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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LUNAR SAMPLE ANALYSIS PROGRAM

# A SUMMARY OF PHASE ANALYSIS ON APOLLO XII SAMPLES

by


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# A SUMMARY OF PHASE ANALYSIS ON APOLLO XII SAMPLES

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## ABSTRACT

The relatively low Ti and high Fe content of the Apollo XII fines and breccia's indicate that a substantial part is derived from the local basalts. The high alkali content of at least a third of the glasses, however, points to a second component with a composition similar to rock 12013. Our trace analyses support this hypothesis. Although some constituents of the breccias are clearly derived by impact, the lithification is apparently mostly due to welding of hot particles and partly plastic, probably relatively silica (and alkali) rich material serving as a glassy cement. The heating and lithification process was rapid and caused little chemical differentiation, analogous to the formation of ignimbritic rocks.

## DESCRIPTORS

| General Descriptors | Specific Descriptors | |
|---|---|---|
| Electron Microprobe | Spheres | Lithic |
| Ion Microprobe | Fragments | Chondrules |
| Glasses | Composition | Metal |
| Trace Elements | Zircons | Plagioclase |
| Breccia | Phosphates | Oxide |
| Olivine | Rare Earth's | Anorthosite |
| Pyroxene | Impact | |

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SECTION I - ELECTRON MICROPROBE ANALYSES

Introduction: Similarly as for Apollo XI, we have performed a large number of electron and ion probe analyses of individual mineral phases on a small variety of Apollo XII rocks, thin sections of which were delivered from the Lunar Receiving Laboratory, i.e. #12009, 12022, 12045, 12051 and 12053; only the last one has been available to us for more than a few weeks. Most of our work has as last year been concentrated on thin sections prepared in our own laboratory by G. Moreland from "soil" samples #12001,64, #12032,46 and 12057,46. Although these samples too have been available only a short time and to a limited extent, the superior quality of the thin sections has allowed some significant work on glasses and breccia fragments. Because of the restrictions in time (and access to samples) thus imposed on us, the analytical results summarized here are partly preliminary and need some refinement. Some detailed electron probe data and interpretations are reported by Mason et al. (2nd Lunar Science Conference). Only selected analytical data related to impact products and features in the lunar samples will be formally published by us before work on future Apollo samples.

CRYSTALLINE ROCKS: For textures, grain size, provisional names, etc. we refer to NASA Report, MSC 01512.
Olivines have been analyzed in rocks 9, 22, 45 and 53 and the results are summarized in Table 1.

Table I. FeO content in olivines in Apollo XII crystalline rocks

| | 12009 | 12022 | 12045-A | 12045-B | 12053 |
|---|---|---|---|---|---|
| FeO Wt.% | 24-32 | 26-39 | 29-36 | 29-43 | 29-37 |

The section of rock 45, Fig. 1, is unusual in having two areas with different olivines (see also section 2) separated by a fine grained semi-opaque area with "flow" structure; perhaps the contact between two flows or two "welded" fragments in a breccia.
Pyroxenes are rather similar to those in the Apollo XI samples, although pyroxferroite was not found, except in fragments from the "soil".
Fe-Ti-oxides are also similar to those reported from Tranquillitatis.

Plagioclases are again similar to those from Tranquillitatis; rock 45, Fig. 1, contains a few grains of nearly pure anorthite.
Metal was analyzed only in four crystalline rocks.

Table II. Metal composition in Apollo XII crystalline rocks

| | 12009 | 12022 | 12045 | 12051 |
|---|---|---|---|---|
| Fe Wt.% | 93.5 | 68.9 | 94-97 | 97.0 |
| Ni Wt.% | 2.1 | 28.8 | 4-5.5 | 2.2 |
| Co Wt.% | 1.4 | 3.8 | 1-2.3 | 1.3 |

MINERAL AND "CRYSTALLINE" LITHIC FRAGMENTS: The variance of the main minerals of the basaltic is somewhat larger in the soil than in the crystalline rocks, reflecting a larger variety of rocks. However, among the lithic fragments are also, like in the Apollo XI "soil", some rather exotic types, e.g. the so-called microanorthositic ones and fragments resembling rock #12013. The latter also contains zirkon and two phosphates, Cl-apatite ($<$1% Ce) and a Cl-F free Ca-phosphate with $\sim$12% REE ($\sim$5% Ce, $\sim$1% Pr, $\sim$2% Nd, $\sim$1% Gd, $\sim$1% La and $\sim$1% Y). The zirkon ($ZrSiO_4$) in these fragments contain 0.8% Hf. Unfortunately, no such samples (and of course not #12013) was made available for Pb-dating of the zirkons with the ion-probe. One basaltic fragment, Fig. 2, shows opaque shock veins analogous to those observed in many chondrites. The dark glass(?) is of the high Fe type resembling analyses 1 and 2 in Table 3.

GLASSES: Some 80 analyses of various glasses are plotted in Figs. 3 and 4. Three distinct groups occur; typical analyses are given in Table 3.

