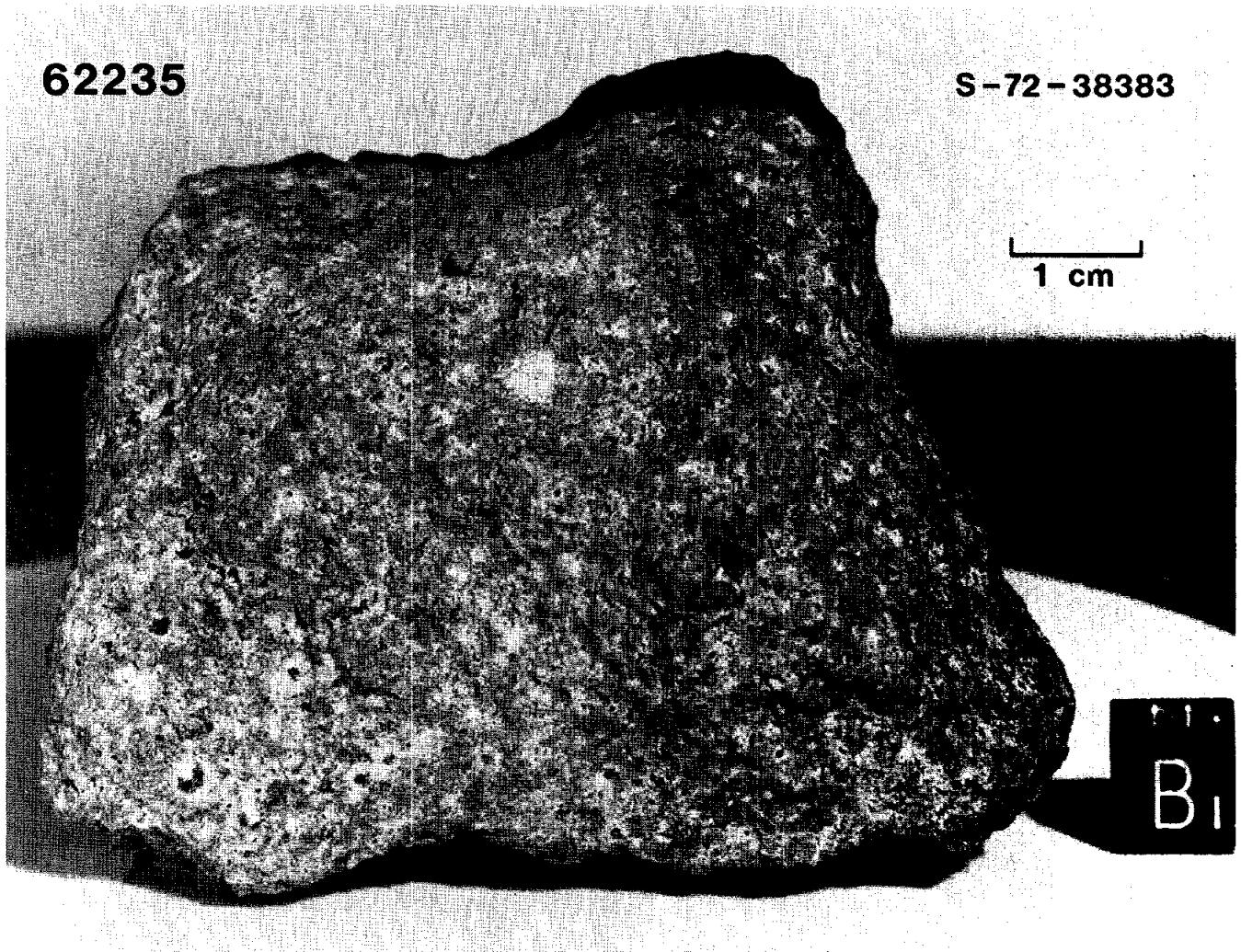


FIGURE 1.

PETROLOGY: Crawford and Hollister (1974) give a detailed petrographic description with mineral analyses. Vaniman and Papike (1981) include 62235 in a study of highland melt rocks. The rock is composed of ~57% calcic plagioclase with the remainder mainly elongate oikocrysts of hypersthene (Fig. 2). The oikocrysts are up to ~1 mm long and are often cored with unzoned olivine and overgrown with pigeonite. Some lamellae and patches of augite are also present within the oikocrysts. Mineral compositions are shown in Figure 3; the

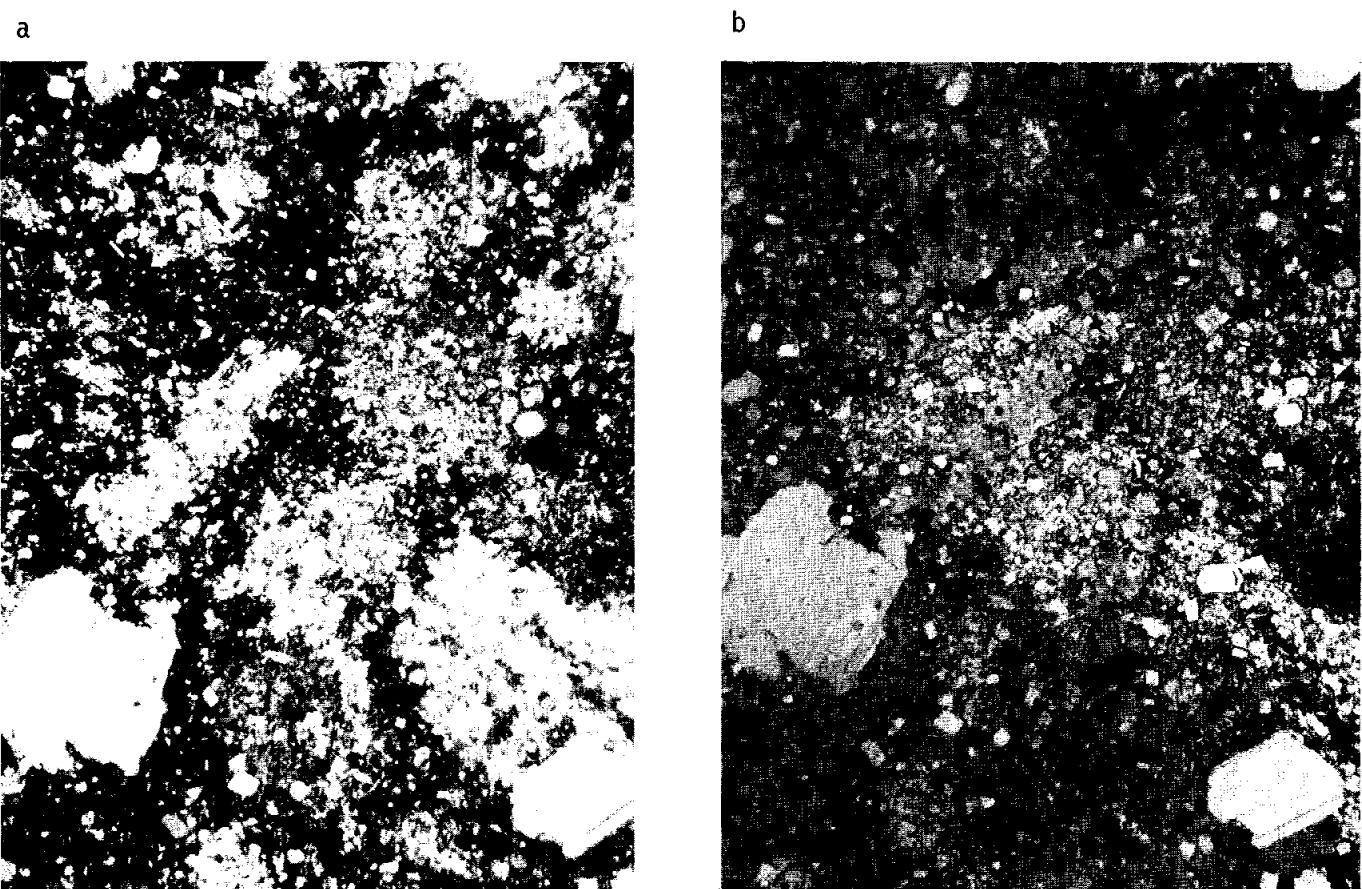


FIGURE 2. 62235,65. general view. width 2mm. a) xpl. b) ppl with reflector in.

early hypersthene is aluminous ($\sim 3\% \text{Al}_2\text{O}_3$). Interoikocryst areas are composed mainly of plagioclase, glass, ilmenite (or armalcolite?) and Fe-metal/troilite (Fig. 2). Pearce *et al.* (1976) show that Fe-metal composes 1.1% of the rock and has compositions within the meteoritic range (Fig. 4). A crystallization sequence of plagioclase \rightarrow pyroxene \rightarrow ilmenite was deduced by Engelhardt (1978, 1979).

Plagioclase occurs in several forms: (i) as large, shocked or polygonal clasts (An_{94-96}), (ii) as small, euhedral, blocky grains (An_{98}) with visible, more sodic ($< \text{An}_{90}$) rims, (iii) as a second group of blocky grains (An_{84}), (iv) as small, rectangular chadacrysts and laths in the interoikocryst areas (An_{92-93}). All of the coarser blocky grains show reverse zoning in their outer rims to An_{92-93} , the same composition as the chadacrysts and interoikocryst laths. Crawford and Hollister (1974) give Fe/Mg data for plagioclase.

Simonds *et al.* (1976) find that 62235 contains 9% total clasts larger than $50 \mu\text{m}$, and that 95% of these clasts are plagioclase. Meyer *et al.* (1974) analyzed minor elements in plagioclase using the ion microprobe (Table 1) and found that the Ba contents of plagioclases larger than $50 \mu\text{m}$ are much too low for the plagioclases to be in equilibrium with the melt. These low-Ba plagioclases are $\sim 10\%$ of 62235.

TABLE 1. Minor elements in 62235 plagioclase (Meyer et al. (1974) (ppm except Na₂O, wt %)

	Na ₂ O	Li	Mg	K	Ti	Sr	Ba
6 xenocrysts	0.42	5	600	240	97	162	9
1 small grain	0.76	10	360	500	130	270	30

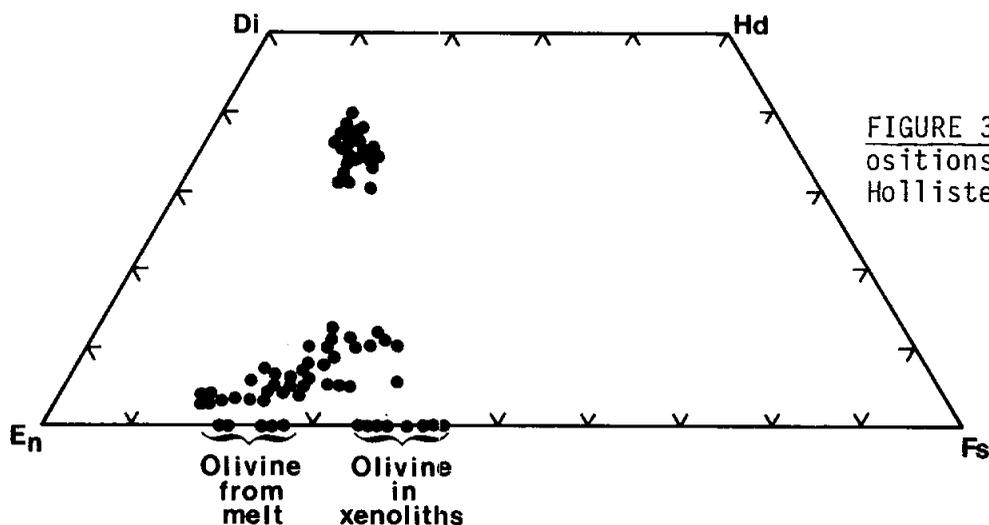


FIGURE 3a. Mineral compositions; from Crawford and Hollister (1974).

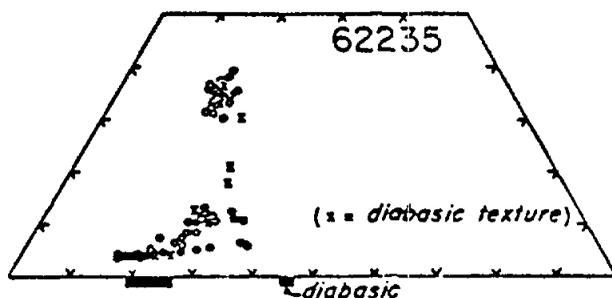


FIGURE 3b. Mineral compositions; from Vaniman and Papike (1981).

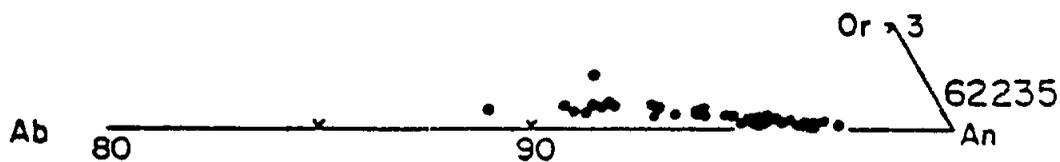


FIGURE 4. Metals; from Pearce et al. (1976).

The characteristics of the rock require that most of it crystallized from a silicate melt, the rest being fragmental. Crawford and Hollister (1974) interpret all but the coarsest shocked plagioclases as having crystallized from the melt and cite several features as suggesting crystallization at depth. They infer a volcanic origin with a source at ~ 200 km. These interpretations are not unique and the evidence of Meyer *et al.* (1974) suggests that more of the plagioclase is fragmental and that some of the features cited by Crawford and Hollister (1974) are due to clast-matrix interactions. The rock is very similar to the other poikilitic samples interpreted as impact melts.

CHEMISTRY: Major and trace element analyses are presented, with little specific comment, by Brunfelt *et al.* (1973), Hubbard *et al.* (1973), LSPET (1973), Laul *et al.* (1974) and Wanke *et al.* (1976). Moore *et al.* (1973) provide C data and Clark and Keith (1973) radionuclide data.

Chemically 62235 is a KREEP-rich, siderophile-rich rock (Table 1, Fig. 5) similar to several other poikilitic rocks. Crawford and Hollister (1974) suggest that the siderophiles are indigenous, but high contents are usually interpreted as meteoritic contamination (Laul *et al.* 1974). The carbon content of 2 ppm (Moore *et al.* 1973) is extremely low.

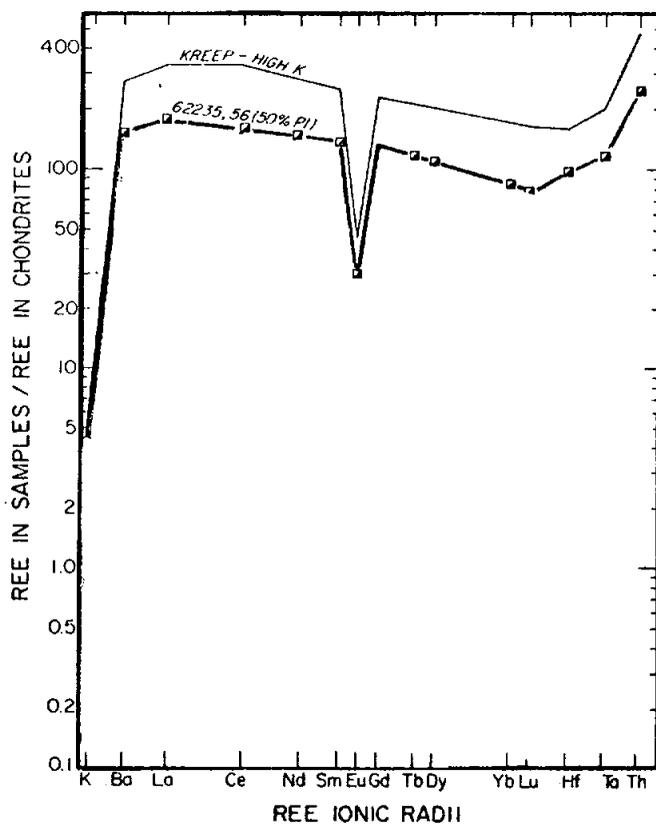


FIGURE 5. Incompatible elements; from Laul *et al.* (1974).

TABLE 2. Summary chemistry of 62235

SiO ₂	47.0
TiO ₂	1.2
Al ₂ O ₃	18.6
Cr ₂ O ₃	0.19
FeO	9.5
MnO	0.11
MgO	10.3
CaO	11.5
Na ₂ O	0.48
K ₂ O	0.34
P ₂ O ₅	0.40
Sr	160
La	60
Lu	2.7
Rb	9
Sc	16
Ni	700
Co	50
Ir ppb	19
Au ppb	17
C	2
N	
S	1000
Zn	2.2-11
Cu	3.9-11

Oxides in wt%; others in ppm except as noted.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: No internal isochron or ^{40}Ar - ^{39}Ar data have been published. Nyquist et al. (1973) and Tera et al. (1974) provide whole-rock Rb-Sr isotopic data giving T_{BABI} ages of ~ 4.5 b.y. (Table 3).

TABLE 3. Rb-Sr data for 62235

Rb ppm	Sr ppm	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}^*$	T_{BABI} (b.y.)	Reference
9.32	161	0.70989 ± 7	0.70042	4.48	Nyquist <u>et al.</u> (1973)
9.03	162	0.70944 ± 9	0.70042	4.50	Tera <u>et al.</u> (1974)

*Calculated for 3.9 b.y., corrected for interlaboratory bias to Caltech data.

