# 12001 - 2216 grams
# 12003 - ~ 300 grams
Reference Soil

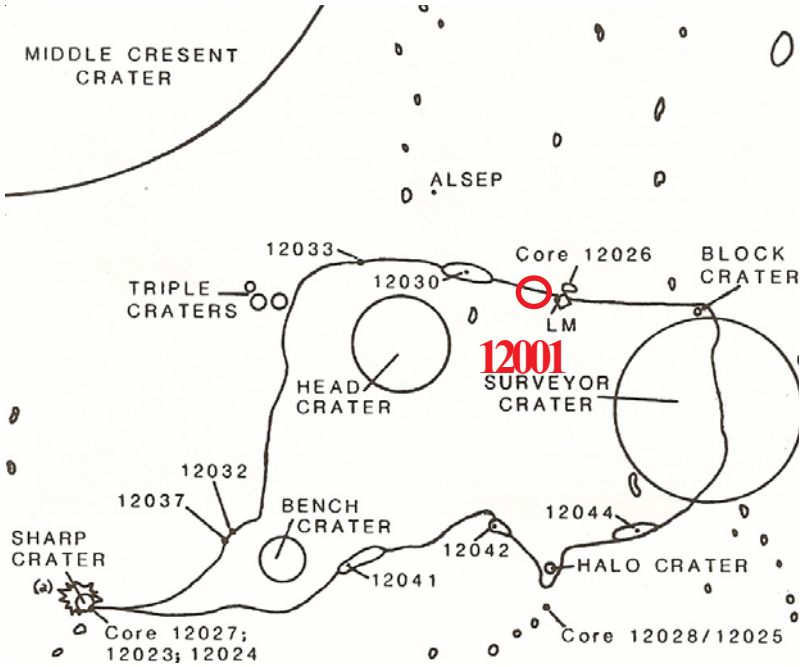



*Figure 1: Map of Apollo 12 site showing location of LM and soil samples.*

*Figure 2: Photo from LM of area where 12001 - 12003 was collected. AS12-47-6960.*

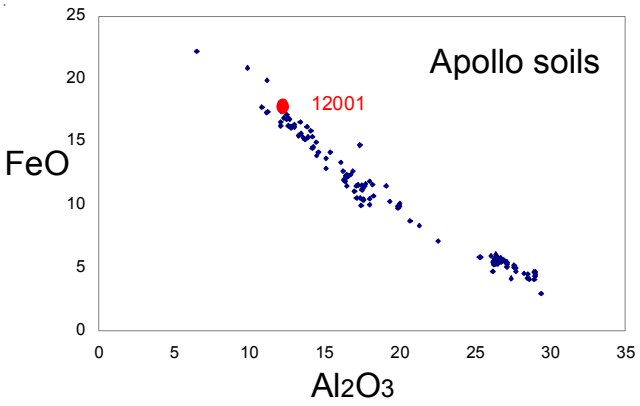



*Figure 3: Composition of 12001 compared with that of other Apollo soil samples.*

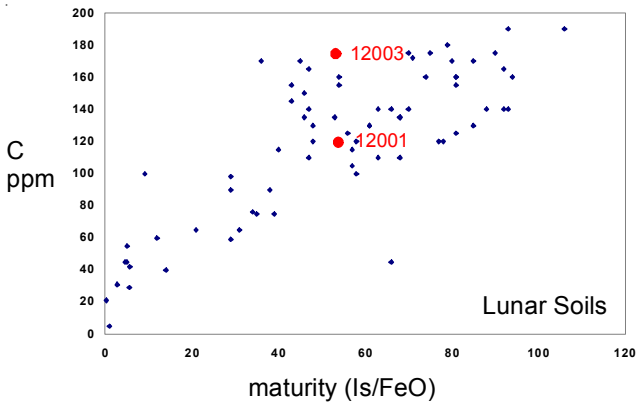



*Figure 4: Carbon content and maturity index for 12001 and 12003.*

## Mineralogical Mode

*Frondel et al. 1971*

| | 12001 | 12003 |
|---|---|---|
| Olivine + Pyroxene | 61.8 % | 63.4 |
| Plagioclase | 15.7 | 17.2 |
| Opaques | 9.5 | 9.6 |
| Glass, angular | 10.8 | 6.1 |
| Glass, rounded | 2 | 3.5 |
| Silica | 0.1 | 0.3 |