Table III. Typical Apollo XII glasses - Chemical composition and norm

| | | | | | | |
|---|---|---|---|---|---|---|
| $SiO_2$ | 47.1 | 45.8 | 49.6 | 49.6 | 45.1 | 44.9 |
| $Al_2O_3$ | 8.6 | 9.0 | 15.1 | 15.8 | 24.5 | 23.5 |
| FeO | 23.9 | 21.4 | 11.1 | 10.8 | 5.6 | 5.8 |
| MgO | 6.7 | 9.7 | 7.8 | 8.2 | 9.2 | 9.9 |
| CaO | 9.9 | 10.5 | 10.8 | 10.6 | 15.2 | 15.0 |
| $Na_2O$ | 0.34 | 0.31 | 1.05 | 1.00 | 0.12 | 0.11 |
| $K_2O$ | 0.26 | 0.22 | 0.83 | 0.82 | 0.1 | 0.1 |
| $TiO_2$ | 4.6 | 3.6 | 2.1 | 1.7 | 0.3 | 0.3 |
| Q | 2.2 | | 1.9 | 1.4 | | |
| OR | 1.5 | 1.3 | 4.9 | 4.9 | | 0.1 |
| AB | 2.9 | 2.6 | 8.9 | 8.5 | 1.0 | 0.9 |
| AN | 21.2 | 22.5 | 34.0 | 36.2 | 66.3 | 63.6 |
| DI | 23.7 | 24.8 | 16.1 | 13.5 | 7.3 | 8.7 |
| HY | 41.5 | 34.5 | 28.9 | 31.1 | 13.3 | 12.5 |
| OL | | 8.3 | | | 11.7 | 13.2 |
| IL | 8.8 | 6.8 | 3.9 | 3.3 | 0.5 | 0.5 |

The type with high alkali and intermediate Fe-Al seems different from any Apollo XI glasses, but Fig. 4 shows similar but weaker anticorrelation between Al and Ti, although the Ti content is generally lower. The high alkali glasses are probably also mostly impact produced; if from the local soil, this soil must contain a substantial part of material similar to rock 12013 or some of its components (Laul et al., Earth Planet. Sci. Lett., Vol. 2, No. 9, 1970). The trace element content, see section 2 below, supports this suggestion.

CHONDRULES: Many glass beads of different composition (note that there are no spheres with high alkalis, Fig. 3) show devitrification textures, reminding one of so-called radiating chondrules. Although the crystallites are often olivine and pyroxene, plagioclase also occurs, reflecting the difference in bulk composition between lunar spheres and chondrules and their respective parent materials. A few glass spheres have olivine and/or pyroxene phenocrysts and resemble porphyritic chondrules. In one case a slightly zoned, 44-46% FeO, 24-22% MgO and 0.5 CaO, was found in a glass with 21% FeO, 7% MgO and 45% $SiO_2$. Apparently olivine precipitated rapidly at around 1400°C.

Breccia fragments. Some of these fragments, consisting mostly of the same mineral and rock fragments as the soil, are cemented with dark brown glass of the high alkali type, analyses 3 and 4 in Table 3. These glasses as mentioned above must contain some of the components of rock 12013, (Earth Planet. Sci. Lett., Vol. 2, No. 9, 1970). Like rock 12013 they were apparently formed by welding of the constituents in a hot cloud, probably as impact-ignimbrite.

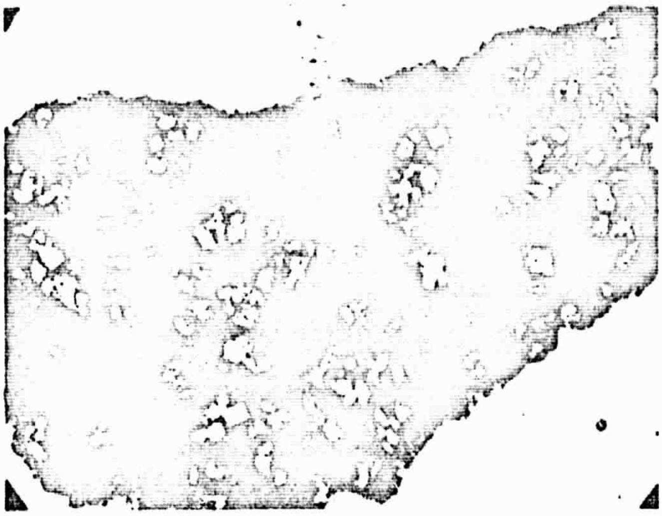


Fig. 1. Polished thin section 12045,6. Length ~1 cm. (see text)

Fig. 2. Basaltic fragment with black, opaque shock veins. Length of section ~0.4 mm.