Tera et al. (1974) provide U, Th, Pb isotopic data demonstrating the presence of much in situ radiogenic lead, as with many other KREEP samples. The sample falls on the U-Pb discord formed by most highland total rock samples, corresponding to a metamorphism age of ~ 3.9 b.y.

RARE GASES/EXPOSURE AGES: Drozd et al. (1974) provide ^{81}Kr -Kr, ^{21}Ne , and ^{38}Ar exposure ages of 153.9 ± 2.9 , 104 ± 54 and 163.0 ± 54 m.y., respectively. However, the sample did not spend its entire 153 m.y. apparent exposure age at its surface location and it must have been lightly shielded. Pepin et al. (1974) show that the ^{21}Ne and ^{38}Ar ages (which depend on spallation production rates) agree with the ^{81}Kr -Kr age if the effective irradiation depth was 90 g/cm^2 . Crozaz et al. (1974) use cosmic tracks to give a maximum exposure age (single point method) of 4 m.y. and a "true" suntan age (track density/depth method) of 2 m.y. There are large grain-to-grain track density variations. Morrison et al. (1973) use microcrater densities to suggest an exposure age of 2-3 m.y.

Lightner and Marti (1974b) provide xenon concentration and isotopic data without a specific interpretation.

MICROCRATERS: Morrison et al. (1973) and Neukum et al. (1973) provide frequency distribution diagrams for microcraters (Fig. 6). Only about half the surface has microcraters and the rock was not continually tumbled. Morrison et al. (1973) conclude that the surface is well below steady-state for craters $< 0.08 \text{ cm}$ in diameter. Neukum et al. (1973) conclude that 62235 has an equilibrium population. McDonnell et al. (1976) and Flavill et al. (1978) experimentally produced microcraters on a sample of 62235 by bombarding it with iron particles. They emphasize the importance of secondary ejecta.

PHYSICAL PROPERTIES: Collinson et al. (1973) provide NRM data for 62235 (Fig. 7) which they discuss further in Stephenson et al. (1974, 1975) and Stephenson and Collinson (1974). They find two components of stable magnetization, one of which is extremely hard and of unusually high intensity. Investigation of paleointensity using the Thellier method suggests a field of 1.2 Oe, and using the anhysteretic remanent magnetization (ARM) method suggests a field of 1.4 Oe. Cisowski et al. (1975) used the data to give a field of 0.3 Oe using the IRM_s method, later revised to 1.0 Oe (Cisowski et al., 1977). These results have been questioned: Brecher (1975) attributes the data to "textural remanance", not to any lunar field, and Pearce et al. (1976) performed heating experiments

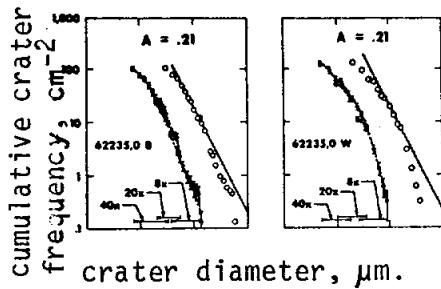


FIGURE 6. Microcraters; from Neukum et al. (1973).

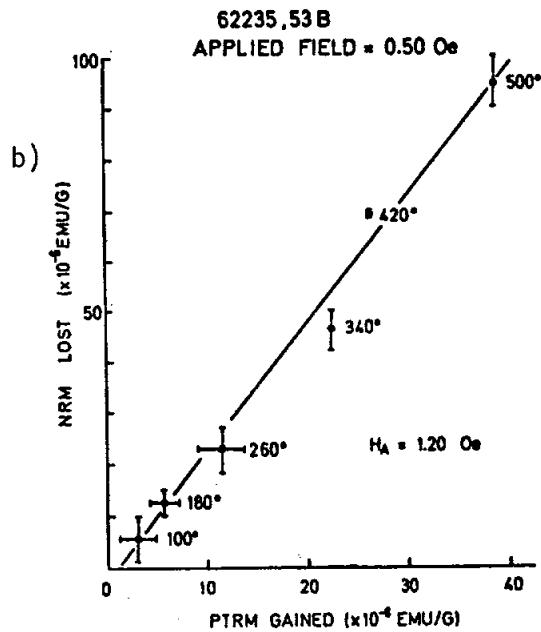
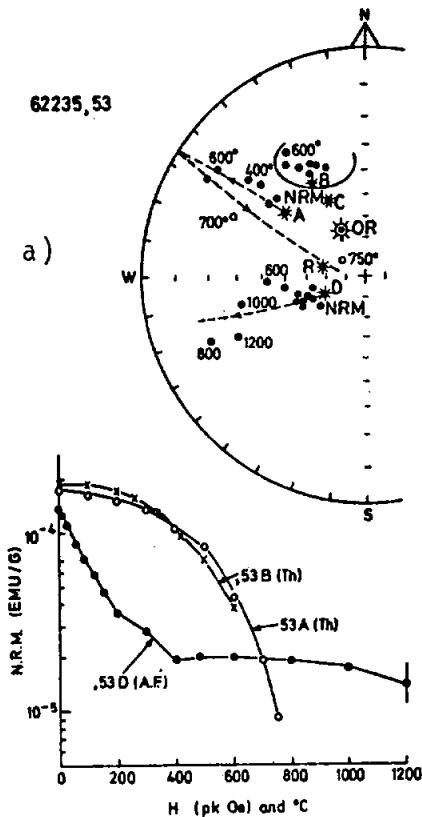


FIGURE 7. Magnetic data; from Collinson et al. (1973) a) Alternating field and thermal demagnetization. b) Field intensity determination.

showing that complexities introduced by Fe-metal and troilite grains make the definition of paleointensity extremely difficult. Contrarily, Hargraves and Dorety (1976) interpret the small variation of NRM and IRM with alternating field demagnetization of 62235 to show that it is a good sample for paleointensity determinations.

Chung and Westphal (1973) provide dielectric constants, dielectric losses, and electrical conductivities for 62235 as functions of frequency and temperature (Fig. 8)

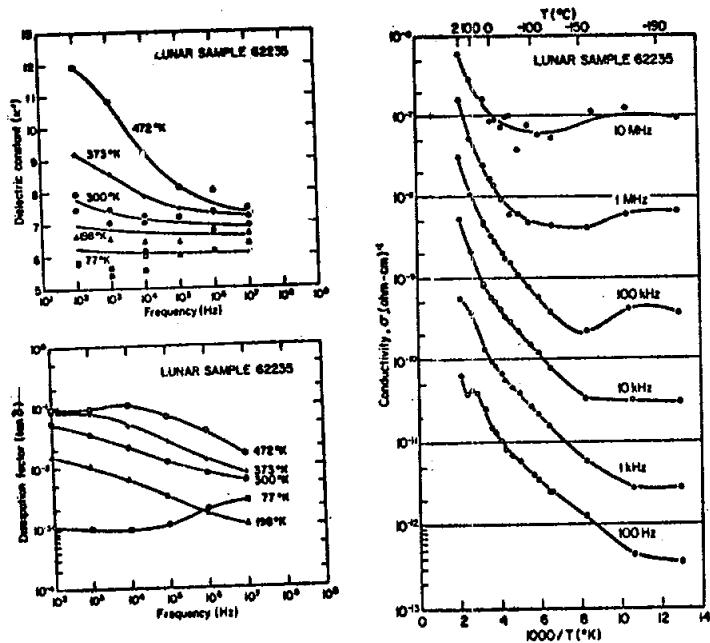


FIGURE 8. Electrical data; from Chung and Westphal (1973).

,54 ,55 unlocated

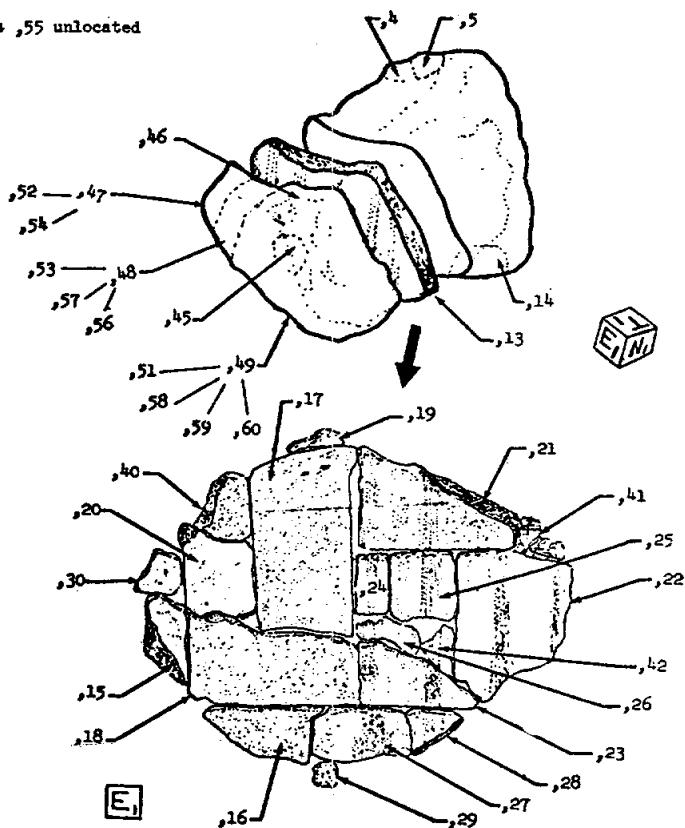


FIGURE 9. Cutting diagram.

PROCESSING AND SUBDIVISIONS: In 1972, 62235 was sawn to produce a slab and two end-pieces (Fig. 9). End piece ,12 and the slab ,13 were split and substantially allocated (Figs.9,10). A few splits are from the ,11 end piece.

62235

S-72-53515

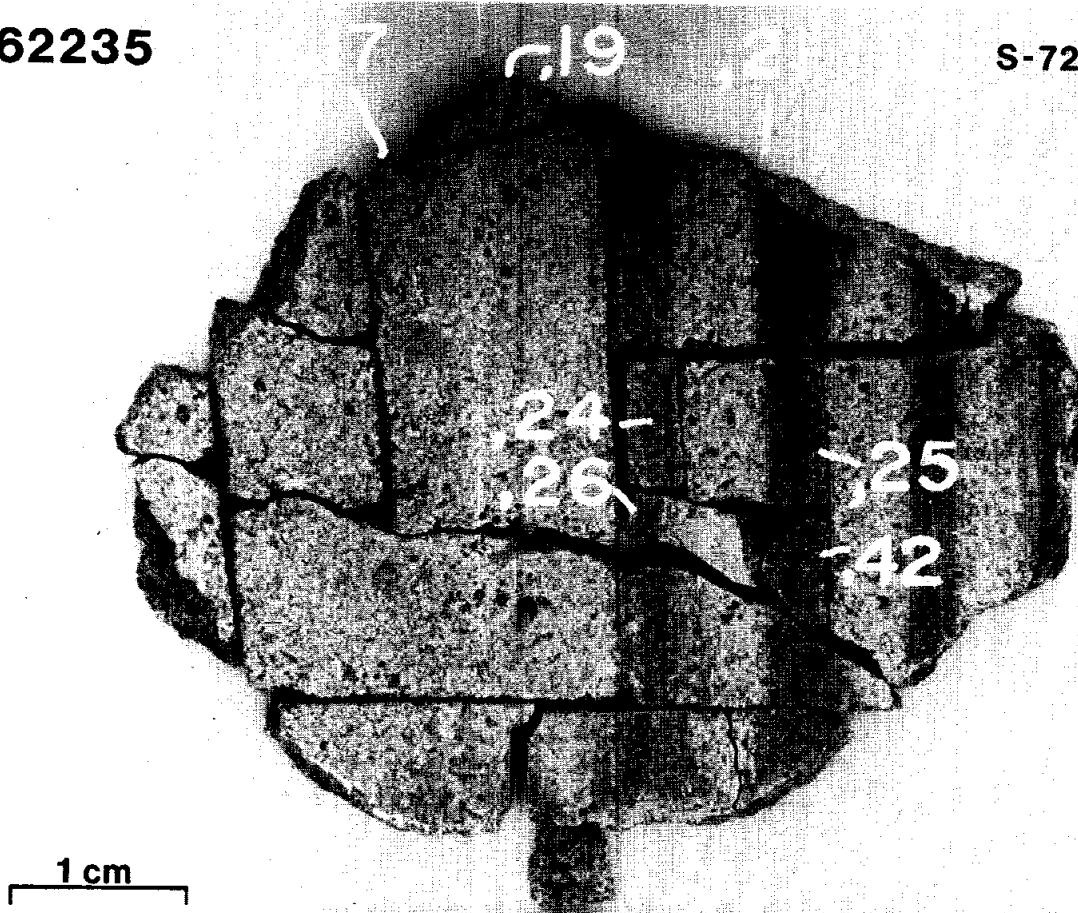


FIGURE 10. Slab subdivision.

INTRODUCTION: 62236 is a monomict breccia, uncontaminated by meteoritic siderophiles, and with mineral compositions indicating an affinity with ferroan anorthosites. These mineral compositions are similar to those in 62237 and, like 62237, it contains more mafic minerals (10-15%) than ferroan anorthosites sensu stricto. The sample is very light gray, angular, and fairly coherent but fractured (Fig. 1).

62236 was collected from the rim of Buster Crater, adjacent to 62235 and 62237, and its orientation is known. A few zap pits and a patina are present on all surfaces.

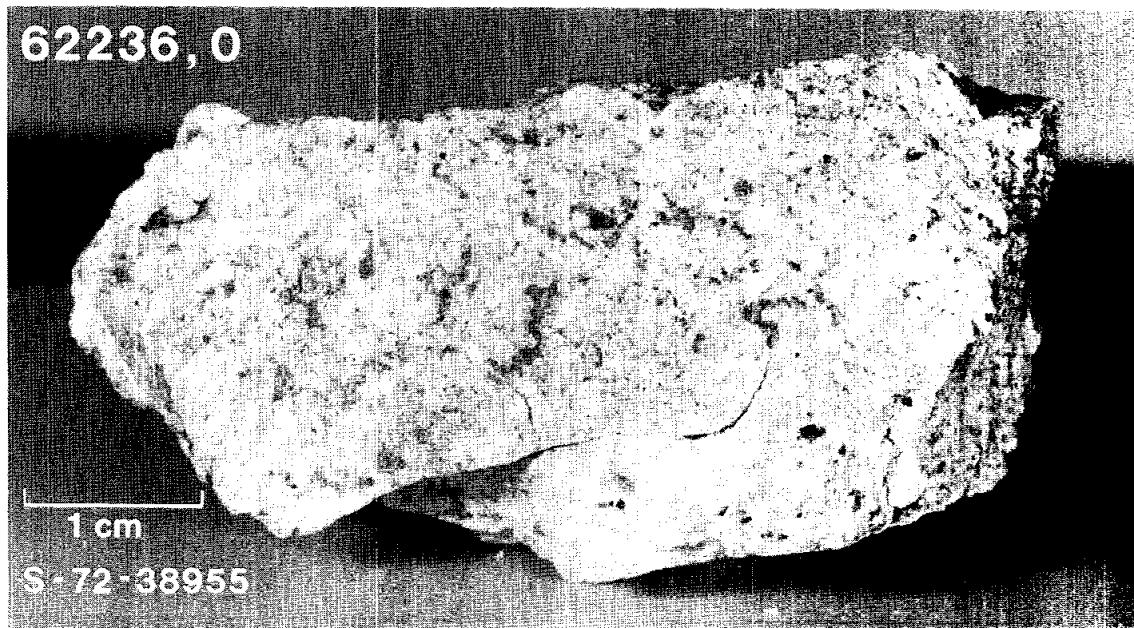


FIGURE 1.

PETROLOGY: Warren and Wasson (1978, 1979) provide a petrographic description of the pristine anorthosite with microprobe mineral analyses. Takeda et al. (1979) report microprobe data on olivines, plagioclases, and exsolved pyroxenes, with x-ray information on the pyroxenes.

62236 is monomict and brecciated (Fig. 2). Original plagioclase and pyroxene grains appear to include at least some larger than 1 mm. The mode is variable on a small scale, but in general the sample is ~ 85% plagioclase, and orthopyroxene dominates over olivine and clinopyroxene. (In 62237, in contrast, olivine dominates over pyroxene.) Cr-spinel, ilmenite (~ 3% MgO) and troilite are also present. The phase compositions (Fig. 3) are homogeneous, identical with those of 62237 and are in the field of ferroan anorthosites. Takeda et al. (1979) note that exsolved pyroxene is not common. X-ray data suggest that the orthopyroxene forms by pigeonite inversion. The exsolved augite has M-shaped Ca-profiles, the only ones so far reported from lunar samples. Cooling rate calculations from the exsolution lamellae suggest a depth of 6.7 km

(22 μm blebs) for the origin of 62236.

CHEMISTRY: Warren and Wasson (1978, 1979) provide major and trace (including siderophile) element abundances for the sample. Clark and Keith (1973) report K, U, Th and radionuclide abundances for the rock, derived from γ -ray spectroscopy.

62236 is extremely low in siderophile and incompatible elements indicating that it is a pristine lunar rock (Table 1, Fig. 4). Although it is more mafic than most other ferroan anorthosites, its rare-earth abundances are similar to pristine ferroan anorthosites and much lower than pristine troctolites and norites.