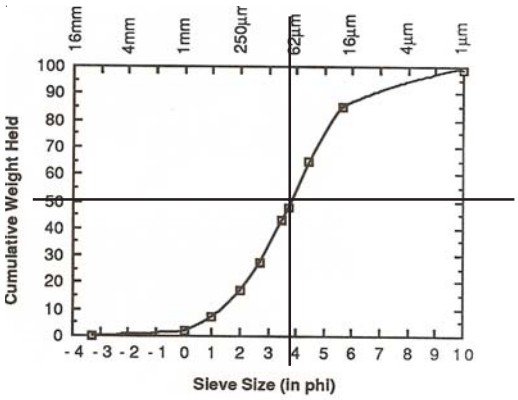
## Modal Mineralogy of 12001

*Simon et al. 1981*

| | |
|---|---|
| LITHIC FRAGMENTS | |
| Mare basalt | 12.9 |
| Highland Component | |
| ANT | 1 |
| LMB | 0.1 |
| Feld. basalt | 0.5 |
| RNB/POIK | 2.3 |
| FUSED SOIL COMPONENT | |
| DMB | 9.5 |
| Agglutinate | 40.1 |
| MINERAL FRAG | |
| Mafic | 18.3 |
| Plag | 3.9 |
| Opaque | 0.2 |
| GLASS FRAG | |
| Orange/black | 0.5 |
| Yellow/Green | 2.8 |
| Brown | 1.5 |
| Clear | 1 |
| MISC | |
| Devitrified glass | 5 |
| Others | 0.5 |

## Introduction

The bulk soil sample 12001 – 12003 was collected about 35 meters from the Lunar Module (figures 1 and 2). It was returned under vacuum in the Apollo Lunar Sample Return Container (ALSRC). 12003 is a portion split off during initial processing and studied under nitrogen (Warner 1970). 12001 is the less that 1 mm fraction, while 12003 is apparently made up of the




average grain size = 73 microns

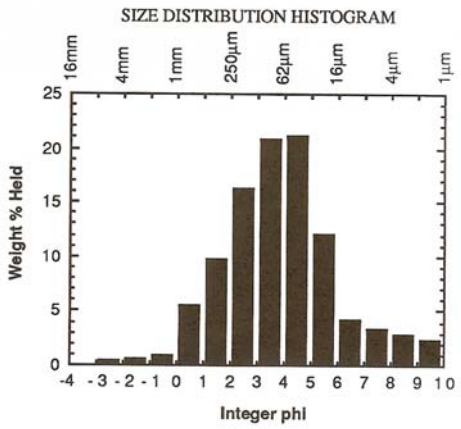



*Figure 5a: Grain size distribution for 12001 (Graf 1993, from data by McKay et al.*

## Mineralogical Mode for 12001

*Labotka et al. 1980*

| | 90-20 micron | 20-10 micron |
|---|---|---|
| Lithic clasts | 2.9 | |
| Agglutinates | 21.3 | 4.7 |
| Pyroxene | 27.5 | 31 |
| Plagioclase | 17.4 | 18 |
| Olivine | 5.3 | 10.2 |
| Silica | 0.8 | 1.5 |
| Ilmenite | 1.2 | 2.7 |
| Mare glass | 18.4 | 24.1 |
| Highland glass | 4.7 | 6.4 |

greater than 1 mm particles, mixed with some friable material found at the bottom of the ALSRC.

This sample was taken at the end of the first EVA (Shoemaker et al. 1970). 12001 is one of the "reference soils" studied by Papike et al. (1982). However, 12070 has been better studied.

## Petrography

12001 is one of the reference soils (Labotka et al. 1980), who studied it as a function of grain size.