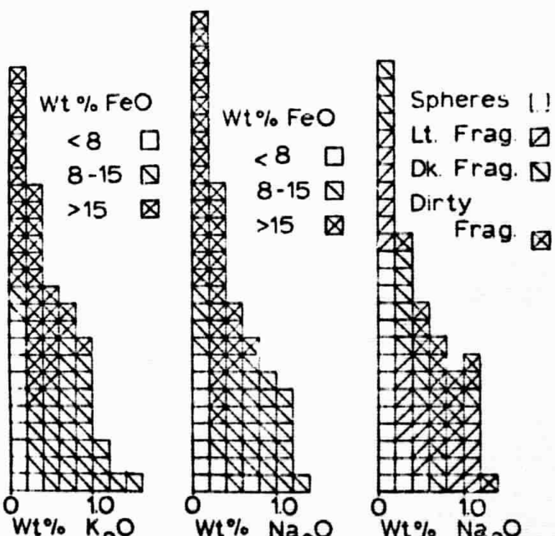



Fig. 3. Alkali content of 80 Apollo XII glasses with different FeO content and "morphology".

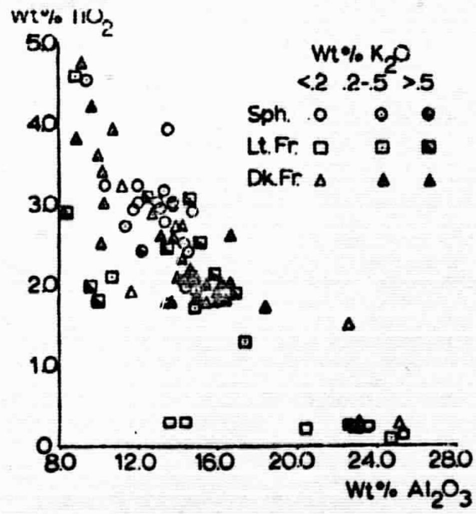



Fig. 4. $Al_2O_3$ versus $TiO_2$ content in 80 Apollo XII glasses.

## Section II, Ion Microprobe Mass Analysis

The trace and major element abundances of selected glasses and individual grains of the major silicate phases of Apollo 12 fines material have been analyzed with the ion microprobe mass analyzer and compared to similar analyses made on Apollo 11 fines material (Andersen et al, 1970). Two rock thin sections (12053, 86 and 12045, 6) and three grain mounts (12057, 46-10F; 12032, 46b and 12032, 46-6) prepared and analyzed with the electron microprobe at the Smithsonian Institution were studied in this investigation.

In general the trace element contents of the individual olivine, clinopyroxene and plagioclase grains in the Apollo 11 and 12 fines materials studied reflect the abundance trends reported for the bulk chemical analyses of these materials (LSPET, 1970). Figure 5 compares the trace element contents of single olivine and plagioclase phenocrysts from an Apollo 12 basalt with similar minerals from an Apollo 11 basalt and an "anorthositic-like" fragment (Reid, 1970). Ti is less abundant and Fe, Mg, Co, V, Cr, Mn, Al, Ca, Na and K are more abundant in the Apollo 12 than in the Apollo 11 material. The olivine of the "anorthositic-like" fragment appears to be enriched in Na, K, B and Li compared to the olivine grains of the other two rocks.

The variability of trace element abundances within the olivine mineral group could only be studied in the Apollo 12 material because of the scarcity of olivine phenocrysts in Apollo 11 fines material and the limited amount of material made available to these studies. Five olivine analyses from Apollo 12 are given in Table V. Analyses #32 and #36 are from two olivine grains in a dense, black, fine-grained matrix, and #6, #31 and #16 represent olivine grains from three areas with different textures in a single basalt thin section.

These analyses show that B, Na and K vary considerably in abundance and span the entire concentration range illustrated in Figure 5 for these elements. Li, however, does not show such a variation and appears to be enriched in the olivine of the "anorthositic-like" fragment. It is noted that in this fragment Li is more concentrated in the olivine than in the plagioclase.

Figure 6 illustrates the element distribution across a zoned clinopyroxene from Apollo 12. the grain has a core of pigeonite surrounded by sub-calcic augite that is rimmed with a pyroxene of an intermediate composition. It is observed that practically all the trace elements analyzed have preferentially entered the augite phase. Sr is the only exception noted. An analysis of a grain of the iron analog of pyroxmangite from 12053, 86 is given in Table IV.

Table IV. Composition of Fe-Pyroxmangite (ppm Atomic)

| | | | | | |
|---|---|---|---|---|---|
| Li | 5 | K | 93 | Mn | 1877 |
| Na | 568 | Ca | 4.50% | Co | 32 |
| Mg | 1.20% | Ti | 3327 | Sr | 18 |
| Al | 2.25% | V | 10 | Y | 15 |
| Si | 18.88% | Cr | 274 | Zr | 17 |
| P | 3 | Fe | 12.52% | | |

Nine Apollo 12 glasses were analyzed in this investigation and their compositions are represented by the four analyses given in Table VI. They are compared to an analysis of an Apollo 11 glass which is representative of four other glasses analyzed in that material. It can be seen that the 12 material is quite variable with generally increased abundances of the alkali and rare earth elements. These elements appear to be covariant and show increased concentration in the lighter colored, low Fe, low Mn glasses. The increased concentrations of Li, B, Na, K, Rb, Y, Zr, Ba, La and Ce in some of the Apollo 12 glasses suggest that they incorporate portions of rocks such as 12013.