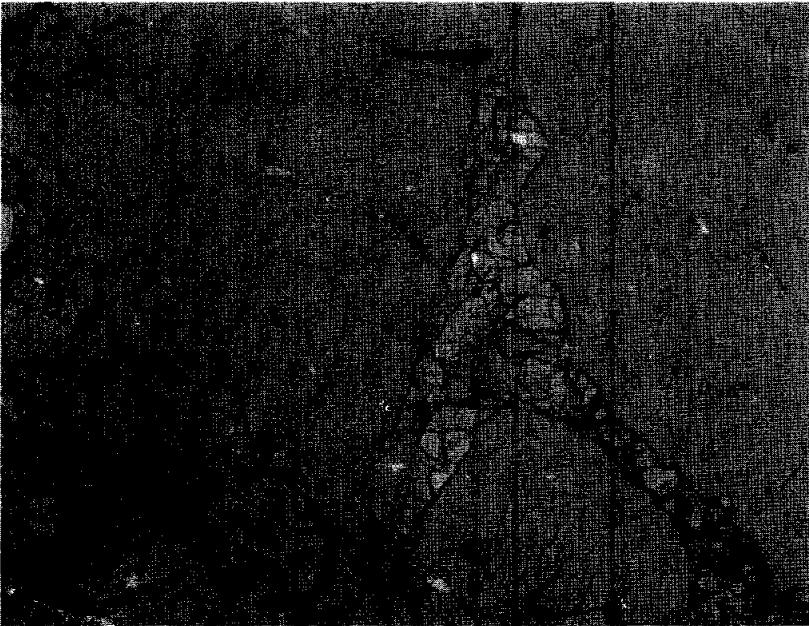


FIGURE 2. 62236,6.
ppl. width 1.5mm.

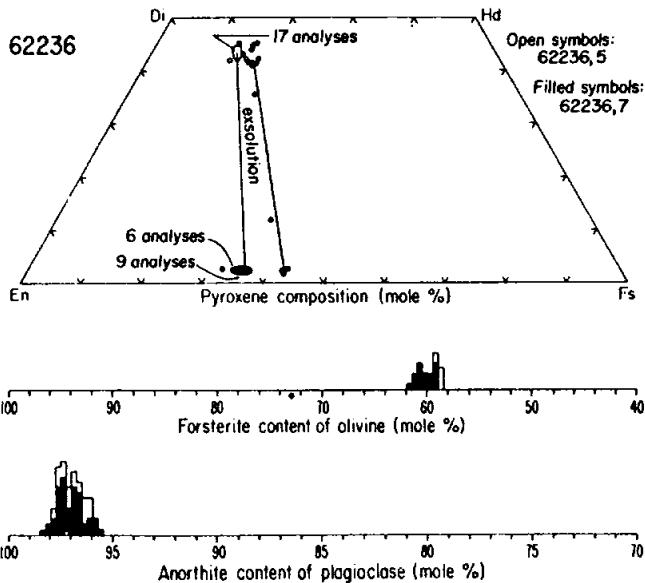


FIGURE 3a. Mineral compositions;
from Warren and Wasson (1979).

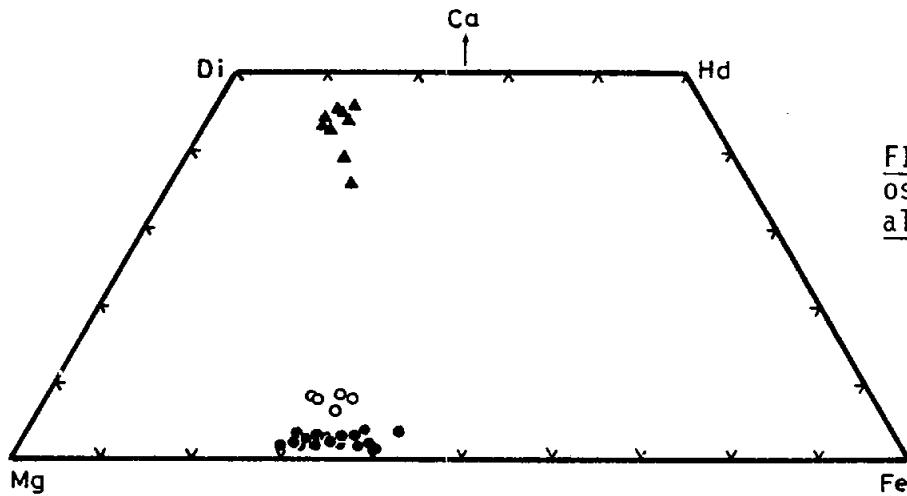


FIGURE 3b. Pyroxene compositions; from Takeda et al. (1979).

TABLE 1 Summary chemistry of 62236

SiO ₂	44.2
TiO ₂	
Al ₂ O ₃	30.1
Cr ₂ O ₃	0.07
FeO	3.7
MnO	0.05
MgO	3.5
CaO	17.6
Na ₂ O	0.215
K ₂ O	0.013
P ₂ O ₅	
Sr	
La	0.18
Lu	0.021
Rb	
Sc	5.8
Ni	4.0
Co	7.9
Ir ppb	<0.028
Au ppb	<0.008
C	
N	
S	
Zn	2.0
Cu	

Oxides in wt %; others in ppm except as noted.

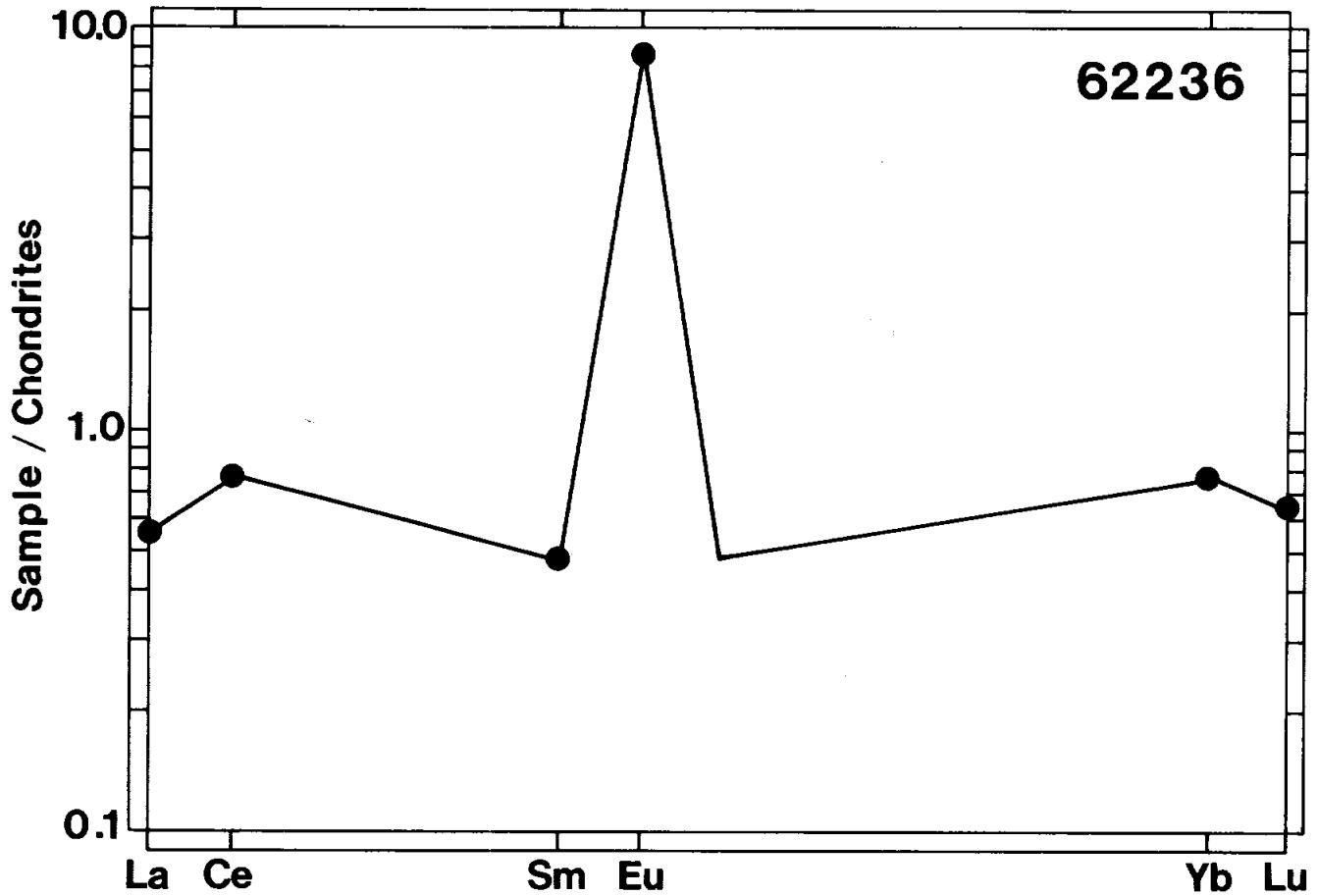


FIGURE 4. Rare earth elements; from Warren and Wasson (1979).

PROCESSING AND SUBDIVISIONS: The sample has not been sawn and only a few chips have been removed from ,0.

INTRODUCTION: 62237 is a monomict breccia, uncontaminated by meteoritic siderophiles. Olivine compositions indicate an affinity with ferroan anorthosites but like 62236 it is less feldspathic ($\sim 85\%$ plagioclase). Also like 62236, the sample is very light gray, subangular, and fairly coherent but with several penetrative fractures (Fig. 1).

62237 was collected from the rim of Buster Crater, adjacent to 62235 and 62236 and its orientation is known. Patina and a few zap pits occur on two faces.

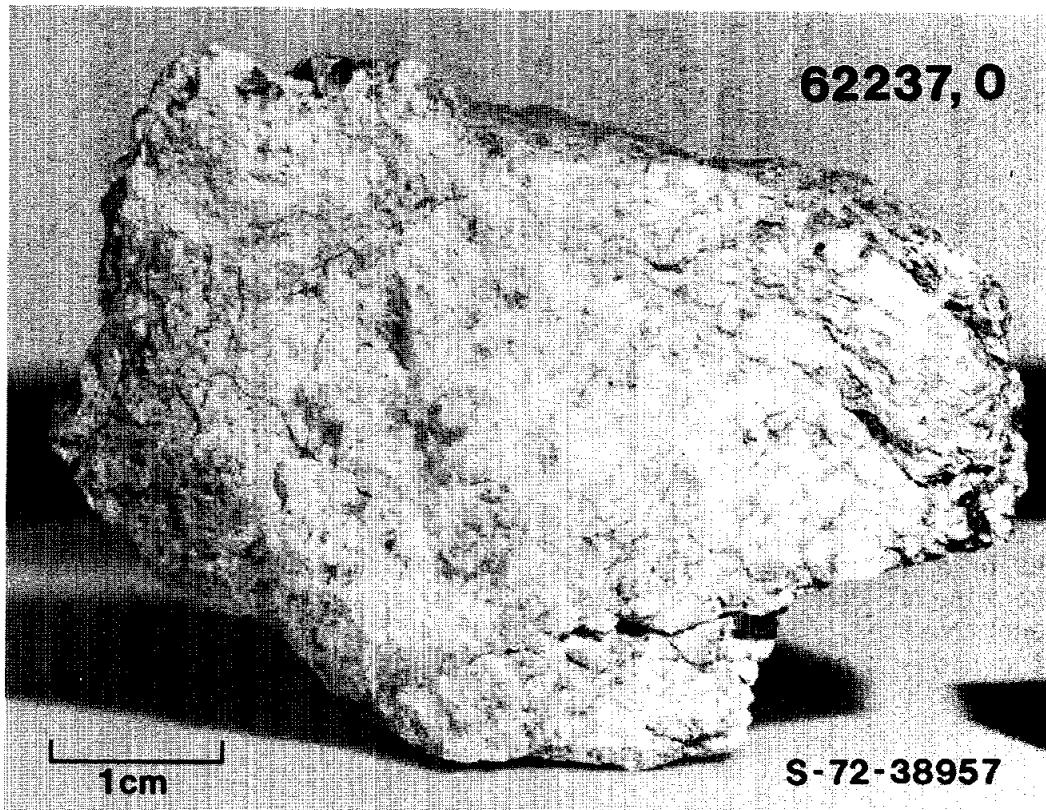


FIGURE 1.

PETROLOGY: Petrographic descriptions with phase analyses and interpretation are presented by Dymek *et al.* (1975) and Warren and Wasson (1977). Meyer (1979) reports minor element abundances in plagioclases (Table 1) and McKay *et al.* (1978) calculate the possible range of Ti/Sm of the parent liquid.

62237 is brecciated (Fig. 2) and texturally inhomogeneous, with the original coarse (> 1 mm) grain size locally preserved. A mode by Dymek *et al.* (1975) has 83% plagioclase, 16% olivine, minor pyroxene, and small amounts of Cr-spinel, ilmenite, and troilite; Warren and Wasson (1977) estimate 89% plagioclase and 10% olivine. The mineral compositions reported by Dymek *et al.* (1975) (Fig. 3) are confirmed by Warren and Wasson (1977). Plagioclases and olivines have low

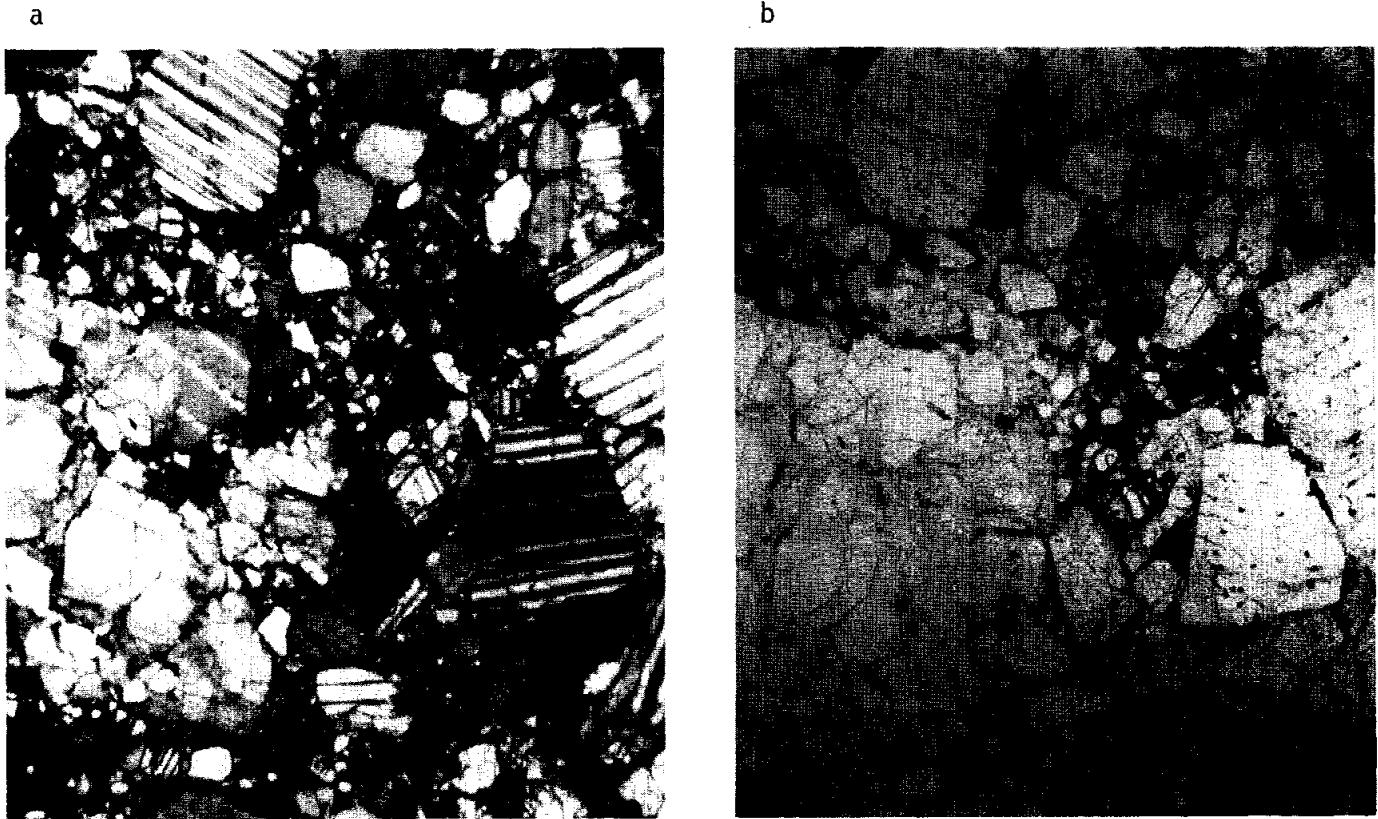


FIGURE 2. 62237,31. general view. width 2mm. a) xpl. b) same field, ppl.

abundances of minor elements. Pyroxenes include some complex, exsolved pigeonites. The mineral compositions are similar to those in 62236 and less mafic ferroan anorthosites. Dymek *et al.* (1975) stress that the olivine must be cumulate, not a product of a trapped liquid.

TABLE 1.