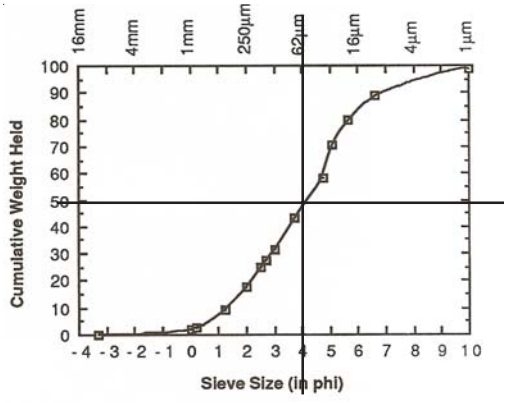
The maturity index ($I_s$/FeO) for 12001 and 12003 are 56 and 57 respectively (Morris 1987). The average grain size of 12001/12003 is about 65 microns (figure 5 and 6), which is relatively mature.

Frondel et al. (1971) determined the mineral mode but did not specify agglutinates. Simon et al. (1981) determined the mode for the coarse fraction and Labotka et al. (1980) determined the fine fractions. There are about 40% agglutinates in the coarse grain fraction, but they become unrecognizable in the finer fractions.

Marvin et al. (1971), Simon and Papike (1985) and Snape et al. (2011) described several large particles from 12001 and 12003.

Frondel et al. (1971) found that 0.06 wt. % metallic iron was attracted to a hand magnet (from a 10 gram split of 12001).

Numerous investigators reported on glass particles in 12001. Delano et al. (1981) reported on the trends in




average grain size = 60 microns

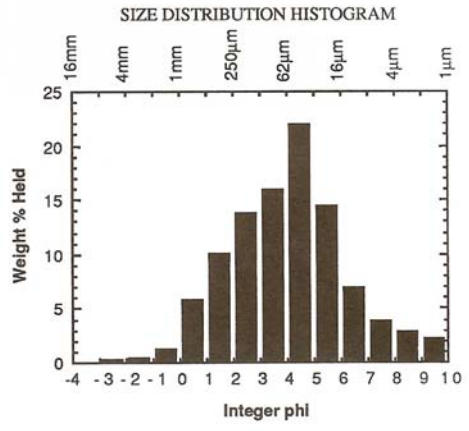
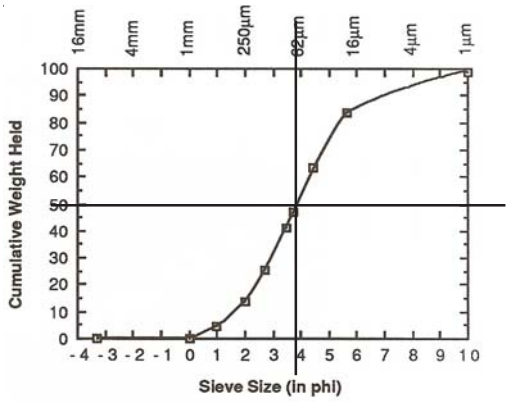



*Figure 5b: Grain size distribution for 12001 (Graf 1993, from data by King et al.*




average grain size = 66 microns

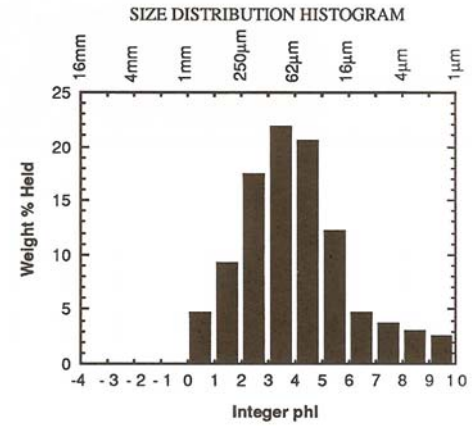



*Figure 6: Grain size distribution for 12003 (Graf 1993, from data by McKay et al.*

composition of Apollo 12 particles (mostly from 12070) and Stone et al. (1982) studied the magnetic properties of individual glass beads.