The greatly increased concentrations of P, K, Rb, Y, Zr, Ba, La and Ce in the glasses over their concentrations in the major silicate phases indicate the presence of minor mineral phases of increased concentrations of these elements. Such minerals were sought in the intergrain areas with the ion microprobe but none were found in the limited amount of Apollo 12 material available to these investigations. We were successful in finding such accessory minerals in Apollo 11 material, however (Andersen et al, 1971). The following phases were analyzed: a Hf bearing Zr oxide; a Y, Fe, rare earth rich Ca phosphate; a K rich glass; and a Ti, Zr, Y rare earth silicate. The latter was found as an inclusion in the plagioclase of the "anorthositic-like" fragment (10085/7-6) and the others were found to coexist in a Type B lunar basalt (10085/17-26). These phases are of particular importance because they are found to contain high concentrations of Th, U and radiogenic Pb. The K rich glass did not contain significant concentrations of these elements. Apparently, major portions of these elements reported on a bulk chemical basis for the Apollo 11 fines material are heterogeneously distributed throughout the rocks in minor mineral phases such as those described above. Pb 207/206 ratios measured with the ion microprobe in these phases including that in the anorthositic-like fragment indicate that the crystalline phases within the fines material have approximately the same apparent age as the coarser crystalline rocks, i.e. 4.1 b.y.

References:

Andersen, C. A., Hinthorne, J. R. and Fredriksson, K. (1970) Ion microprobe analysis of lunar material from Apollo 11. Proceed. of the Apollo 11 Lunar Science Conf., Vol. 1, Pergamon Press, N.Y., pp 159-167.

Andersen, C. A., Hinthorne, J. R. and Fredriksson, K. (1971) Manuscript in preparation.

LSPET (1970) Preliminary examination of lunar samples from Apollo 12. Science 167, 1325-1339.

Reid, A. (1970) NASA, Houston, Personal communication.

