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APOLLO 16 SOIL CATALOG
61220

CLASSIFICATION AND DESCRIPTION OF 1-4 MM FINES

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Introduction

While preparing a Catalog of the 4-10 mm fraction of 61220, Marvin (1972) found three fragments of a coarse-grained, friable gabbro (61224,6) that proved to be a unique variety of pristine plutonic rock with a eucritic character (Marvin and Warren, 1980). The combined weight of the three fragments was 340 mg. After portions were used to prepare three thin sections and perform neutron activation analyses, only 150 mg remained (see Figure 1). In the hope of finding additional particles of this exceptional lithology, Marvin spent two days in August 1980 searching through the 1-4 mm fractions in storage at the Pristine Storage Laboratory (PSL) and the Returned Sample Laboratory (RSL).

The search by binocular microscope yielded several small fragments of the gabbro. In the PSL there are 2 samples that are unmistakably the same lithology: 61223,45 (1 particle, 17 mg), and 61222,38 (2 particles, 5 mg). In the RSL one particle, 61222,23 (2 mg), is also the same lithology. Together these new samples increase the earth's supply of this lunar highlands gabbro by 14% (24 mg). An additional sample in RSL, 61222,24 (2 particles, 4 mg), is probably, but not assuredly, of the same rock type.

During the search, each size-fraction of soil in the PSL hand picked into the separate lithologic groups described in this Catalog.

61220: Source and general characteristics

The astronauts dug a trench in the rim of Plum Crater at Station 1, exposing a layer of white soil at a depth of 30-35 cm. Sample 61220 was collected from this layer. Several different analytical techniques applied to both the bulk soil and various size fractions show this to be an extremely immature soil with several unusual characteristics. Heiken, McKay, and Fruland (1973) found a large median grain size (234 μm) for the total soil and a low content of glass-bonded agglutinates (6.3%). Morris (1978) measured a ferromagnetic-resonance surface-exposure index (I_s/FeO) of only 9.4 on a scale where immature soils range from 0 to 29, submature soils from 30 to 50, and mature soils measure above 60. A very low proportion (12%) of grains carrying evidence of solar flare irradiation was found by Rao, Venkatesan, Goswami, Nautiyal, and Padia (1979). Mean siderophile values (Ni = 290 μg/g; Ir = 7 ng/g) are about one-half those of mature soils (Boynton, Chou, Bild, Baedecker, and Wasson, 1976).

Early measurements of cosmogenic and solar-wind implanted noble gas contents showed a highly distinctive signature. In measuring abundances and isotopic compositions of He, Ne, Ar, Kr, and Xe in Apollo 15 and 16 cores, Bogard and Nyquist (1973) found by far the highest ratio of trapped $^{40}Ar/^{36}Ar$ (4.1) in 61221.

Bogard, Nyquist, Hirsch, and Moore (1973) reported that 61221 contains only 25% or less of the amount of trapped ^{4}He found in any other bulk soil they measured. They also found the trapped Xe content to be typical of Apollo 16 surface fines, which suggests that the white soil once resided at the surface for a considerable time. Heymann, Walton, Jordan, Lakatos, and Yaniv (1975) demonstrated that Apollo 16 surface soils fall into three distinct categories on the basis of their ratios of $^{4}He/^{20}Ne/^{40}Ar/^{36}Ar$. Only the "truly unique" white soil, 61221, plots in a distinct, separate category. After dissection

of the Apollo 16 deep drill cores, however, splits from sections 60002 and 60001 proved to resemble 61221 strongly in their ratios of these gases as well as in several other characteristics (Bogard and Hirsch, 1975, 1976).

While measuring volatile elements, Gibson and Moore (1973) found fractions of 61220 to be low in H_2, but unusually rich in an array of gases including H_2O, CO_2, NO, and HCN. They suggested that the white soil might be ejecta from a comet impact. Wszolek, Simoneit, and Burlingame (1973) found most of the species identified by Gibson and Moore plus some previously unidentified gases (SO_2, H_2S, CS_2) and hydrocarbons. After comparing the pattern of released gases from 61220 with those from the carbonaceous meteorites Murray and Murchison, Wszolek, Simoneit, and Burlingame suggested that the white soil layer might have been emplaced on the surface by the impact of a carbonaceous chondrite. Epstein and Taylor (1973) could not confirm the presence of either HCN or especially high values of the other volatiles reported by Gibson and Moore, but they did find that the H_2 they extracted at temperatures above 700°C was the most deuterium-rich hydrogen fraction (δD = -88%) of any lunar soil. They also found an anomalously high carbon content (97 ppm) relative to the measured value of δC^{13} (-13.9%) and to the low value of H_2. Such a combination was markedly different from that of any previously analyzed lunar carbon. They commented that the δC and δD values are both compatible with those found in carbonaceous chondrites. Morgan (1978) reported that the Apollo 16 soils, particularly some dark components of 61222, are dominated by the type 1H ancient meteorite component, and that this soil also appears to contain a "carbonaceous" or "cometary" component.