## Chemistry

Laul and Papike (1980) give the most definitive analysis (table 1 and figure 7). They find a higher content of REE in the finest fraction (<10 microns).

Moore et al. (1971) determined the carbon content of 12001 and 12003 as 120 ppm and 180 ppm, respectively. They also reported 110 and 85 ppm nitrogen. Kerridge et al. (1978) found 102 ppm C and 54 ppm N, while Norris et al. (1983) found 96 ppm carbon and 78 ppm nitrogen.

Analyses of 12001 should be compared with that of 12070, which has received more study.

## Cosmogenic isotopes and exposure ages

Begemann et al. (1972) reported the cosmic-ray-induced activity of $^{22}Na$, $^{26}Al$, $^{36}Cl$, $^{39}Ar$ and $^{54}Mn$ for 12001.

## Other Studies

Arrhenius et al. (1971) studied the frequency of grains with high fossil nuclear tracks in 12001 (and all other Apollo 12 soil and core samples)(see figure in section on 12070).

Norris et al. (1983) studied the isotopic composition of carbon and nitrogen as function of release temperature.

Eberhardt et al. (1972) found that the abundance of rare gas in this soil correlated strongly with grain size, showing that they are implanted in the outer layers of particles (figure 9 and 10).

Fechtig et al. (1977) studied the microcrater population on a glass surface of a coarse fine particle from 12001 (figure 11). Further investigations on one of these craters illustrate the Complexity of Nature (Nagel et al. 1978).

## Processing

The ALSRC contained 40 to 60 microns of gas pressure when returned to the LRL.

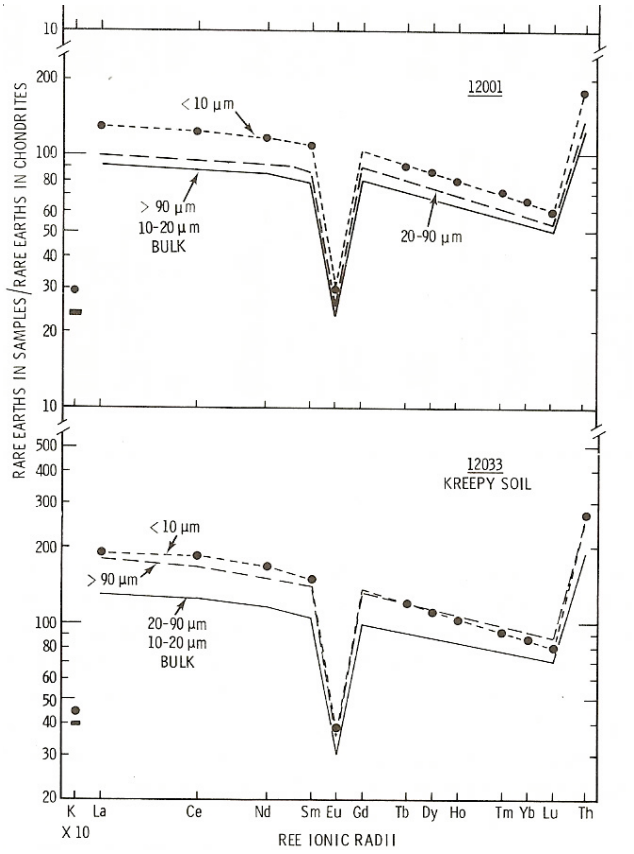



*Figure 7: Normalized rare-earth-element diagram for 12001 (and 12033 )(Laul and Papike 1981).*