Figure 5

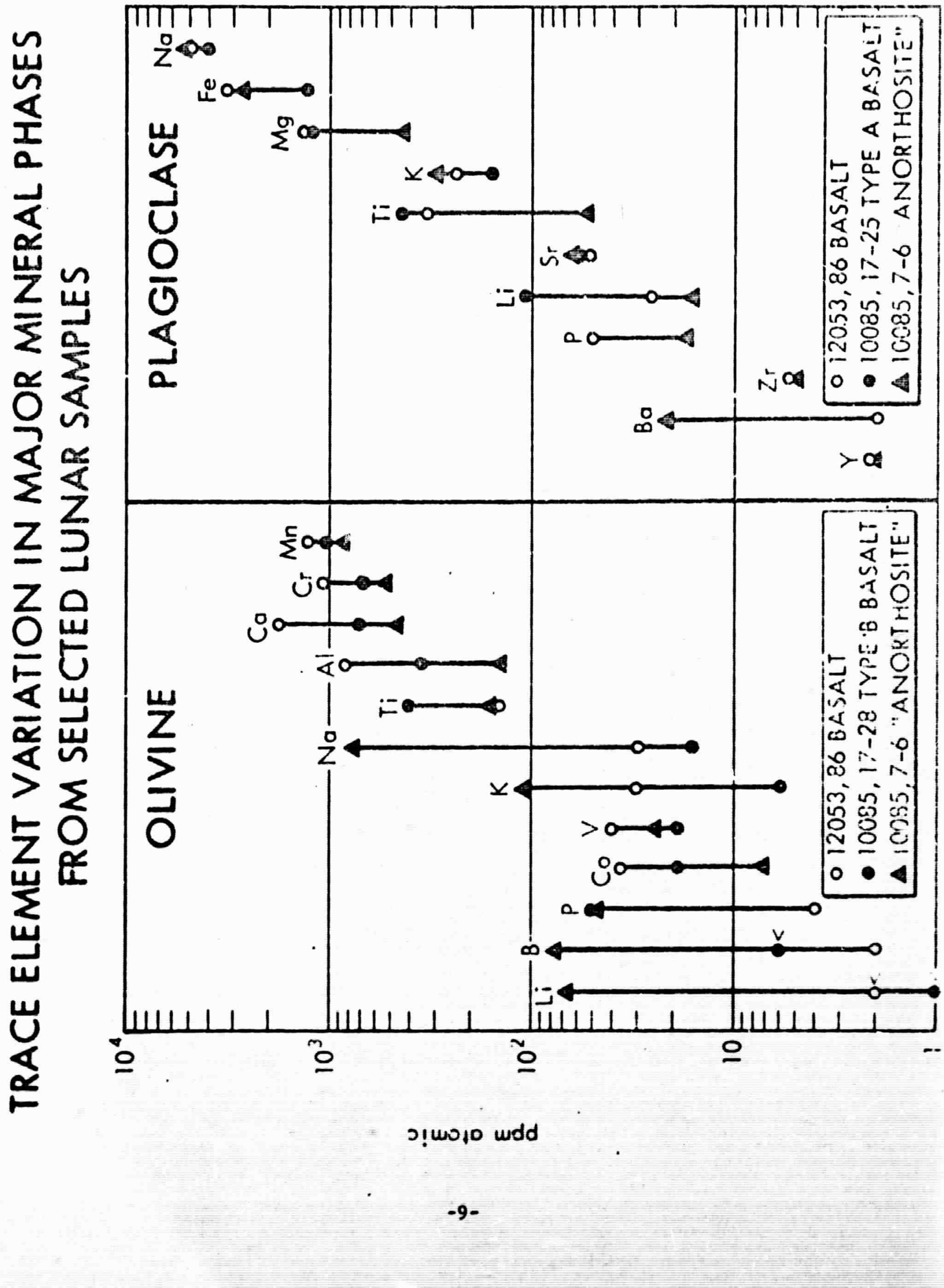

TRACE ELEMENT VARIATION IN MAJOR MINERAL PHASES
FROM SELECTED LUNAR SAMPLES
ppm atomic
$10^4$
$10^3$
$10^2$
10
1
OLIVINE
Li
B
P
Co
V
K
Na
Ti
Al
Ca
Cr
Mn
○ 12053, 86 BASALT
● 10085, 17-28 TYPE B BASALT
▲ 10085, 7-6 "ANORTHOSITE"
PLAGIOCLASE
Y
Ba
Zr
P
Li
Sr
Ti
K
Mg
Fe
Na
○ 12053, 86 BASALT
● 10085, 17-25 TYPE A BASALT
▲ 10085, 7-6 "ANORTHOSITE"

Table V

# APOLLO 12 OLIVINE ANALYSES BY ION MICROPROBE MASS SPECTROMETRY

(ppm atomic)

| | 12032, 46-6 | | 12045, 6 | | |
|---|---|---|---|---|---|
| | #32 | #36 | $A_1$ #6 | $C_1$ #31 | $A_2$ #16 |
| Li | 4 | < .5 | 6 | 7 | 9 |
| B | 5 | 32 | 13 | 68 | 85 |
| Na | 43 | 216 | 117 | 305 | 877 |
| Mg | 20.0% | 20.65% | 18.95% | 16.92% | 19.90% |
| Al | 815 | 811 | 384 | 540 | 855 |
| Si | 14.25% | 14.25% | 14.27% | 14.26% | 14.24% |
| P | 20 | 2.7 | 37 | 12 | 21 |
| K | 20 | 8.8 | 33 | 127 | 610 |
| Ca | 915 | 1530 | ~1200 | 1230 | 880 |
| Ti | 118 | 171 | 250 | 131 | 207 |
| V | 37 | 48 | 27 | 27 | 31 |
| Cr | 1030 | 2160 | 829 | 717 | 921 |
| Mn | 1280 | 1040 | 1180 | 1453 | 1029 |
| Fe | 8.14% | 7.33% | 9.25% | 11.21% | 8.19% |
| Co | 66 | 44 | 56 | 52 | 54 |
| Sr | <3 | <1 | <3 | <3 | <4 |
| Y | 1 | < .5 | < .5 | 1 | 2 |
| Zr | <2 | <1.6 | 0.1 | 4 | 5 |