Ion probe analyses for minor elements (ppm)
in 62237 plagioclase (Meyer, 1979)

	Li	Mg	Ti	Sr	Ba
grain a)	4	700			
grain b)	2.7	370	75	203	10

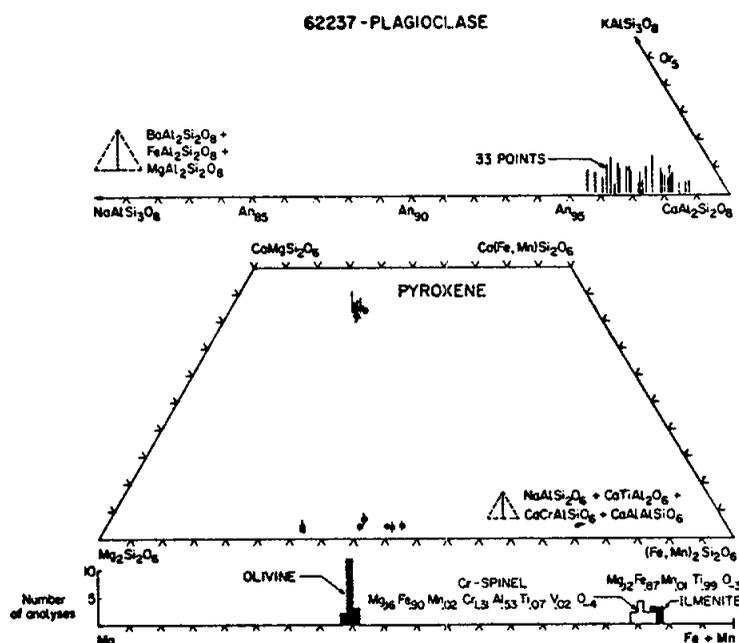


FIGURE 3. Mineral compositions; from Dymek *et al.* (1975).

CHEMISTRY: Warren and Wasson (1978) report two analyses for major and trace (including siderophile) elements for a split of 62237, and Dymek *et al.* (1975) reconstruct the chemical composition from the mode and mineral analyses. K, U, Th and radionuclide abundance data are presented by Clark and Keith (1973) from γ -ray spectroscopy, and Schaeffer and Schaeffer (1977) report K and Ca abundances.

The chemistry (Table 2, Fig. 4) confirms the affinity with pristine ferroan anorthosites. The rare-earth abundances are similar to 62236 and much lower than pristine noritic and troctolitic rocks.

TABLE 2

Summary chemistry of 62237 (from Warren and Wasson, 1978)

SiO ₂		Sr	
TiO ₂	0.02 ?	La	0.19
Al ₂ O ₃	31.1	Lu	0.015
Cr ₂ O ₃	0.06	Rb	
FeO	4.8	Sc	4.4
MnO	0.05	Ni	5.8
MgO	4.2	Co	11.1
CaO	17.0	Ir ppb	0.015 ?
Na ₂ O	0.21	Au ppb	0.017
K ₂ O	0.013	C	
P ₂ O ₅		N	
Oxides in wt%; others in ppm		S	
except as noted		Zn	1.6
		Cu	

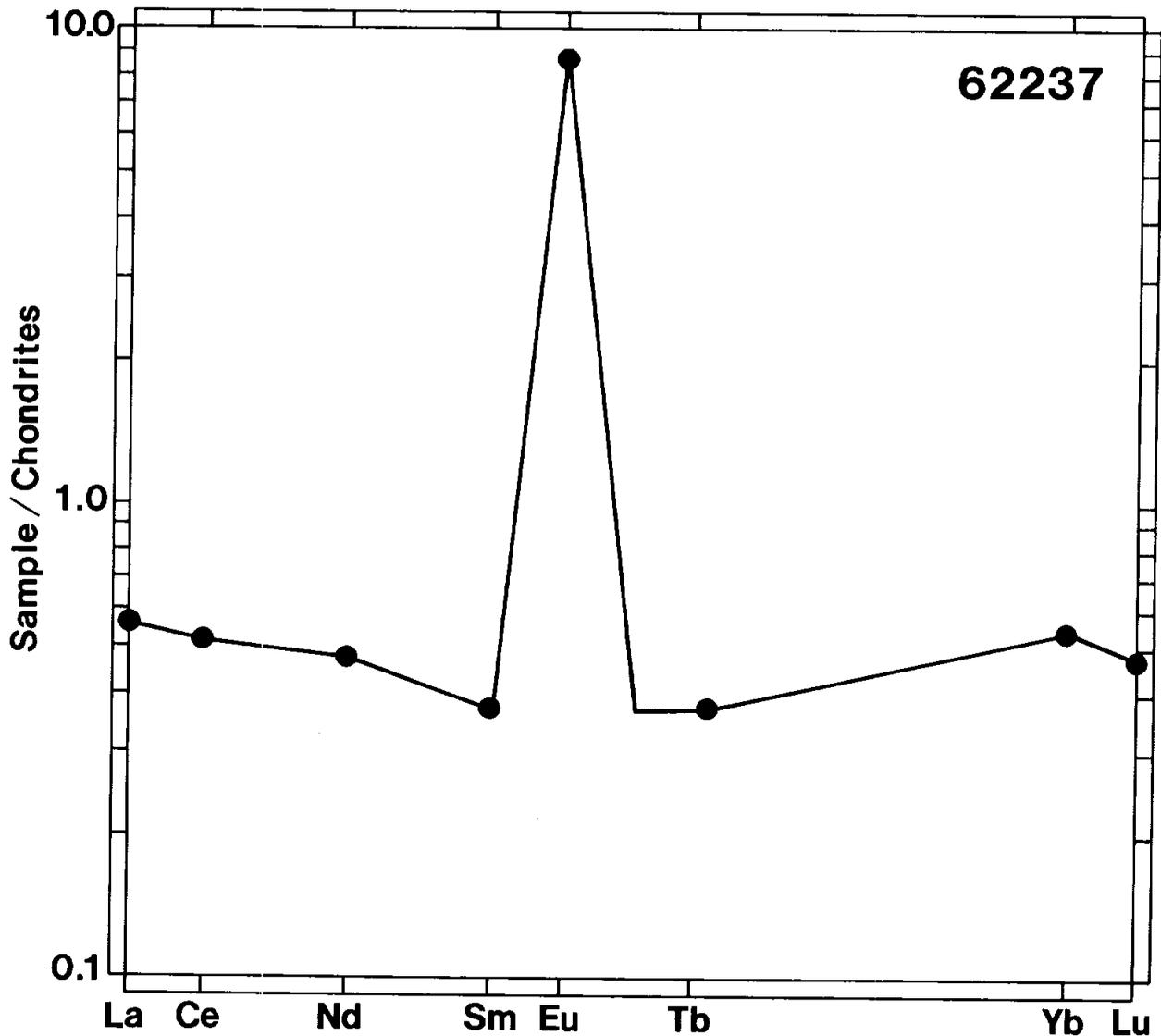


FIGURE 4. Rare earth elements; from Warren and Wasson (1978).

GEOCHRONOLOGY: Schaeffer and Schaeffer (1977) present Ar isotopic data. No plateau was obtained and the argon system is clearly extremely disturbed, with more than one trapped component. Individual releases give ages ranging from 2.49-5.68 b.y. with a total K-Ar "age" of 3.59 ± 0.05 b.y.

EXPOSURE AGES: Schaeffer and Schaeffer (1977) calculate ^{38}Ar -Ca ages ranging from 24 to 2385 m.y. with an average of 32.9 m.y. The disturbed argon system makes the ages extremely unreliable.

PROCESSING AND SUBDIVISIONS: No saw cuts have been made, and most of the sample is preserved in two larger chips ,0 (37.9 g) and ,1 (8.9 g). A number of small chips in the range 0.5 - 2.0 g exist. The current thin sections are from a single potted butt (,4).

INTRODUCTION: 62238 is an angular, coherent, white sample (Fig. 1). It contains rare yellow minerals and is probably a cataclastic anorthosite. It has some adhering soil. It was taken from a soil sample collected on the south rim of Buster Crater, and lacks zap pits.

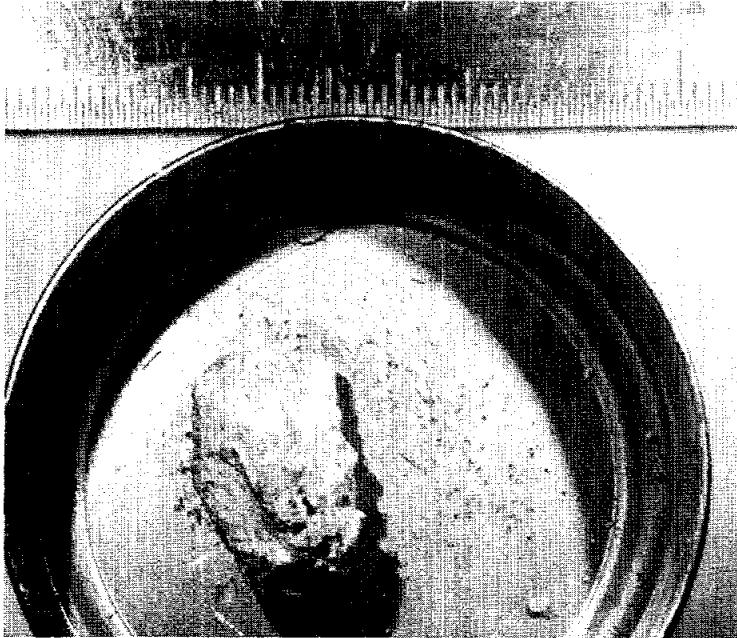


FIGURE 1. Smallest scale divisions in 0.5mm.

INTRODUCTION: 62245 is a coherent, medium gray, crystalline rock that is probably an impact melt (Fig. 1). The N surface appears fresh and lacks zap pits whereas the other surfaces have patina and abundant zap pits. This rock was taken from the soil sample from the southeast rim of Buster Crater.



FIGURE 1. Sample is about 2 cm. wide.
S-72-41308

INTRODUCTION: 62246 appears to be a coherent, white, cataclastic anorthosite coated by dark, vesicular glass (Fig. 1). Considerable soil adheres to the glass and several white clasts are suspended in the glass. This rock was taken from the soil sample from the southeast rim of Buster Crater. A few zap pits are present on the glass coat.



FIGURE 1. Sample is about 3 cm. long.

S-72-41308

INTRODUCTION: 62247 is a friable, olive gray, clastic breccia (Fig. 1). It was taken from the soil sample from the southeast rim of Buster Crater. Zap pits are rare.

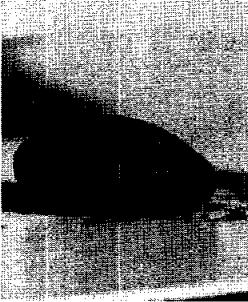


FIGURE 1. Sample is about 2 cm. wide
S-72-41308

INTRODUCTION: 62248 is a friable, olive gray, clastic breccia (Fig. 1). A small amount of splash glass is present on one surface. Traces of metal or glass spheres and granular aggregates of white material (cataclastic anorthosite ?) are visible macroscopically. This rock was taken from the soil sample from the southeast rim of Buster Crater. Zap pits are either absent or completely covered by dust.

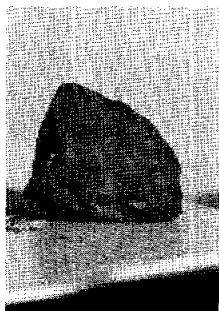


FIGURE 1. Sample is about 1.5 cm. wide.

S-72-41308

INTRODUCTION: 62249 is a friable, olive gray, clastic breccia (Fig. 1). It is rounded and lacks zap pits. It was taken from the soil sample from the southeast rim of Buster Crater.

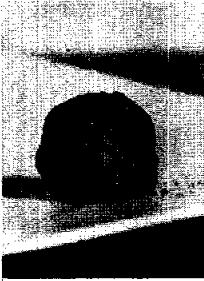


FIGURE 1. Sample is about 1 cm. wide.
S-72-41308.

62255 DILITHOLOGIC (PRISTINE ANORTHOSITE AND IMPACT MELT) BRECCIA,
PARTLY GLASS-COATED

1239 g

INTRODUCTION: 62255 consists of ~65% ferroan anorthosite and 35% dark, finely crystalline melt (Fig. 1). Two sides are coated with black vesicular glass (Fig. 1) apparently distinct from the crystalline melt phase. The anorthosite is chemically pristine but enriched in some volatiles. The sample is blocky, and moderately coherent but fractured.

62255 was collected at the south rim of Buster Crater and its orientation is known. It was apparently perched. Patina and zap pits are present on most faces.



FIGURE 1a.

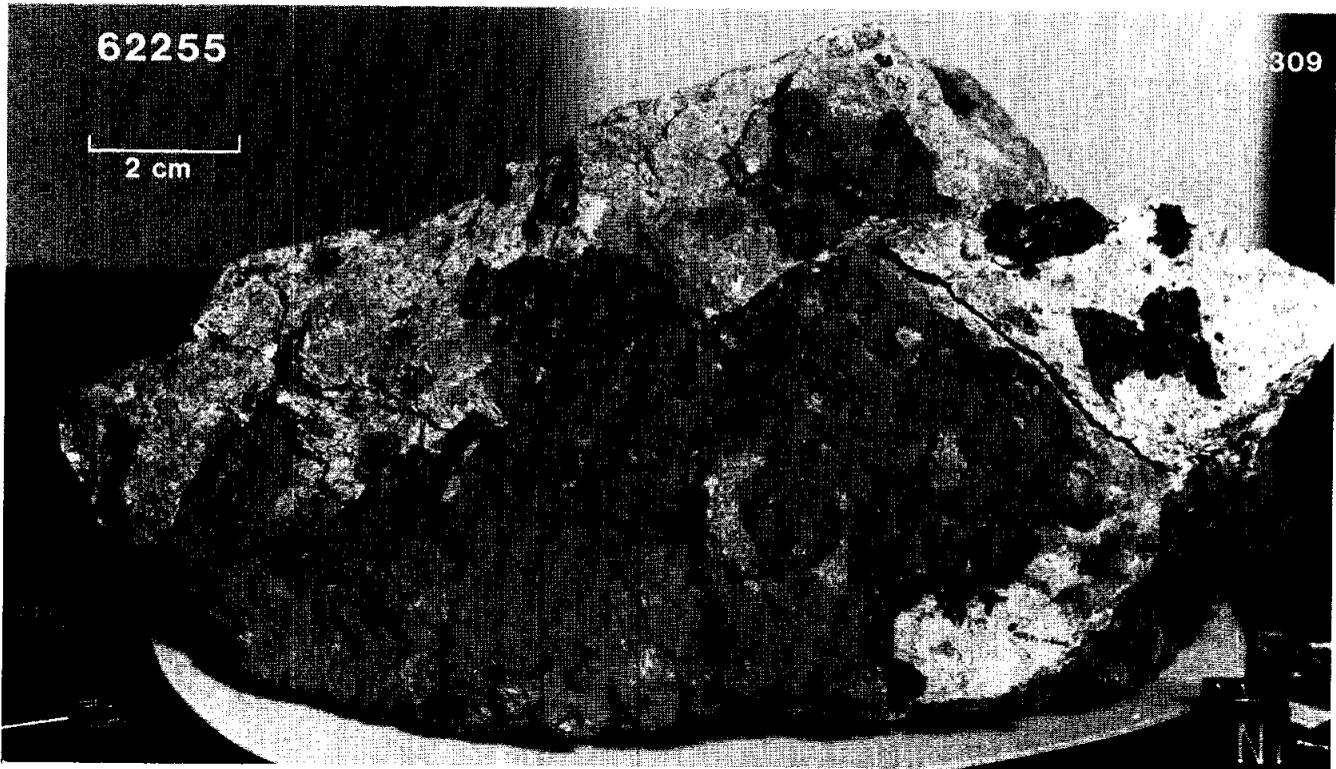


FIGURE 1b.

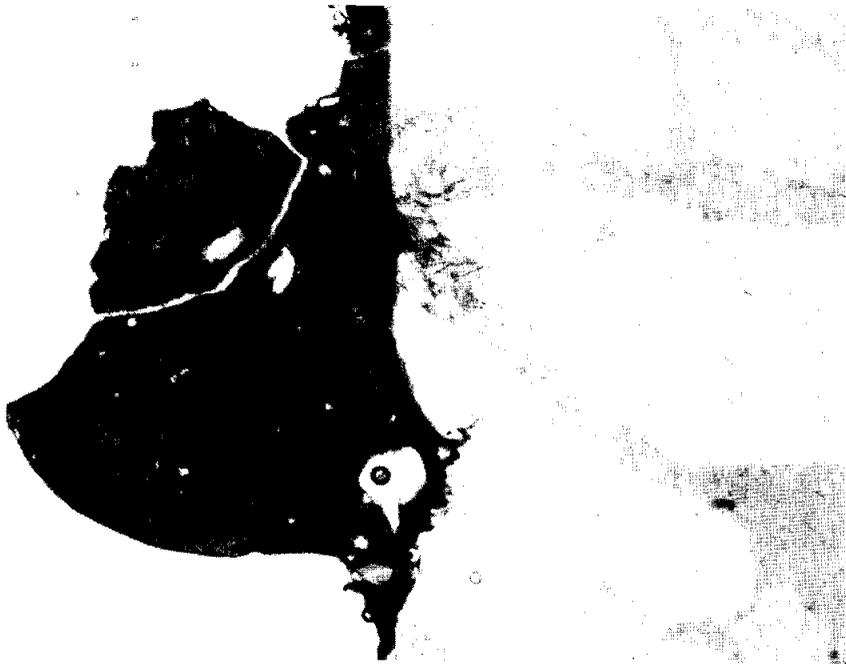


FIGURE 2. 62255,44. glass coat (left) and anorthosite (right), partly xpl. width 3mm.

PETROLOGY: Little petrographic work on 62255 has been published. Schaal *et al.* (1976) report on studies of microcraters in the anorthosite and provide some information on the anorthosite itself. Ryder and Norman (1978) provide a brief petrographic description of the anorthosite with mineral compositions and Meyer (1979) tabulates data for minor elements in plagioclase from ion microprobe studies.