## Table 1. Chemical composition of 12001.

| *reference* | Papike 82 | | Wanke71 | | Schnetzler71 | | Frondel71 | | | Kharkar71 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *weight* | Laul81 | | | | | | < 1 mm | < 0.037 | | ave. | |
| SiO2 % | 46 | (a) | 46.2 | (a) | | | 45.6 | 46.1 | (d) | | |
| TiO2 | 2.8 | (a) | 2.67 | (a) | | | 3 | 2.9 | (d) | 3.84 | (c ) |
| Al2O3 | 12.5 | (a) | 12.56 | (a) | | | 13.9 | 14.8 | (d) | | |
| FeO | 17.2 | (a) | 16.85 | (a) | | | 16.2 | 15.6 | (d) | 15.82 | (c ) |
| MnO | 0.22 | (a) | 0.22 | (a) | | | 0.21 | 0.19 | (d) | 0.21 | (c ) |
| MgO | 10.4 | (a) | 9.8 | (a) | | | 10.2 | 9.05 | (d) | | |
| CaO | 10.9 | (a) | 8.54 | (a) | | | 10.25 | 10.81 | (d) | 11.76 | (c ) |
| Na2O | 0.48 | (a) | 0.43 | (a) | | | 0.45 | 0.45 | (d) | 0.46 | (c ) |
| K2O | 0.26 | (a) | 0.25 | (a) | 0.24 | (c ) | 0.23 | 0.23 | (d) | | |
| P2O5 | | | | | | | 0.25 | 0.22 | (d) | | |
| S % | | | | | | | | | | | |
| *sum* | | | | | | | | | | | |
| | | | | | | | | | | | |
| Sc ppm | 40.2 | (a) | 38.1 | (a) | | | | | | 39 | (c ) |
| V | 110 | (a) | | | | | | | | | |
| Cr | 2805 | (a) | 2430 | (a) | | | 2053 | 1847 | (d) | 2430 | (c ) |
| Co | 42.5 | (a) | 38.3 | (a) | | | | | | 40 | (c ) |
| Ni | 190 | (a) | 310 | (a) | | | | | | | |
| Cu | | | 7.2 | (a) | | | | | | | |
| Zn | | | | | | | | | | | |
| Ga | | | 4.2 | (b) | | | | | | | |
| Ge ppb | | | | | | | | | | | |
| As | | | | | | | | | | | |
| Se | | | | | | | | | | | |
| Rb | | | *23?* | | 6.48 | (c ) | | | | | |
| Sr | 140 | (a) | 130 | | 145.5 | (c ) | | | | | |
| Y | | | | | | | | | | | |
| Zr | | | | | | | | | | | |
| Nb | | | | | | | | | | | |
| Mo | | | | | | | | | | | |
| Ru | | | | | | | | | | | |
| Rh | | | | | | | | | | | |
| Pd ppb | | | 9 | (b) | | | | | | | |
| Ag ppb | | | | | | | | | | 57 | (c ) |
| Cd ppb | | | | | | | | | | | |
| In ppb | | | 92 | (b) | | | | | | | |
| Sn ppb | | | | | | | | | | | |
| Sb ppb | | | | | | | | | | | |
| Te ppb | | | | | | | | | | | |
| Cs ppm | | | 0.53 | (b) | | | | | | | |
| Ba | 430 | (a) | 460 | (a) | 370 | (c ) | | | | | |
| La | 35.6 | (a) | 32.4 | (a) | | | | | | 32 | (c ) |
| Ce | 85 | (a) | 87 | (a) | 87.2 | (c ) | | | | 71 | (c ) |
| Pr | | | 10.8 | (a) | | | | | | | |
| Nd | 57 | (a) | 72 | (a) | 55.1 | (c ) | | | | | |
| Sm | 17.3 | (a) | 15 | (a) | 16.1 | (c ) | | | | 15.2 | (c ) |
| Eu | 1.85 | (a) | 1.8 | (a) | 1.78 | (c ) | | | | 1.82 | (c ) |
| Gd | | | 19.4 | (a) | 19.4 | (c ) | | | | | |
| Tb | 3.7 | (a) | 3.78 | (a) | | | | | | 3.1 | (c ) |
| Dy | 22 | (a) | 22.6 | (a) | 22.1 | (c ) | | | | 24.6 | (c ) |
| Ho | 5 | (a) | 5 | (a) | | | | | | | |
| Er | | | 14.5 | (a) | 12.6 | (c ) | | | | | |
| Tm | 1.8 | (a) | | (a) | | | | | | | |
| Yb | 13 | (a) | 11 | (a) | 12 | (c ) | | | | 12.6 | (c ) |
| Lu | 1.85 | (a) | 1.56 | (a) | 1.81 | (c ) | | | | 1.69 | (c ) |
| Hf | 11.8 | (a) | 13.3 | (a) | | | | | | 13.7 | (c ) |
| Ta | 1.5 | (a) | 1.4 | (a) | | | | | | 2 | (c ) |
| W ppb | | | 630 | (b) | | | | | | | |
| Re ppb | | | | | | | | | | | |
| Os ppb | | | | | | | | | | | |
| Ir ppb | | | 11 | (b) | | | | | | | |
| Pt ppb | | | | | | | | | | | |
| Au ppb | | | 2.6 | (b) | | | | | | 2.9 | (c ) |
| Th ppm | 5.4 | (a) | 5.5 | (a) | | | | | | | |
| U ppm | | | 1.67 | (a) | | | | | | 1.23 | (c ) |