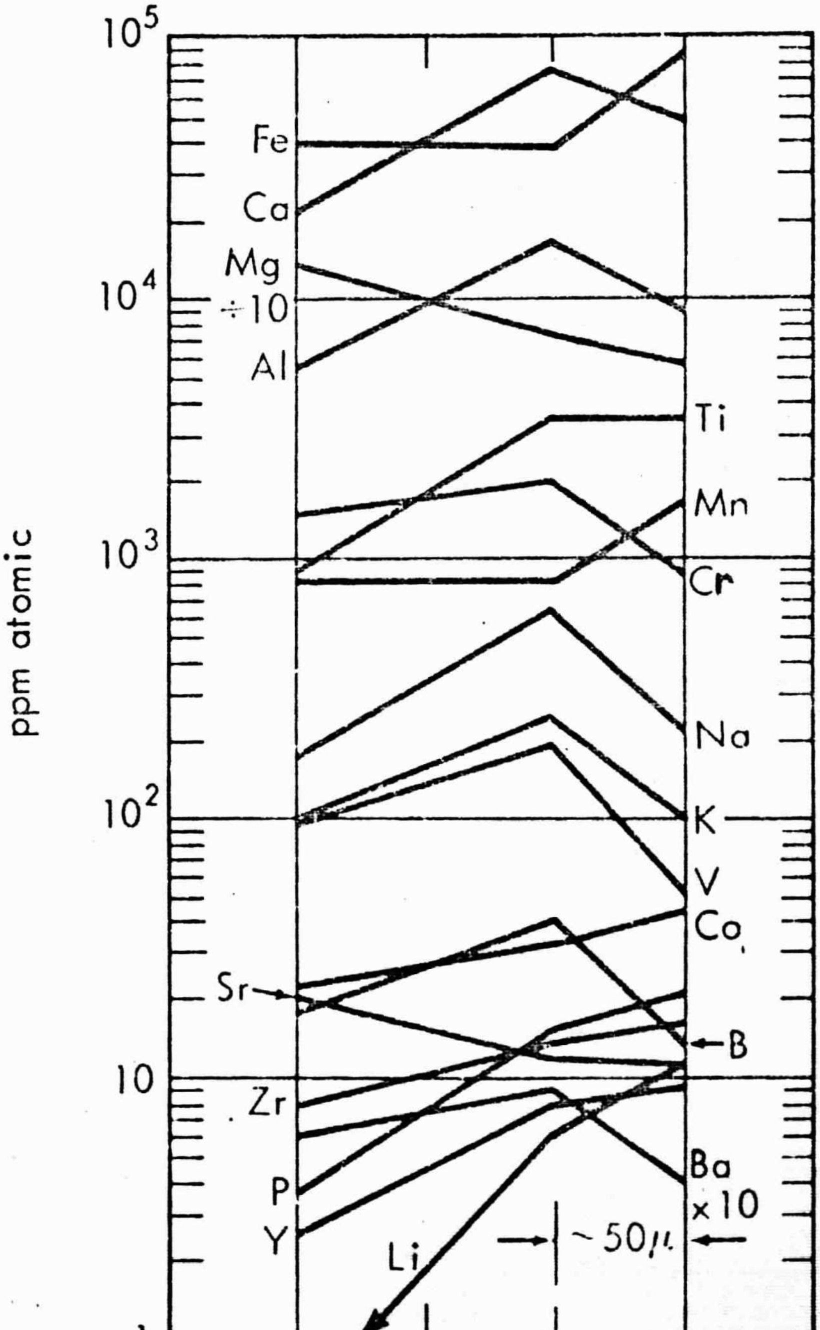
Table VI

# TRACE ELEMENT ANALYSES OF SELECTED LUNAR GLASSES
(ppm atomic)

| | APOLLO 12 | | | | APOLLO 11 |
|---|---|---|---|---|---|
| | 57,46-10F #34 CLEAR FRAGMENT | 32,46-B #18 TURBID FRAGMENT | 57,46-10F #22 BROWN SPHERULE | 57,46-10F #39 BLACK FRAGMENT | 85,17-17 #5 GREEN CRUST GLASS |
| Li | 115 | 215 | 94 | 24 | 33 |
| B | 73 | 32 | 13 | 22 | 30 |
| Na | 11060 | 8460 | 4130 | 2580 | 335 |
| P | 368 | 495 | 17 | 56 | 212 |
| K | 8840 | 8470 | 3330 | 1120 | 815 |
| Ti | 7330 | 5900 | 6890 | 13000 | 19000 |
| V | 82 | 51 | 49 | 80 | 59 |
| Cr | 877 | 770 | 97 | 1720 | 1170 |
| Mn | 512 | 763 | 690 | 1240 | 1040 |
| Ni | 1070 | 1020 | 1275 | 324 | 1000 |
| Co | 45 | 55 | 33 | 35 | 30 |
| Rb | 13 | 11 | 5 | 4 | 5 |
| Sr | 73 | 82 | 85 | 50 | 42 |
| Y | 93 | 139 | 87 | 15 | 27 |
| Zr | 540 | 703 | 288 | 53 | 85 |
| Ba | 161 | 267 | 226 | 16 | 67 |
| La | 24 | 36 | 20 | 4 | < 2 |
| Ce | 42 | 97 | 54 | 4 | 7 |

Figure 6

# ELEMENT DISTRIBUTION IN ZONED CLINOPYROXENE, SAMPLE 12032, 46-6



## APPENDIX I

## GLASSES

GLASS-SPHERULES

| Sample No. | Gr. | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | FeO | Total | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12057,46-10 | 22 | 0.41 | 7.60 | 15.91 | 50.03 | 0.47 | 10.61 | 1.94 | 14.17 | 101.14 | Clear-light |
| 12001,64-3 | 5 | $<$0.1 | 10.8 | 12.6 | 39.2 | 0.14 | 12.2 | 3.2 | 17.9 | 96.14 | clear-dark |
| | 7 | 0.1 | 12.1 | 12.5 | 41.6 | 0.16 | 12.2 | 3.0 | 17.7 | 99.36 | clear-lighter dark |
| | 9 | 0.06 | 8.8 | 14.5 | 41.2 | 0.31 | 12.7 | 3.0 | 18.0 | 98.57 | clear-dark |
| | 11 | 0.10 | 8.0 | 10.8 | 43.5 | 0.16 | 12.0 | 3.2 | 20.2 | 97.96 | clear-lt. dark-oblong |
| | 12 | 0.20 | 10.9 | 14.1 | 44.4 | 0.17 | 11.2 | 2.8 | 18.1 | 101.87 | dark-opaque inclusions |
| | 13 | 0.22 | 10.7 | 12.9 | 44.7 | 0.60 | 11.4 | 2.4 | 16.9 | 99.82 | very dark-mottled |
| | 15 | $<$0.10 | 10.1 | 14.5 | 42.3 | 0.11 | 13.3 | 2.9 | 16.7 | 100.01 | clear-lighter dark |
| | 16 | $<$0.10 | 10.5 | 15.0 | 40.1 | 0.22 | 13.4 | 2.5 | 16.9 | 98.72 | clear-dark |
| | 24 | $<$0.10 | 10.8 | 13.7 | 40.2 | 0.16 | 12.9 | 3.0 | 18.7 | 99.56 | clear-dark |
| | 29 | 0.19 | 8.7 | 12.2 | 46.6 | 0.19 | 11.3 | 3.0 | 18.6 | 100.78 | clear-lighter dark |
| | 36 | 0.04 | 10.7 | 13.7 | 43.8 | 0.17 | 11.8 | 3.8 | 18.7 | 102.71 | clear-dark |
| | 39 | 0.02 | 9.8 | 15.5 | 44.0 | 0.19 | 12.2 | 2.9 | 16.9 | 101.51 | clear-dark |
| | 44 | 0.04 | 10.8 | 16.2 | 41.0 | 0.17 | 12.8 | 3.3 | 17.6 | 101.91 | clear-lighter dark |
| | 45 | 0.23 | 10.2 | 13.5 | 45.8 | 0.25 | 10.9 | 3.9 | 18.1 | 102.88 | Clear-lighter dark |
| | 46 | 0.12 | 12.4 | 11.6 | 45.9 | 0.21 | 10.8 | 2.7 | 19.5 | 103.23 | clear-lighter dark |
| | 52 | 0.25 | 7.2 | 10.6 | 44.6 | 0.22 | 11.9 | 4.5 | 21.8 | 101.3 | clear-inclusions |