The anorthosite (Fig. 2) is cataclastic and consists of plagioclase (An_{92-97}) with minor amounts of two pyroxenes ($En_{50-45}Wo_{4-8}$) (Ryder and Norman, 1979; Schaal *et al.*, 1976). Low-calcium pyroxene occurs mainly as discrete grains (rarely up to 2 mm), but some plagioclases contain numerous tiny pyroxene grains. Some of the pyroxenes contain exsolution lamellae. Plagioclase grains are up to 4 mm in diameter and relict grain boundaries are visible in places. Ilmenite and troilite are rare. The minor element data for plagioclase from Meyer (1979) are presented in Table 1.

TABLE 1. Ion microprobe data for minor elements (ppm) in plagioclase
(Meyer, 1979)

	Li	Mg	Ti	Sr	Ba
grain a)	2.6	500			
grain b)	2.3	534	214	181	22

Schaal *et al.* (1976) note that glass in microcraters on the anorthosite consists entirely of plagioclase and even next to a pyroxene grain is not enriched in Mg, Fe, or Ca. In contrast, Brownlee *et al.* (1975) did note a slight enrichment of Mg and Fe in glass craters as compared with the underlying feldspar grain. This enrichment might be meteoritic.

The melt phase has a finely crystalline, "salt and pepper" texture which varies greatly. It contains 1-2% metal fragments. The contacts with the white are sharp but the relationship is unknown--the melt is not present in thin sections. The macroscopic features are consistent with the melt being a basaltic-textured impact melt.

In thin section, the glass coat (Fig. 2) is vesicular and contains anorthosite fragments and tiny metal blebs. It is brown and partly crystallized into spherulites of plagioclase. The contact with the anorthosite is generally sharp but in a few places the anorthosite is melted and in others tiny apophyses (200-300 μ m) of glass intrude the anorthosite.

CHEMISTRY: All published chemical data are for the anorthosite. S.R. Taylor *et al.* (1974) present major and trace element analyses and Taylor and Bence (1975) diagram rare-earth abundances for the anorthosite and a plagioclase separate from it. Cripe and Moore (1974) and Moore and Lewis (1977) present S, and C and N data respectively. Hertogen *et al.* (1977) tabulate and discuss meteoritic siderophile and volatile element abundances. Ca and K data are presented by Jessberger *et al.* (1977) but the chip is described as pyroxene-rich.

The data are summarized in Table 2 and Figure 3. The siderophiles demonstrate that the ferroan anorthosite is free of meteoritic contamination but abundances of Tl (etc.) (not tabulated) demonstrate an enrichment in volatiles.

TABLE 2. Summary chemistry of 62255 pristine anorthosite

SiO ₂	44.1
TiO ₂	
Al ₂ O ₃	35.3
Cr ₂ O ₃	0.002
FeO	0.20
MnO	
MgO	0.37
CaO	19.1
Na ₂ O	0.49
K ₂ O	0.09
P ₂ O ₅	
Sr	
La	0.46
Lu	
Rb	0.025
Sc	
Ni	1.6
Co	
Ir ppb	0.016
Au ppb	0.062
C	20
N	9
S	90
Zn	0.31
Cu	<1

Oxides in wt%; others in ppm
except as noted.

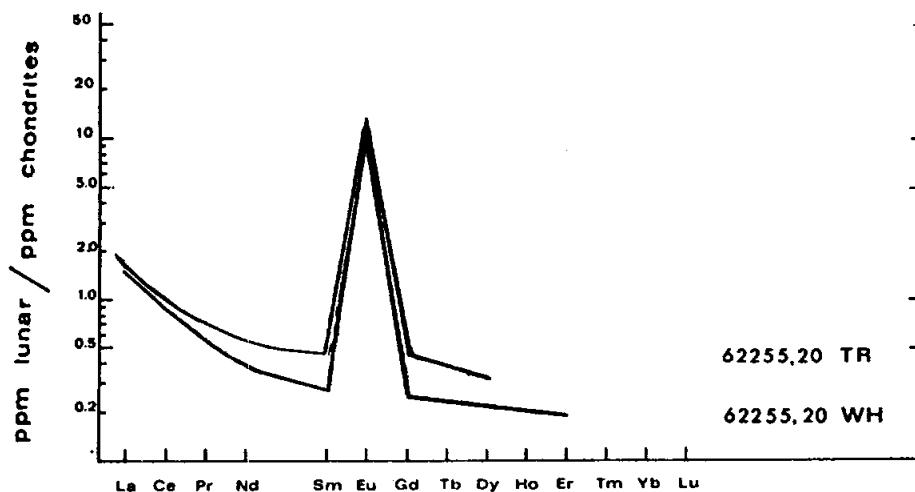


FIGURE 3. Rare earth data for 62255. TR= whole rock anorthosite. WH=plagioclase separate from anorthosite; from Taylor and Bence (1975).

GEOCHRONOLOGY: Jessberger *et al.* (1977) found no plateau in ^{39}Ar - ^{40}Ar studies and state that the sample is not datable. Thus the total K-Ar "age" of $3.66 \pm .08$ b.y. is unreliable.

RARE GASES AND EXPOSURE AGES: Jessberger *et al.* (1977) list an argon exposure age of 3 ± 1 m.y., Lightner and Marti (1974a) state that the exposure age is 2 m.y., and Drozd *et al.* (1977) quote (Marti, 1975, pers. comm.) an age of 1.9 m.y. The method for the study which gave the latter two ages is ^{81}Kr -Kr (Marti, 1980, pers. comm.).

Lightner and Marti (1974a) present xenon isotopic data for an interior chip of anorthosite. The spallation component is small because the sample has both low incompatible element abundances and a short exposure age. As expected, no fissionogenic xenon was found. Trapped xenon is isotopically similar to terrestrial xenon but Lightner and Marti (1974a) argue that it is not terrestrial in origin. However, as discussed by Hertogen *et al.* (1977), contamination is possible, as Niemeyer and Leich (1976) found that terrestrial xenon could be strongly adsorbed on surfaces. Hertogen *et al.* (1977) suggest that the lunar volatile enrichment might somehow make the surface conducive to later xenon adsorption.

MICROCRATERS AND SURFACES: Schaal *et al.* (1976) report physical and chemical characteristics of microcraters on the anorthosite and Brownlee *et al.* (1975) report chemical data for such craters.

Padawer *et al.* (1974) determined the abundances of C and F1 with depth in exterior and interior chips of the anorthosite, but the abundances derived from both are considered to be contamination from Teflon packaging and other sources.

PHYSICAL PROPERTIES: Housley *et al.* (1976) show a FMR (ferromagnetic resonance) derivative spectrum and a corresponding absorption spectrum for an anorthosite chip. The FMR is very weak.

PROCESSING AND SUBDIVISIONS: Several large chips were taken from the sample and subdivided prior to sawing of the rock in October, 1975. The single saw-cut produced four large pieces-- ,0 (694 g); ,64 (53 g); ,80 (251 g); and ,81 (101 g) in addition to many smaller pieces (Fig. 4).

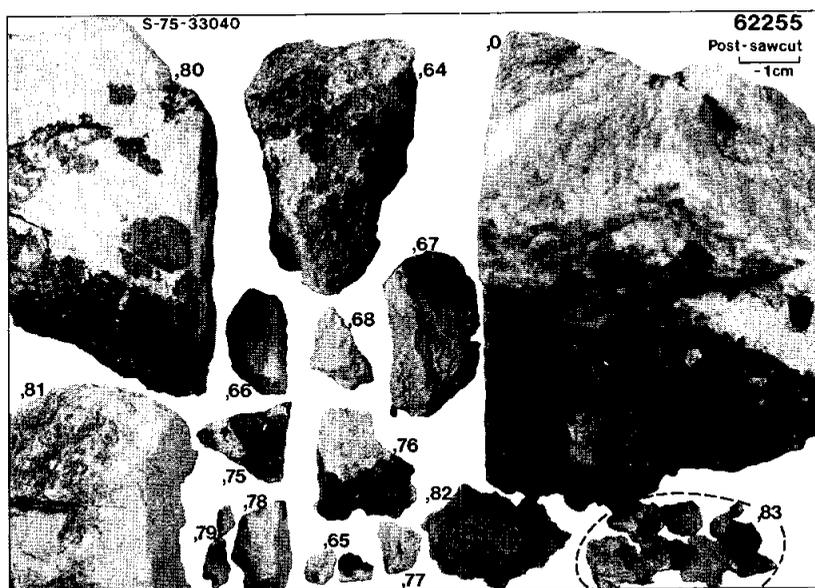


FIGURE 4. Sawn subdivisions of 62255.

INTRODUCTION: 62275 is a white, very friable, cataclastic anorthosite. Mineral compositions and limited chemical data suggest that the rock is monomict. Macroscopically it has a chalky to sugary texture and a locally streaked appearance. There is no glass coat but a thin layer of patina is present on some surfaces. Zap pits are rare to absent on all surfaces but the rock's friable nature is not amenable to the preservation of surface features. The sample was collected ~ 25 m southeast of Buster Crater as a single specimen but has since disintegrated (Fig. 1). Lunar orientation is known.

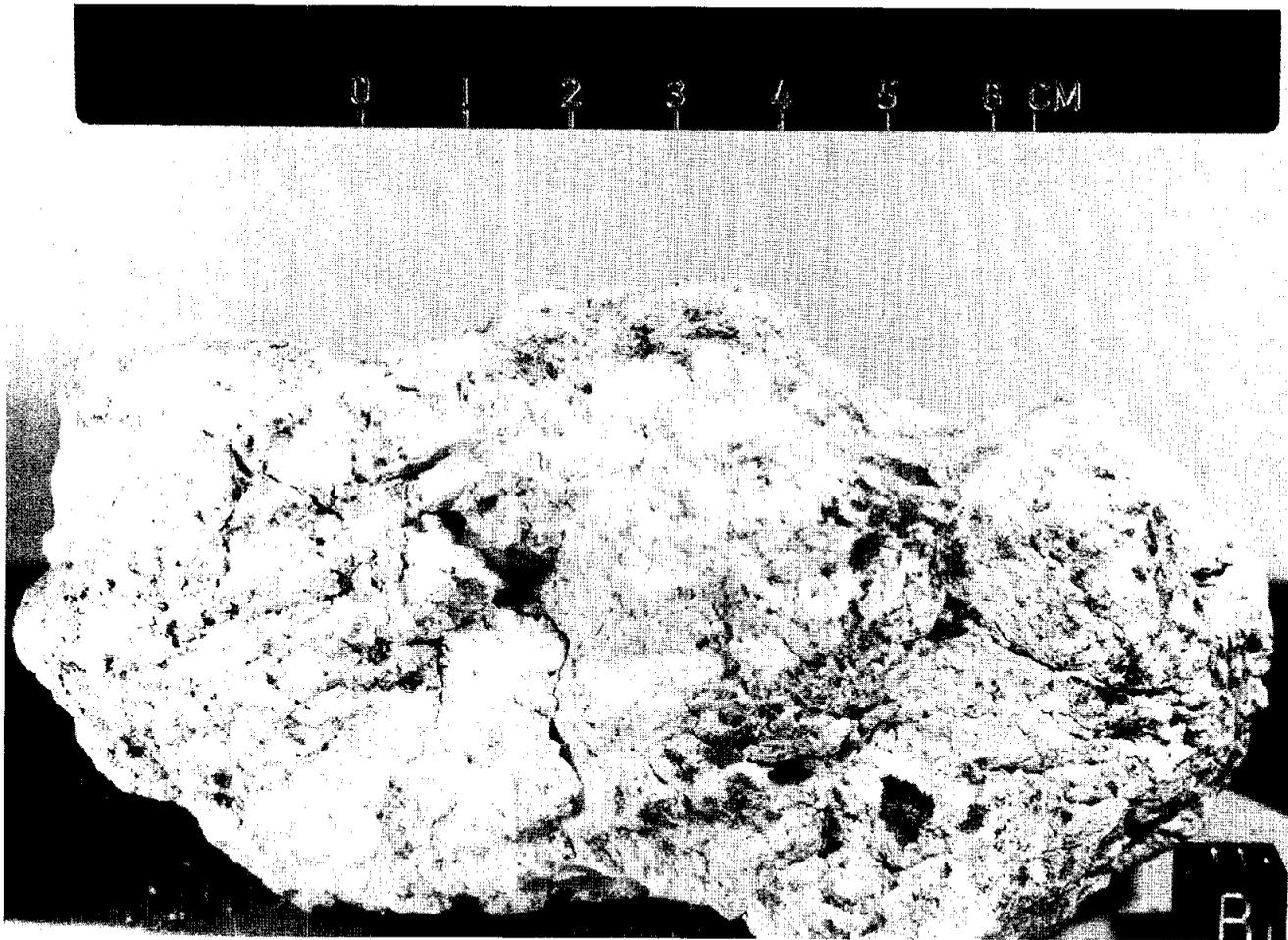


FIGURE 1. S-72-38386

PETROLOGY: Prinz et al. (1973) and Dowty et al. (1974a) provide petrographic information. The rock is an extremely shocked and cataclastic anorthosite (Fig. 2). Isolated clasts of plagioclase (An_{97-99}) and a brownish microcrystalline material (up to 2 mm long) rest in a finely comminuted anorthositic matrix. Modal data are given in Table 1. The brownish clasts are not simply recrystallized plagioclase but are enriched in Fe and Mg relative to both pure plagioclase and the bulk rock (Table 2). From the data available it is not possible to tell if these clasts represent foreign material or

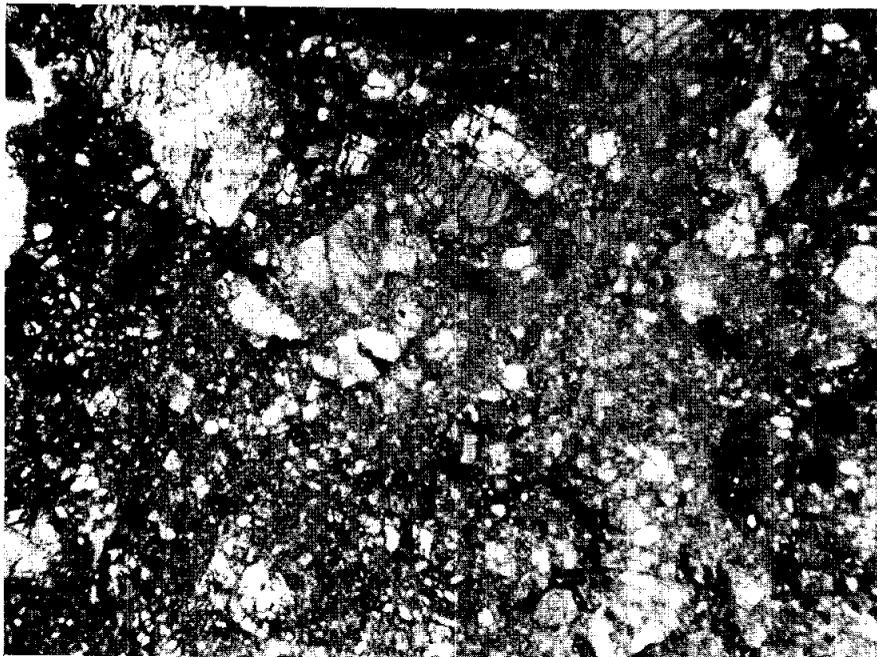


FIGURE 2. 62275,4.
general view, partly
xpl. width 3mm.

were formed more or less *in situ*. Mafic minerals are concentrated in highly crushed zones. Despite extensive cataclasis, a relict cumulate texture is discernable in some areas and a few mafic-plagioclase grain boundaries have survived. Mineralogically 62275 is similar to known pristine anorthosites. Mafics are ferroan and largely equilibrated (Fig. 3). The small range of mineral compositions indicate that the rock may be monomict. Chromite-rich spinel (FeCr_2O_4 \sim 60 mol%), rare Fe-metal and troilite are accessory minerals.

From the composition of the olivine-2 pyroxene-plagioclase assemblage, Herzberg (1979) calculates a temperature of equilibration of \sim 780-980°C and a pressure of equilibration of \sim 1.3 - 3.2 kb.

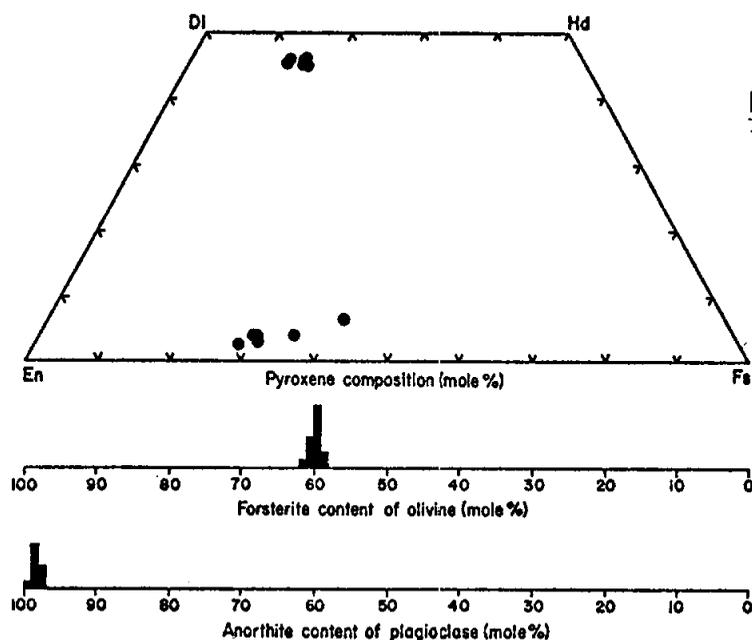


FIGURE 3. Mineral compositions;
from R. Warner et al. (1976b).