*technique: (a) INAA, (b) RNAA, (c ) IDMS, (d) wet*

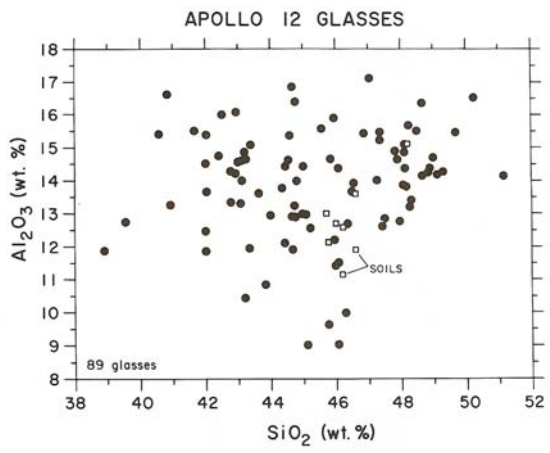



*Figure 8: Composition of 89 glass particles from Apollo 12 soil (Delano 1979).*

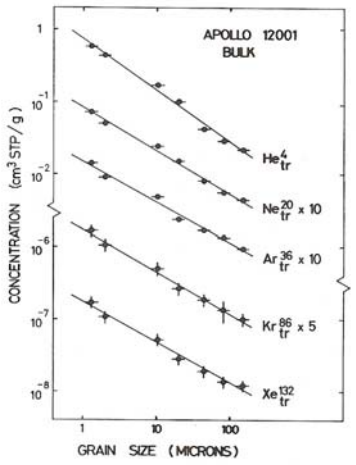



*Figure 9: Rare gas as function of grain size (Eberhardt et al. 1972).*

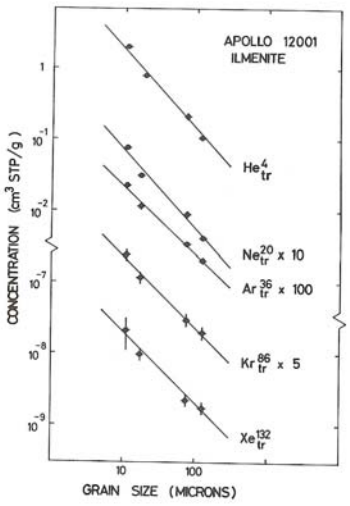



*Figure 10: Rare gas content as function of grain size for ilmenite (Eberhardt et al. 1972).*