## GLASS-FRAGMENTS

| Sample No. | Gr. | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | FeO | Total | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **<8 % FeO** | | | | | | | | | | | |
| 12057,46-10 | 14 | 0.18 | 8.32 | 27.41 | 45.53 | 0.05 | 15.39 | 0.29 | 5.88 | 103.05 | clear-light |
| 12001,64-3 | 2 | 0.08 | 9.3 | 24.0 | 43.4 | 0.10 | 15.9 | 0.27 | 6.5 | 99.55 | clear-light |
| | 3 | 0.24 | 9.4 | 24.5 | 45.8 | 0.14 | 15.8 | 0.28 | 6.3 | 102.46 | clear-light |
| | 4 | <0.1 | 9.6 | 23.8 | 42.3 | 0.14 | 16.4 | 0.26 | 6.4 | 99.00 | clear-light |
| | 6 | 0.08 | 8.4 | 26.4 | 42.3 | 0.23 | 17.3 | 0.25 | 4.7 | 99.66 | clear-light |
| | 33 | 0.05 | 7.5 | 26.0 | 45.6 | 0.17 | 14.9 | 0.28 | 6.3 | 100.80 | clear-light |
| | 41 | 0.60 | 7.8 | 24.2 | 45.8 | 0.18 | 15.2 | 0.24 | 6.0 | 100.02 | dark to very dk. |
| | 48 | 0.27 | 9.0 | 24.3 | 46.1 | 0.14 | 15.4 | 0.31 | 7.2 | 102.72 | clear to mottled dk. |
| **>15 % FeO** | | | | | | | | | | | |
| 12057,46-10 | 24 | 0.67 | 9.00 | 14.15 | 47.47 | 0.36 | 10.97 | 2.89 | 15.95 | 101.46 | clear-light dk.w/incl. |
| | 25 | 0.36 | 10.65 | 11.15 | 45.50 | 0.23 | 10.58 | 3.62 | 21.44 | 103.53 | clear-dk. w/fl & incl. |
| | 39 | 0.31 | 7.85 | 12.39 | 47.69 | 0.20 | 11.73 | 3.21 | 20.30 | 103.68 | very dark |
| | 48 | 0.38 | 6.51 | 10.31 | 46.59 | 0.27 | 9.98 | 4.61 | 24.04 | 102.69 | clear mottled lt.-dk. |
| 12032,46-6 | (E) | 0.28 | 6.75 | 10.92 | 47.61 | 0.53 | 11.59 | 3.94 | 22.61 | 104.23 | dark w/incl. |
| 12001,64-3 | 1 | 0.26 | 9.7 | 8.9 | 42.5 | 0.95 | 11.1 | 2.9 | 21.4 | 97.71 | dark crust w/incl. |
| | 10 | 0.36 | 9.0 | 10.7 | 44.9 | 0.31 | 11.6 | 2.5 | 18.8 | 98.17 | clear-lighter dark |
| | 28 | 0.49 | 8.7 | 10.1 | 47.4 | 0.26 | 11.1 | 3.0 | 20.1 | 101.15 | clear-dark |
| | 34 | 0.54 | 11.1 | 11.2 | 47.4 | 0.45 | 10.1 | 3.6 | 19.2 | 103.59 | clear-dark w/incl. |
| | 37 | 0.16 | 6.6 | 10.7 | 45.9 | 0.20 | 11.1 | 5.4 | 21.7 | 101.76 | clear-dk. to very dk. |
| | 42 | 0.55 | 8.1 | 13.6 | 48.6 | 0.53 | 10.7 | 2.6 | 16.3 | 100.98 | very dark |
| | 49 | 0.48 | 9.1 | 13.8 | 46.1 | 0.46 | 11.4 | 2.5 | 16.0 | 99.84 | clear-lt. dk. w/incl. |