TABLE 1 Mode of 62275 (Prinz *et al.*, 1973)

	<u>vol %</u>
feldspathic glass and plagioclase	93
olivine	6
orthopyroxene	1
clinopyroxene	tr
chromite	tr

TABLE 2 Summary chemistry of 62275 (DBAs from Prinz *et al.*, 1973)

	<u>Bulk Rock</u>	<u>Brownish clasts</u>
SiO ₂	43.7	44.3
TiO ₂	0.04	0.13
Al ₂ O ₃	33.1	30.2
Cr ₂ O ₃	0.29	0.06
FeO	2.20	3.4
MnO	<0.01	0.04
MgO	1.91	3.1
CaO	18.4	18.6
Na ₂ O	0.30	0.34
K ₂ O	0.06	0.03
P ₂ O ₅		

Oxides in wt%

CHEMISTRY: A "bulk rock" defocussed electron beam analysis (DBA) of a thin section is presented by Prinz *et al.* (1973) and reproduced in Dowty *et al.* (1974a) and here as Table 2 with an average microprobe analysis of the brownish clasts. The high Fe/Mg of the rock is comparable to that of other ferroan anorthosites.

Clark and Keith (1973) provide natural and cosmogenic radionuclide abundance data. The very low K (119 ppm), Th (0.009 ppm) and U (<0.006 ppm) indicate very little, if any, contamination by KREEP.

EXPOSURE AGES: Cosmogenic radionuclide data are reported by Clark and Keith (1973). The rock is probably saturated in ²⁶Al relative to ²²Na(²⁶Al/²²Na = 3.4)



FIGURE 4. Most of 62275,0. Largest piece is about 5 cm. across.

PROCESSING AND SUBDIVISIONS: Although returned as one piece, from which ,1 was chipped to produce thin sections ,3 and ,4, 62275 has disintegrated into numerous pieces and powder (Fig.4).

INTRODUCTION: 62285 is a brown, extremely friable sample, most of which has disintegrated to powder (Fig. 1). It is a loosely lithified soil clod. It was taken from a soil sample collected about 30 m south of Buster Crater.



FIGURE 1. Smallest scale division in 0.5mm.

INTRODUCTION: 62286 is a brown, extremely friable sample, most of which has disintegrated to powder (Fig. 1). It is a loosely lithified soil clod. It was taken from a soil sample collected about 30 m south of Buster Crater.



FIGURE 1. Smallest scale division in 0.5mm.

INTRODUCTION: 62287 is an angular, coherent, medium dark gray fragment (Fig. 1). It contains rare, small white and black clasts, and has conchoidal fracture in places. It is probably a fine-grained or glassy impact melt. It was taken from a soil sample collected about 30 m south of Buster Crater and lacks zap pits.

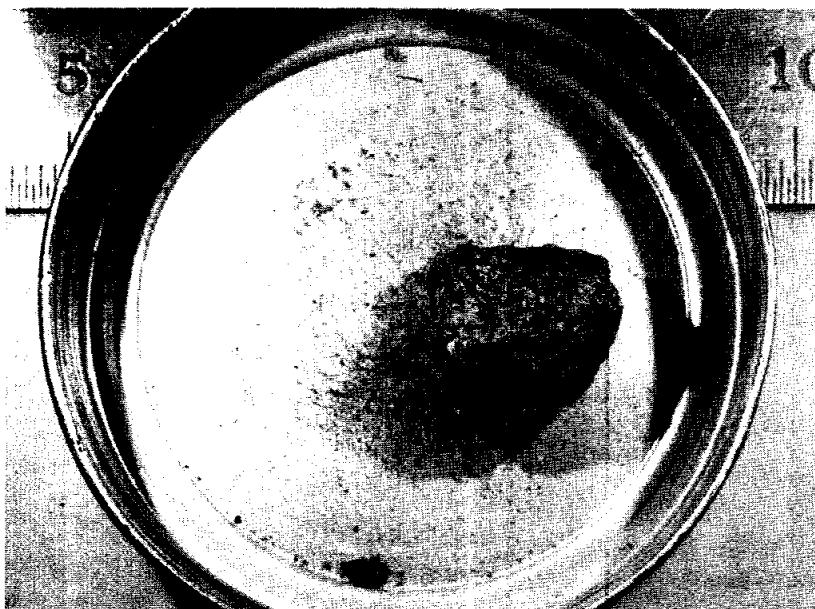


FIGURE 1. Smallest scale division in 0.5mm.

INTRODUCTION: 62238 is a coherent, pale to medium gray breccia containing a variety of small light and dark clasts (Fig. 1). The matrix is coherent and the fragment population varies from angular to rounded. It was taken from a soil sample collected 30 m south of Buster Crater and lacks zap pits.



FIGURE 1. Smallest
scale division in
0.5mm.

INTRODUCTION: 62289 is a brown, almost totally disaggregated soil clod (Fig. 1). It was taken from a soil sample collected about 30 m south of Buster Crater.

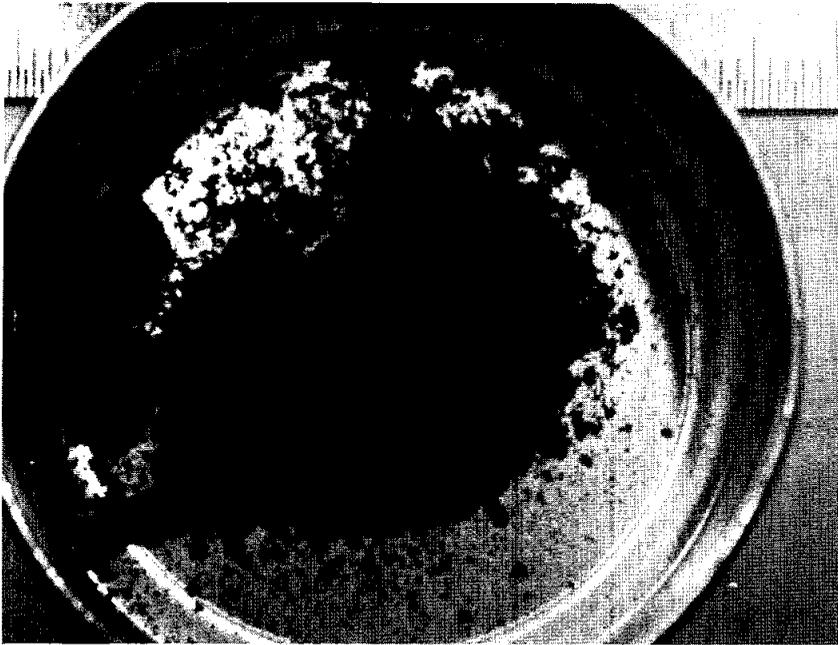


FIGURE 1. Smallest scale division in 0.5mm.

INTRODUCTION: 62295 is a mesostasis-rich, basaltic impact melt that is unique in being very magnesian and rich in olivine and spinel. Macroscopically it is greenish-gray in color and quite tough (Fig. 1). It was collected ~ 35 m southwest of Buster Crater. Zap pits are abundant on the "lunar top" surface, rare to absent on other surfaces.

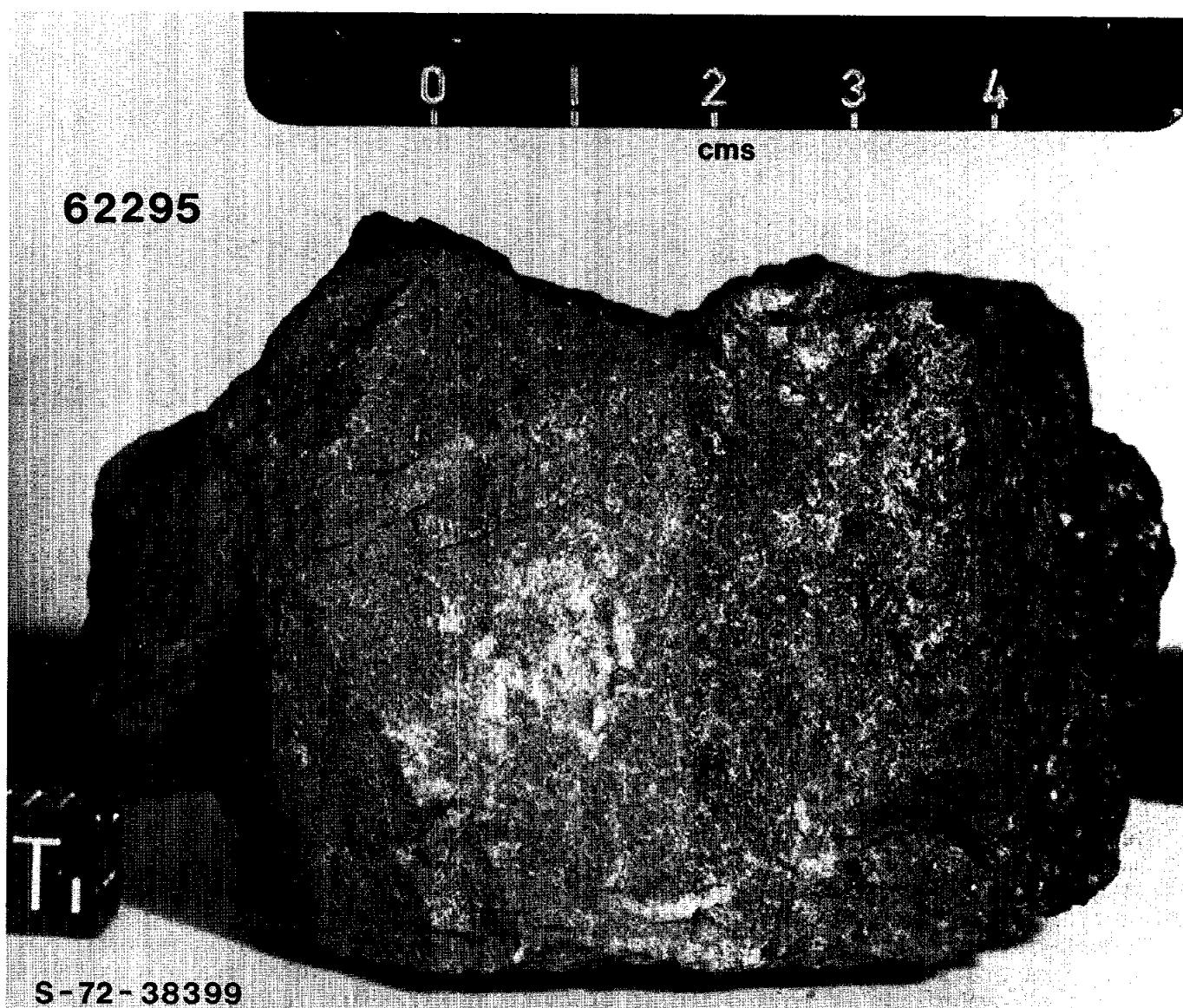


FIGURE 1.

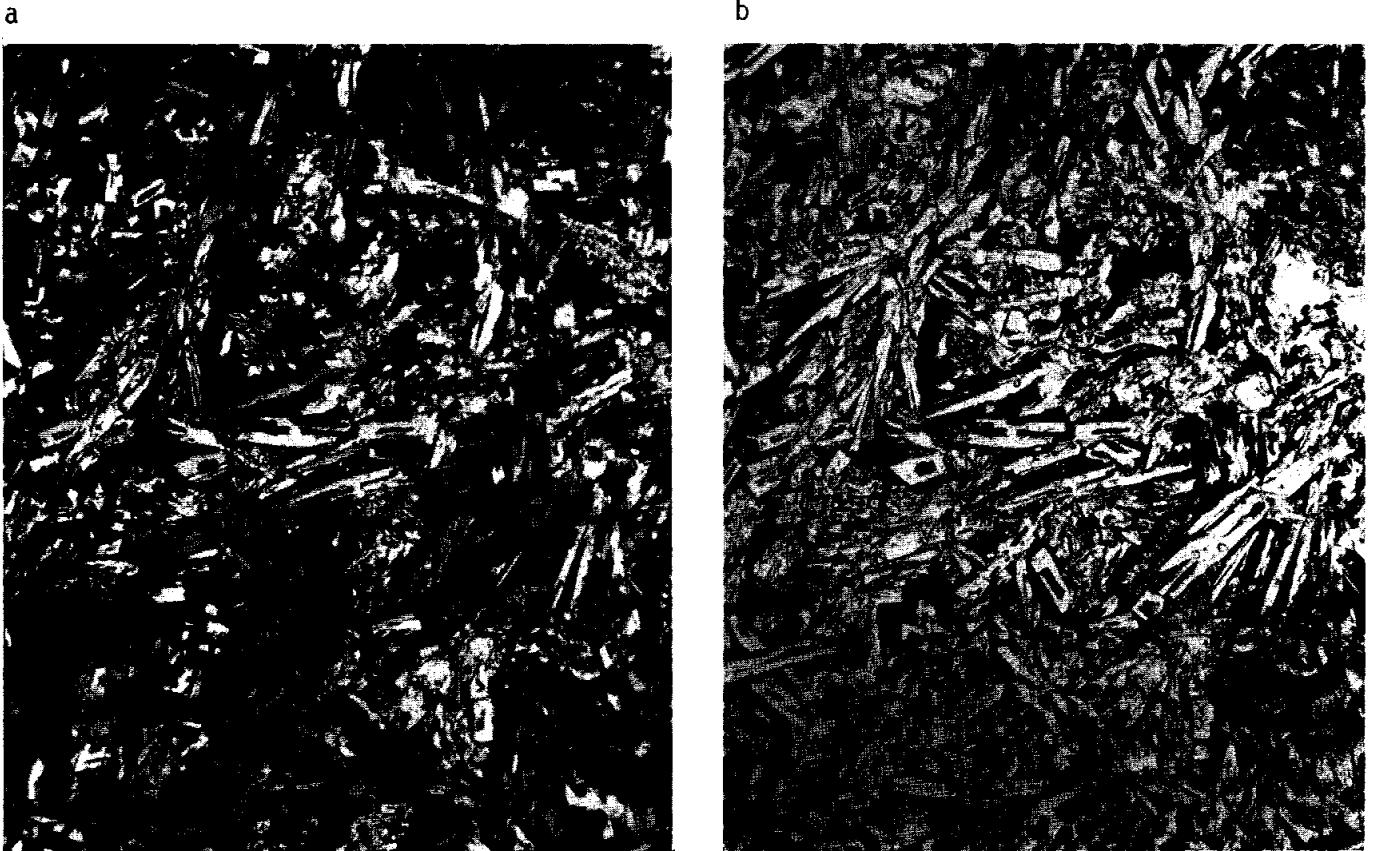


FIGURE 2. 62295,69. general view. width 2mm. a) xpl. b) ppl.

PETROLOGY: General petrographic descriptions are given by Agrell *et al.* (1973), Brown *et al.* (1973), Hodges and Kushiro (1973), Walker *et al.* (1973), Nord *et al.* (1973), Weiblen and Roedder (1973), McGee *et al.* (1979) and Vaniman and Papike (1981). Steele and Smith (1975) provide data on minor elements in olivines. Nord *et al.* (1973) studied mineral structures using high-voltage transmission electron spectroscopy (HVTEM). Misra and Taylor (1975) report metal compositions. Melt inclusions were studied by Weiblen and Roedder (1973).

62295 is a fine-grained, mesostasis-rich basaltic impact melt with the mineralogy of a spinel troctolite (Fig. 2). It is somewhat heterogeneous on the thin section scale, an approximate mode being 55% plagioclase, 25% olivine, 15% mesostasis and 5% spinel. Xenocrysts (up to 1.5 mm) of olivine (Fo₉₀₋₉₅), plagioclase (An₉₄₋₉₉), pink spinel (9-16 mol% chromite) and metal are preserved in a finer-grained matrix (<1 mm) characterized by a variety of quench textures. Normally-zoned olivine (Fo₇₈₋₉₂) and plagioclase (An₉₀₋₉₆) are the principal matrix minerals and occur as hollow, euhedral laths and skeletal grains, as variolitic to graphic intergrowths and as clots with a feathery to spinifex texture. Inclusions of a colorless to pale yellow spinel (2-4 mol% chromite) are abundant in both matrix olivine and plagioclase. These spinels are metastable and their existence implies rapid cooling and crystal growth rates. A complex, cryptocrystalline mesostasis of plagioclase, olivine, clinopyroxene, metal, troilite, schreibersite and a fluor-phosphate fills interstices and hollow crystals. The

pyroxenes are ferroaugites (Fig. 3) and occur only in the mesostasis. Metal shows a large range in composition (Fig. 4). Co-existing schreibersite is unusually rich in Ni ($\sim 42\%$ Ni) (see Misra and Taylor, 1975; Brown *et al.*, 1973; Weiblen and Roedder, 1973 for other metal data).