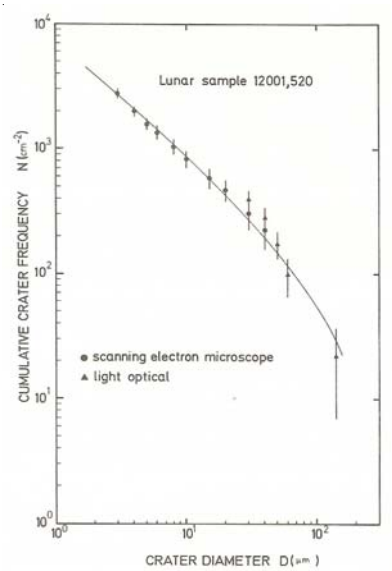
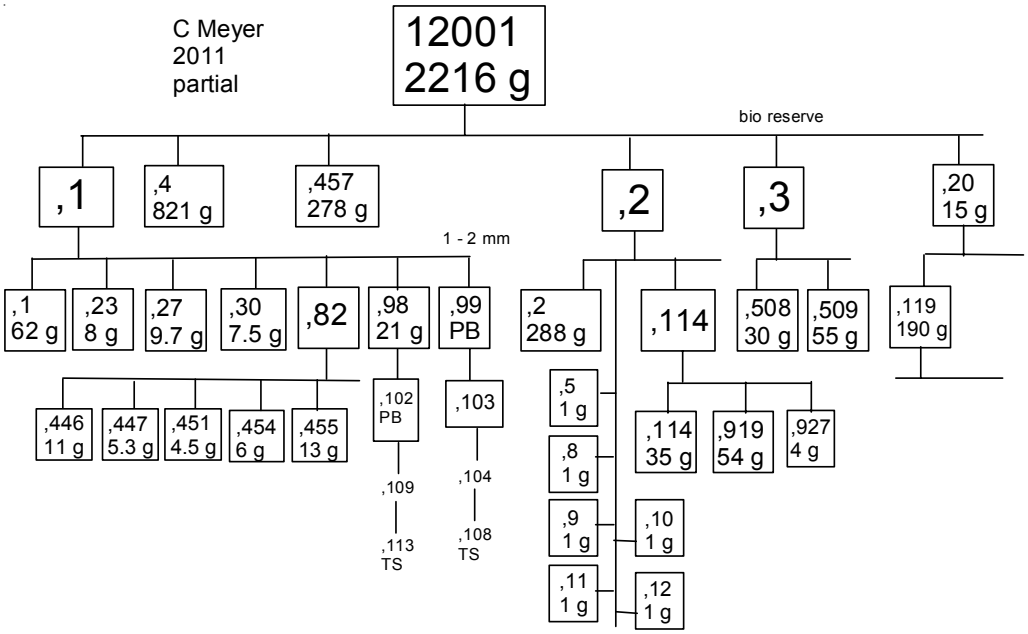



*Figure 11: Microcrater size distribution on 12001,520 (Fectig et al. 1977).*

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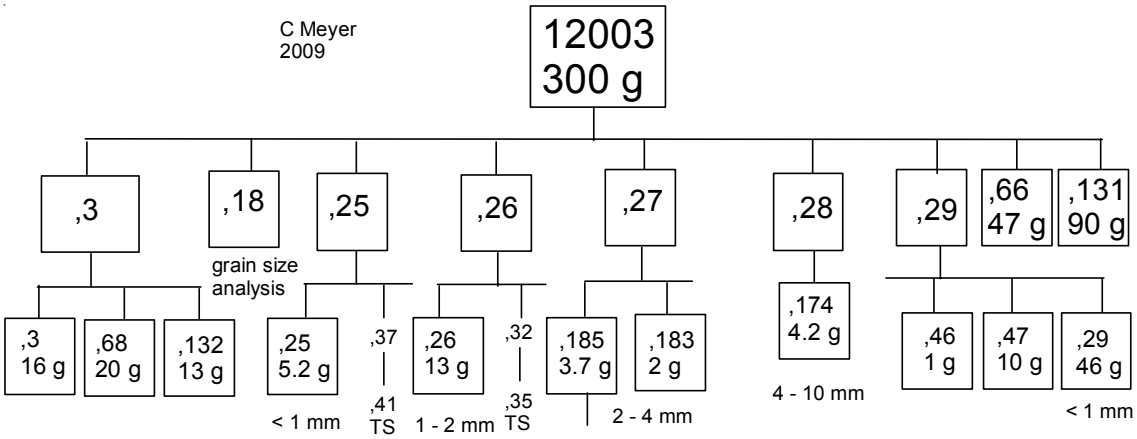



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