GLASS-FRAGMENTS (continued)

8-15 % FeO

| Sample No. | Gr. | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $K_2O$ | CaO | $TiO_2$ | FeO | Total | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12057,46-10 | 8 | 0.39 | 7.92 | 18.11 | 50.54 | 1.46 | 11.00 | 2.00 | 11.39 | 102.81 | clear-dark |
| | 18 | 1.01 | 7.76 | 17.78 | 49.18 | 0.84 | 10.97 | 1.77 | 11.01 | 100.32 | clear-light w/incl. |
| | 23 | 1.37 | 6.90 | 17.07 | 50.93 | 0.49 | 11.43 | 1.83 | 11.64 | 101.66 | very dark |
| | 27 | 0.86 | 8.72 | 16.56 | 48.85 | 0.76 | 11.02 | 2.51 | 12.41 | 101.69 | clear-lt. dk. w/incl. |
| | 29 | 0.92 | 8.03 | 17.33 | 49.32 | 0.83 | 10.86 | 2.05 | 12.49 | 101.83 | clear-light |
| | 34 | 1.09 | 7.27 | 17.66 | 49.31 | 0.86 | 11.04 | 2.10 | 11.23 | 100.56 | clear-mottled light |
| | 44 | 0.47 | 7.42 | 16.49 | 50.04 | 0.62 | 11.27 | 2.08 | 12.08 | 100.47 | clear-dark w/incl. |
| | 51 | 0.56 | 11.55 | 19.26 | 47.00 | 0.24 | 11.59 | 1.32 | 10.38 | 101.90 | clear-lighter dark |
| | 54 | 1.05 | 7.80 | 18.31 | 49.93 | 0.68 | 11.11 | 1.94 | 10.67 | 101.49 | clear-lighter dark |
| 12032,46-B | X | 0.75 | 7.59 | 18.24 | 50.75 | 0.84 | 10.99 | 1.94 | 11.55 | 102.65 | clear-lt. to dk. w/incl. |
| | Y | 0.68 | 7.94 | 15.52 | 49.73 | 0.76 | 10.80 | 2.15 | 11.66 | 99.24 | clear-lt. to dk. w/incl. |
| | Z | 1.05 | 7.85 | 17.16 | 50.21 | 0.62 | 10.73 | 2.22 | 12.16 | 102.00 | clear-lt. to dk. w/incl. |
| 12032,46-4(24-33) | | 0.97 | 7.47 | 17.77 | 49.23 | 0.95 | 10.81 | 1.89 | 11.44 | 100.53 | cl.-lt. to dk. fl. crust |
| 12001,64-5 | 8 | 0.17 | 10.0 | 15.9 | 49.4 | 0.28 | 11.2 | 1.8 | 13.8 | 102.55 | clear-light |
| | 21 | 0.42 | 7.9 | 15.8 | 48.8 | 1.05 | 12.0 | 1.8 | 11.5 | 99.27 | very dark |
| | 22 | 0.50 | 9.0 | 13.1 | 46.4 | 0.63 | 11.9 | 3.1 | 14.3 | 98.93 | clear-light |
| | 23(1t) | 0.84 | 8.0 | 15.5 | 47.9 | 0.78 | 11.6 | 2.1 | 12.2 | 98.92 | clear-lighter dark |
| | 26 | 0.35 | 7.9 | 14.2 | 48.8 | 1.39 | 11.4 | 1.8 | 12.5 | 98.34 | very dark |
| | 27 | 1.19 | 5.8 | 20.2 | 47.4 | 0.64 | 10.0 | 1.8 | 11.5 | 98.53 | very dark |
| | 30 | 1.06 | 7.7 | 13.4 | 51.3 | 0.95 | 10.5 | 2.6 | 13.9 | 101.41 | clear-dark |
| | 31 | 0.49 | 9.5 | 14.2 | 51.4 | 0.23 | 11.0 | 2.2 | 13.5 | 102.52 | clear-light |
| | 32 | 1.06 | 7.5 | 14.8 | 49.8 | 0.92 | 10.9 | 3.1 | 13.0 | 101.08 | clear-lighter dark |
| | 35 | 0.72 | 6.6 | 16.4 | 52.2 | 1.04 | 11.2 | 1.8 | 11.8 | 101.76 | dark to very dark |
| | 38 | 0.51 | 9.2 | 15.3 | 50.7 | 0.28 | 11.1 | 2.0 | 12.4 | 101.49 | clear-light |
| | 40 | 0.81 | 8.6 | 14.8 | 49.4 | 0.56 | 11.1 | 2.5 | 13.7 | 101.47 | clear-light |
| | 47 | 0.94 | 7.6 | 15.1 | 51.1 | 0.92 | 10.6 | 2.3 | 13.4 | 101.96 | clear-lighter dark |
| | 50 | 0.86 | 7.7 | 15.6 | 48.3 | 0.76 | 10.6 | 2.4 | 13.6 | 99.82 | clear-lighter dk. w/incl. |

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