The xenocrysts are inhomogeneously distributed through the rock and often core the radiate intergrowths mentioned above; all are mantled by fine-grained reaction rims. Several authors note that the xenocryst population is mineralogically similar to the pink spinel troctolite (PST) clast in 67435. Steele and Smith (1975) find the xenocryst olivines to be poor in minor elements (except Cr) compared to matrix olivines (Table 1). Roedder and Weiblen (1977b) describe

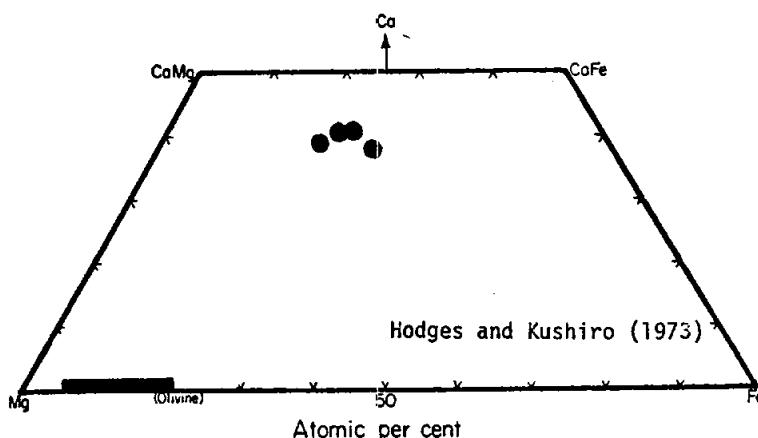
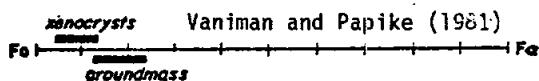
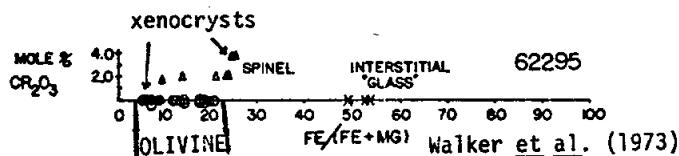


FIGURE 3a. Mafic mineral compositions.



an unusual chondrule-like particle consisting of a single crystal of barred olivine with thin stringers of plagioclase and opaques separating the bars. The olivine shows reverse zoning with an intermediate area more magnesian (Fo_{92}) than either the core or rim (both $\sim Fo_{88}$). The plagioclase stringers bear no crystallographic relation to the olivine and thus are not exsolution lamellae.

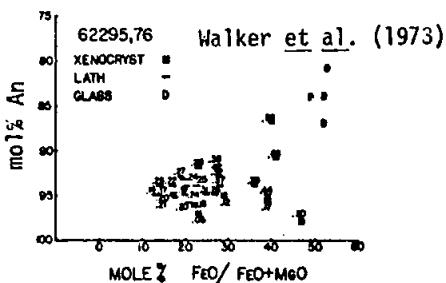
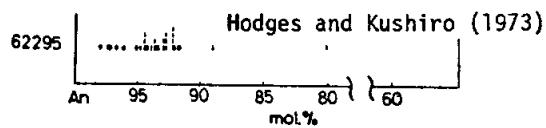


FIGURE 3b. Plagioclase compositions.

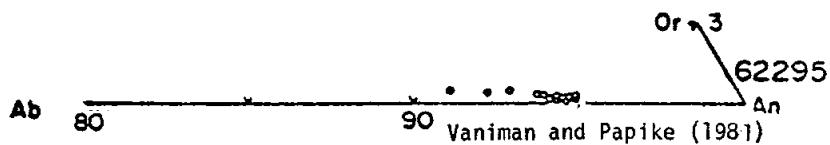


TABLE 1. Minor elements in 62295 olivine (Steele and Smith, 1975)

	CaO	TiO ₂	MnO	Al ₂ O ₃	Cr ₂ O ₃
Matrix	0.250	0.017	0.092	0.130	0.087
Xenocryst	0.060	0.009	0.045	0.048	0.124

Oxides in wt%

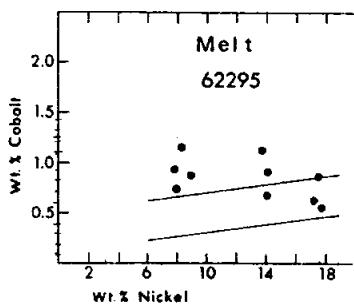


FIGURE 4. Metals; from Misra and Taylor (1975).

EXPERIMENTAL PETROLOGY: Crystallization experiments on the 62295 composition are reported by Walker *et al.* (1973), Hodges and Kushiro (1973) and Ford *et al.* (1974). All authors find spinel to be the liquidus phase at all pressures. At low pressure spinel is followed by olivine, plagioclase and pyroxene with decreasing temperature. Below $\sim 1250^{\circ}\text{C}$ and at low pressure, spinel reacts with the liquid to form olivine and plagioclase. At progressively higher pressures the spinel field expands and olivine is replaced by pyroxene. There is no approach to multiply saturated conditions with increasing pressure (Figs. 5,6).

This crystallization sequence (spinel, olivine, plagioclase, pyroxene) is consistent with that predicted by low pressure phase diagrams (Fig. 7) and determined by textural studies (e.g. Engelhardt, 1978). Data from silicate melt inclusions (Weiblen and Roedder, 1973) are in basic agreement with this sequence except for apparently requiring a minor amount of a Ti-rich phase to follow olivine and precede plagioclase (Fig. 8).

L. A. Taylor *et al.* (1976) performed subsolidus heating experiments on natural rock chips to observe changes in metal composition and morphology. Their results are summarized in Figure 9.

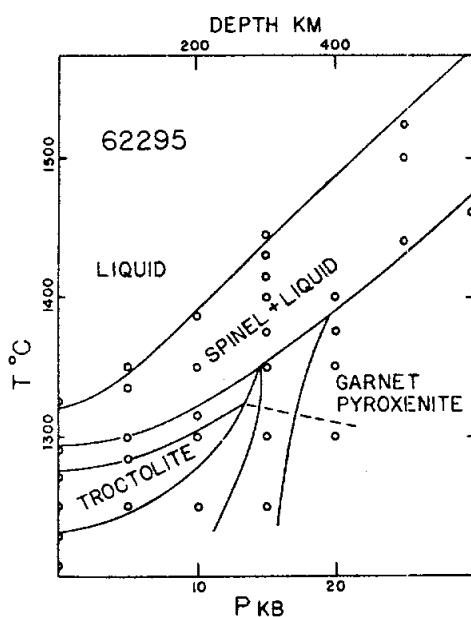


FIGURE 5. from Walker *et al.* (1973).

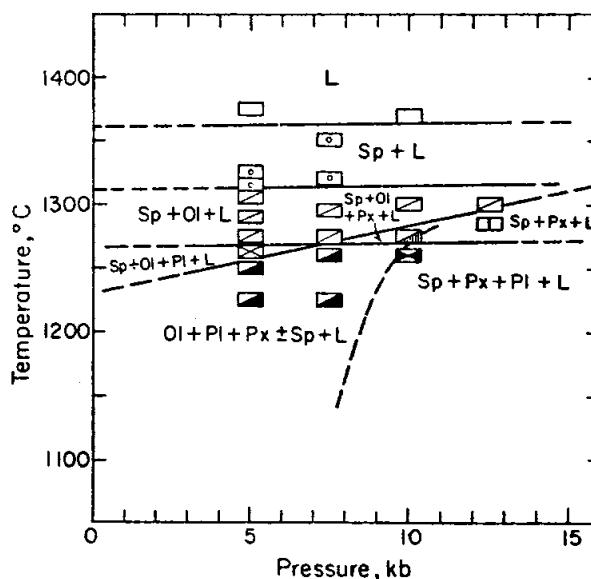


FIGURE 6. from Hodges and Kushiro (1973).

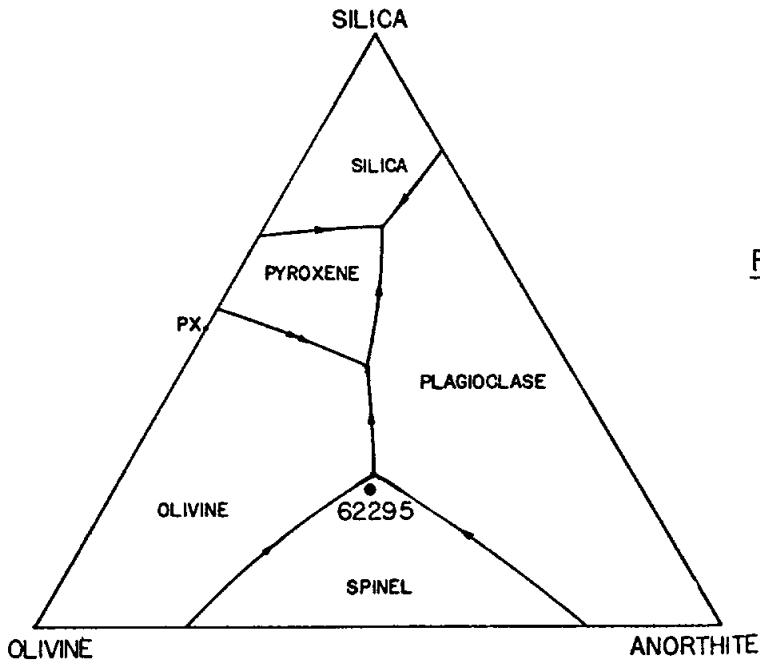
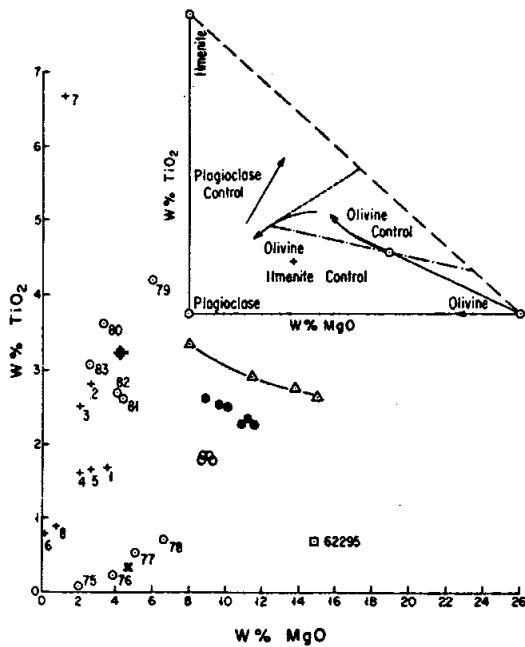


FIGURE 7. from Walker et al. (1973).



- △ Four Apollo 12 basalts which can be related by low pressure olivine fractionation.
- Apollo 15 olivine basalts.
- Apollo 15 quartz basalts.
- Melt inclusions in 62295
- ◆ Average of melt inclusions interstitial to and in plagioclase in 62295
- × Average of melt inclusions in olivine in 62295
- +
- Bulk composition of 62295

FIGURE 8. TiO_2 v. MgO ; from Weiblen and Røedder (1973).

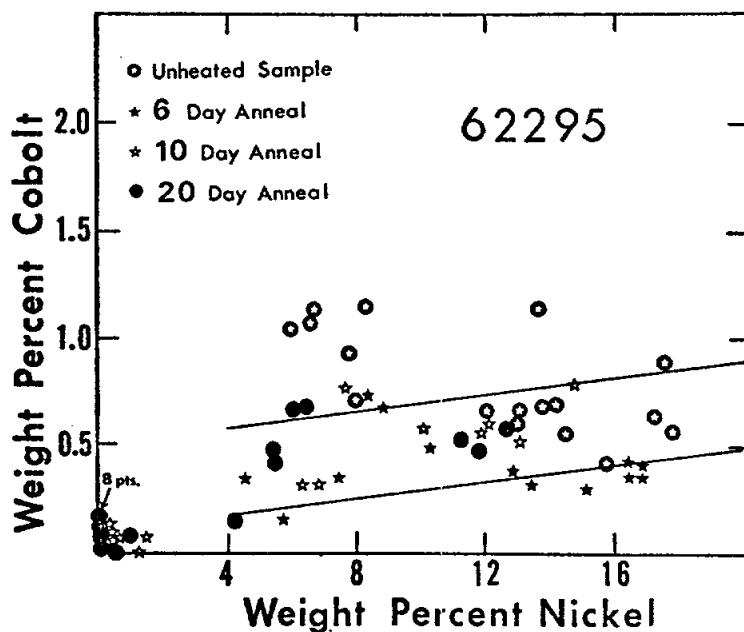


FIGURE 9. from L.A. Taylor et al. (1976).

CHEMISTRY: Major and trace element analyses are provided by Hubbard et al. (1973), Rose et al. (1973) and Wänke et al. (1976). Krähenbühl et al. (1973) give siderophile and volatile element data and Eldridge et al. (1973) report natural and cosmogenic radionuclide abundances. Walker et al. (1973) present major elements obtained by electron microprobe analyses of natural rock powder fused to a glass. Other chemical data are found in the work of geochronologists (referenced below).

62295 is among the most magnesian, and has one of the highest Mg/Fe (Mg/Mg+Fe molar = 0.81), of any lunar impact melt analyzed (Table 2). Nonetheless it is chemically distinct from the ultramafic PST clast in 67435 which contains ~ 34% MgO. Lithophile elements (Fig. 10) are slightly enriched over local soils and are dominated by KREEP. Eldridge et al. (1973) note the low K/U ratio (770); Th/U is typical of lunar rocks (3.9). The siderophile elements indicate a meteoritic component (Table 2). Ganapathy et al. (1973) mention the high Ge content (642 ppb) but do not consider it indicative of fumarolic volatiles due to the normal volatile to involatile ratios (e.g. Tl/Cs and Tl/U) of the rock. Hertogen et al. (1977) assign this sample to meteoritic group 1H, a group largely restricted to Apollo 16.

STABLE ISOTOPES: Taylor and Epstein (1973) report whole rock $\delta^{18}\text{O}$ and $\delta^{30}\text{Si}$ values of +5.81 and -0.27 ‰ respectively.

TABLE 2. Summary chemistry of 62295

SiO ₂	45.3	Sr	131
TiO ₂	0.72	La	19
Al ₂ O ₃	20.5	Lu	0.88
Cr ₂ O ₃	0.17	Rb	5.2
FeO	6.2	Sc	10
MnO	0.09	Ni	285
MgO	14.7	Co	25
CaO	11.6	Ir ppb	4.3
Na ₂ O	0.45	Au ppb	5.1
K ₂ O	0.08	C	
P ₂ O ₅	0.14	N	
Oxides in wt%, others in ppm		S	700
except as noted.		Zn	18.9
		Cu	14.1

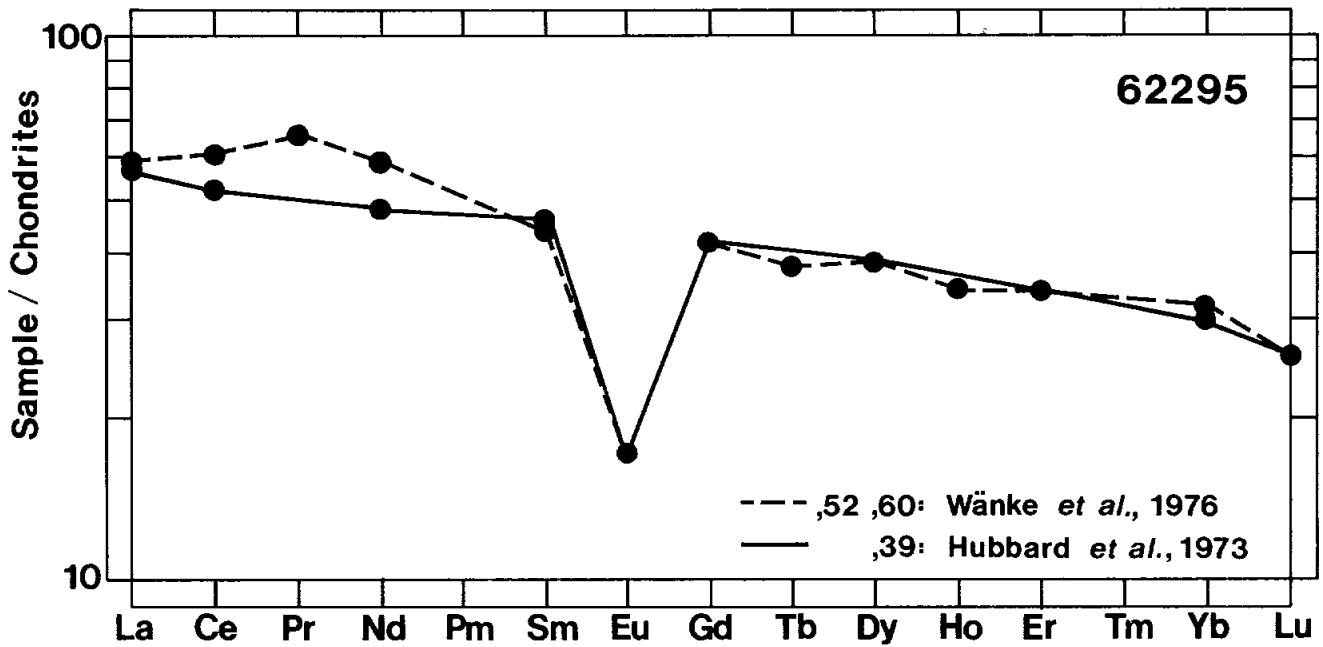


FIGURE 10. Rare earth elements.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: An Rb-Sr internal isochron age of 4.00 ± 0.06 b.y. with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ of 0.69956 ± 6 (Fig. 11) was reported by Mark *et al.* (1974). The age is interpreted as the crystallization age of the impact melt.

The isochron is not simply a mixing line because one fraction (H) falls off such a line (Fig. 11). Mark *et al.* (1974) and Nyquist *et al.* (1973) provide whole-rock Rb-Sr data, summarized in Table 3.

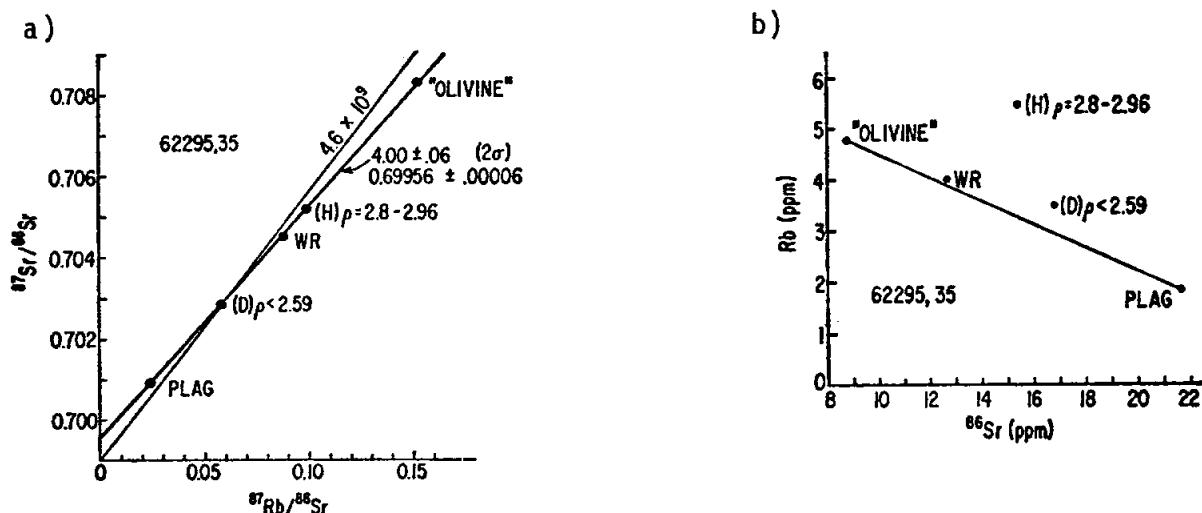


FIGURE 11. Rb-Sr data. a) isochron. b) Rb v. ^{86}Sr ; from Mark *et al.* (1974).

TABLE 3 Summary of whole rock Rb-Sr data for 62295

	$\frac{^{87}\text{Rb}}{^{86}\text{Rb}}$	$\frac{^{87}\text{Sr}/^{86}\text{Sr}}$ measured	$\frac{^{87}\text{Sr}/^{86}\text{Sr}}$ at 4.6 b.y.*	T_{BABI} (b.y.)	T_{LUNI} (b.y.)	Reference
62295,34	0.0958	0.70501	0.69955	4.31	4.38	Nyquist <i>et al.</i> (1973)
,34 II	0.0994	0.70519	0.69946	4.28	4.35	Nyquist <i>et al.</i> (1973)
,35	0.0877	0.70452	0.69956	4.39	4.46	Mark <i>et al.</i> (1974)

*corrected for interlaboratory bias by Nyquist (1977)

Turner *et al.* (1973) could not obtain a good ^{39}Ar - ^{40}Ar plateau due to equipment problems during the low temperature release, but an age of 3.89 ± 0.05 b.y. was inferred from the 900° and 1000° release data. A maximum age of 3.91 ± 0.05 b.y. was also calculated (Fig.12). The total Ar release age is 3.31 b.y.

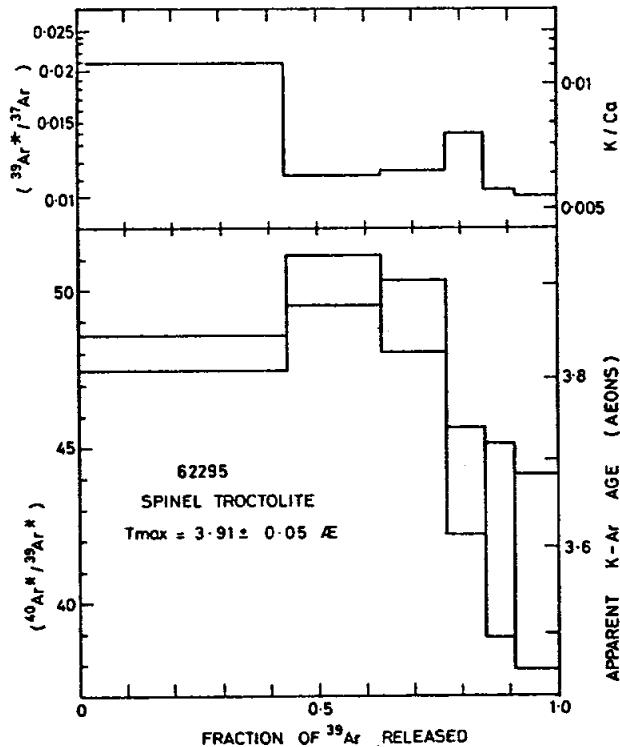


FIGURE 12. Ar release; from Turner *et al.* (1973).

RARE GAS/EXPOSURE HISTORY: From fossil track analyses Bhandari *et al.* (1973) infer that 62295 had a simple exposure history without shallow burial exposure in the regolith. A surface exposure age of 2.7 m.y. was calculated. Turner *et al.* (1973) report cosmogenic Ar isotope ratios and calculate an Ar exposure age of 310 m.y. Marti (1974, pers. comm., referenced in Hörz *et al.*, 1975) determined a Kr exposure age of 235 m.y. Eldridge *et al.* (1973) provide short-lived cosmogenic radionuclide abundances and Lightner and Marti (1974b) report various Xe isotope concentrations.

MICROCRATERS: Morrison *et al.* (1973) and Neukum *et al.* (1973) provide size-frequency data. Microcraters occur on only one surface indicating a simple exposure history. The cratered surface is probably still in production.

PHYSICAL PROPERTIES: Magnetic and mossbauer studies by Brecher et al. (1973) indicate that 62295 contains 0.37 wt% metal, predominantly as coarse, multi-domain particles. There is also a small but significant fraction of single domain grains which are capable of carrying a relatively stable component of natural remanence (Figs. 13,14). Remanent properties of different chips scatter over an order of magnitude due to the inhomogeneous distribution of metal and the ability of the chips to acquire a viscous remanence. Cyclical heating experiments produced irreversible changes in the magnetic properties through the subsolidus reduction of Fe^{2+} to produce new metal grains and the coalescence of preexisting metal grains.

MAGNETIZATION CURVE

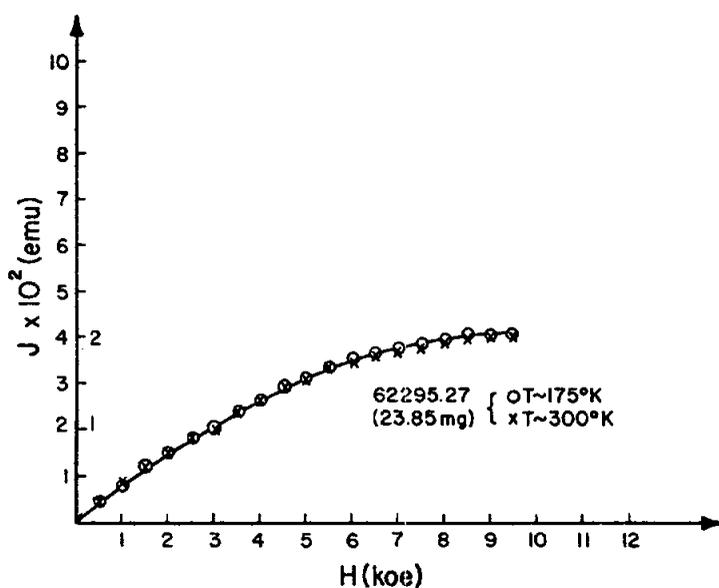


FIGURE 13. Magnetic behaviour; from Brecher et al. (1973)

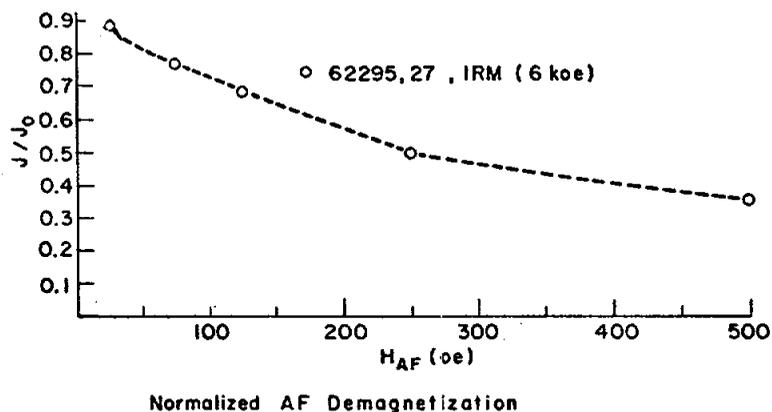


FIGURE 14. IRM stability; from Brecher et al. (1973).

Todd et al. (1973) and Wang et al. (1973) report elastic property measurements under confining pressures of 1-5000 bars (Fig.15). Todd et al. (1973) also calculate and measure values of the mean volume thermal expansion coefficient over the range 25-200°C. The calculated value ($16.9^{\circ}\text{C}^{-1}$) was an order of magnitude greater than the measured value (6.8°C^{-1}) apparently due to the presence of void space in the rock into which the minerals were able to expand.

Katsube and Collett (1973a,b) present and discuss measurements of the electrical characteristics of the rock (Fig.16).

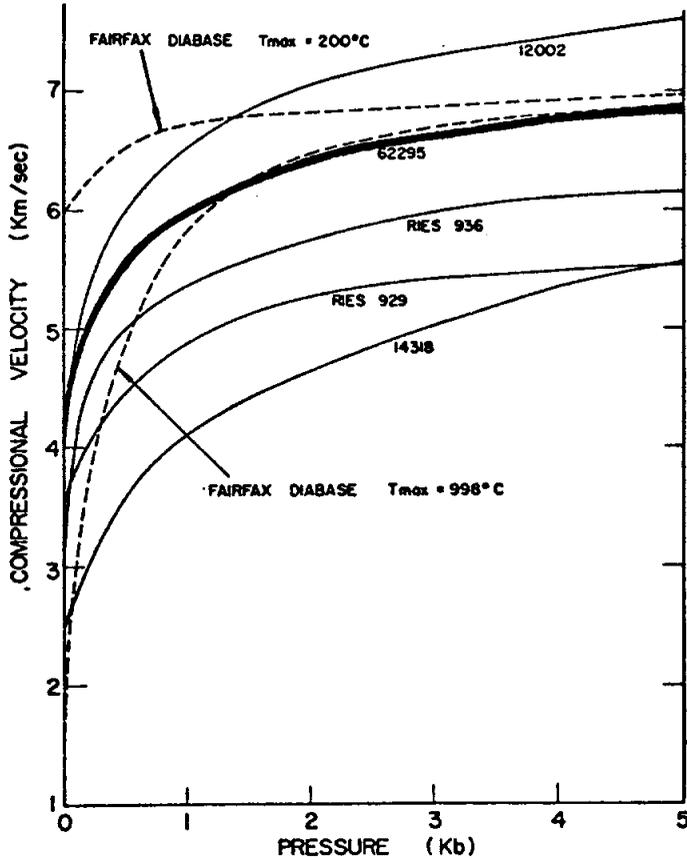


FIGURE 15. Elastic properties; from Todd et al. (1973).

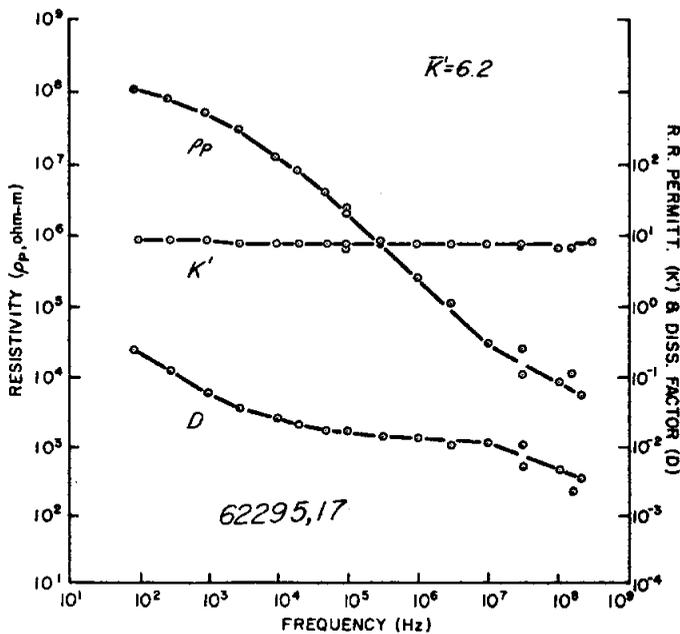


FIGURE 16. Electrical characteristics; from Katsube and Collett (1973a,b).

PROCESSING AND SUBDIVISIONS: In 1972, 62295 was broken along a natural fracture into three main pieces (.4, .5 and .6). That same year .5 was sawn into many pieces (Fig. 17) and widely allocated. .6 was cut into two pieces and then broken up into smaller chips for allocation and storage. In 1975, .4 was sawn into two pieces (.4 and .122) and the smaller of these (.122) sent to the Brooks remote storage vault. Most of the thin sections were made from .12 (a portion of .5) and .45 (a portion of .6). .46 (a 5.41g split of .6) was homogenized to a 100 mesh powder for 0.5g allocations to the experimental petrologists. 2.17g of this powder remains. The largest single pieces remaining today are .4 (108.5g) at JSC and .122 (48.1g) at Brooks.

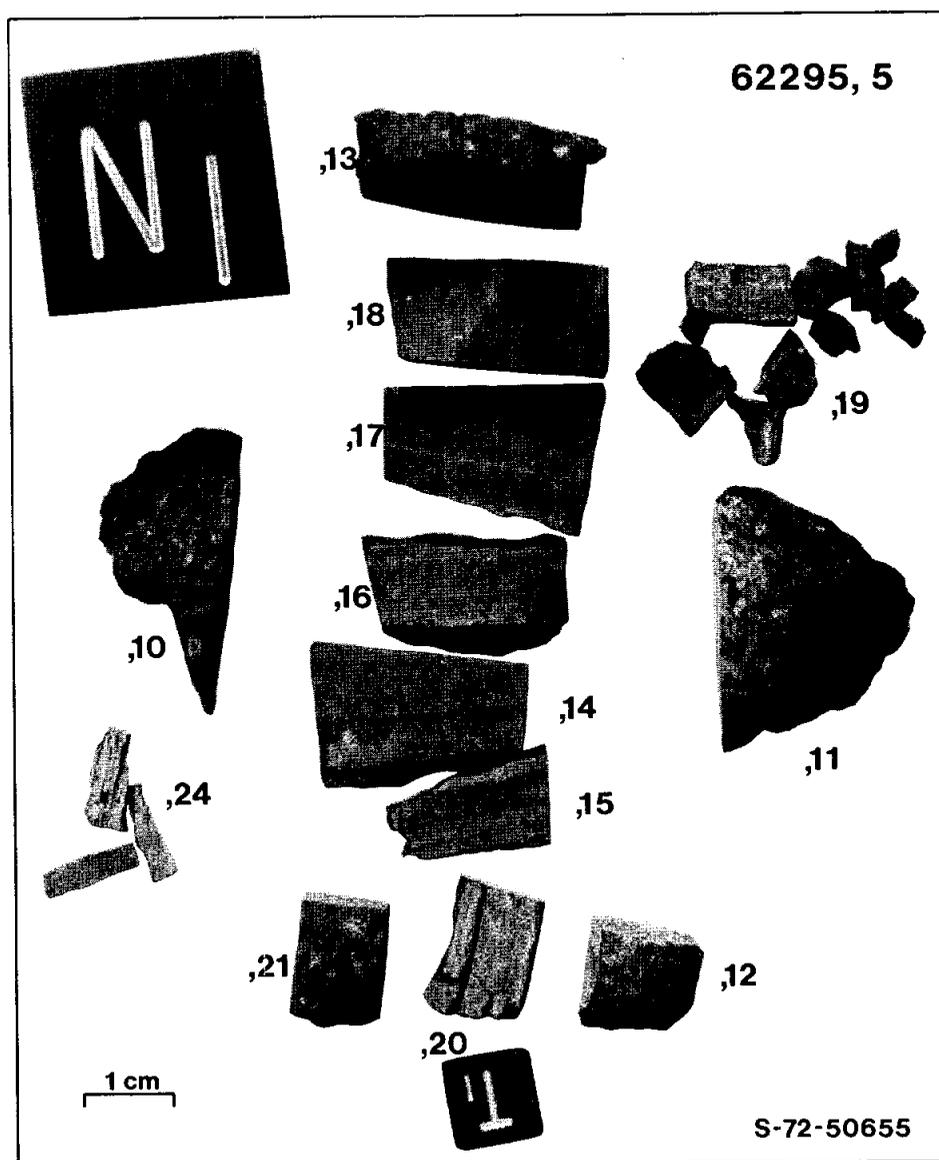


FIGURE 17. Subdivisions following sawing.

INTRODUCTION: 62305 is an extremely friable, gray breccia (Fig. 1). It contains a few small white clasts. It was taken from a soil sample collected 30 m south of Buster Crater and lacks zap pits.



FIGURE 1. Smallest scale division 0.5mm.

INTRODUCTION: 62315 is a friable, olive gray, clastic breccia (Fig. 1). It is rounded with smooth, hummocky surfaces. This rock was taken from the soil sample from the southeast rim of Buster Crater (62240). Zap pits are absent.



FIGURE 1. Sample is about 1 cm. across.
S-72-41308