Bogard, Nyquist, Hirsch and Moore (1973) calculated a ^{21}Ne exposure-age for 61221 of approximately 320 m.y. Becker and Clayton (1977) assembled additional exposure-age data for 61221 from reports published by several

laboratories. The results, based on values of ^{21}Ne, ^{15}N, and ^{126}Xe, ranged from 250 to 530 m.y. Such ages show that the soil is not ejecta from North Ray Crater, which has a ^{35}Ar age of 35-75 m.y., or from the much younger South Ray Crater with an age of 2-5 m.y.

The modes determined on subsamples of 61220 correlated well with an origin by impact on a formation of anorthositic light matrix breccia, as suggested by Heymann, Walton, Jordan, Lakatos, and Yaniv (1975). Heiken, McKay, and Fruland (1973) found 61221 to be 2 to 10 times richer in fragments of colorless glass than any other Apollo 16 soil they examined. They counted 10.9% of clear glass and 7.6% of maskelynite. Electron microprobe analyses by Ridley, Reid, Warner, Brown, Gooley, and Donaldson (1973) show that about 57% of the glass fragments are melted plagioclase (An_{95}) and nearly 5% are maskelynite (An_{84}). The maskelynite of this composition falls within the range (An_{79-87}) of that in the eucrite-like gabbro (61224,6) described by Marvin and Warren (1980). This suggests that the gabbro may have been fairly abundant in the source area of soil 61220.

Many other studies of this white soil have been made, but these references suffice to sketch in a picture of an anorthositic lunar breccia formation being pulverized by the impact of a carbonaceous chondrite, its debris spraying forth and forming a layer of white soil that lay exposed at the surface for a few hundred million years. Subsequently, the soil was sheilded from solar wind, cosmic radiation and micrometeorite impact by a blanket of younger ejecta. 61220 is a soil layer that is old but immature.

The Eucrite-like Gabbro

This is a coarse-grained, pristine, plutonic gabbro with a cumulate texture in which chains of anhedral hypersthene and augite grains coexist with plagioclase (An_{83}). The plagioclase has been shocked *in situ* to a leafy, optically-randomized state, and the grain boundaries are occupied by a selvage of pyroxene-plagioclase glass containing minute crystallites (Marvin and Warren, 1980).

Samples (see Figure 1)

Discovered in 1973

61224,6
4-10 mm
3 pieces; 0.34 grams

Present weight
1 piece; 0.15 grams

Discovered in 1980

PSL

61223,45
2-4 mm
1 particle; 0.017 grams

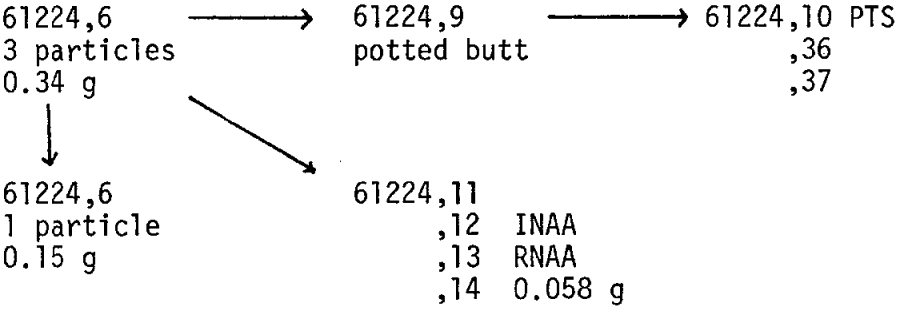
61222,38
1-2 mm
2 particles; 0.005 grams

RSPL

61222,23
1 particle; 0.002 grams

61222,24, probable
2 particles; 0.004 grams

Geneology of 61224,6



Samples processed and examined in the Pristine Storage Laboratory
August 27-29, 1980

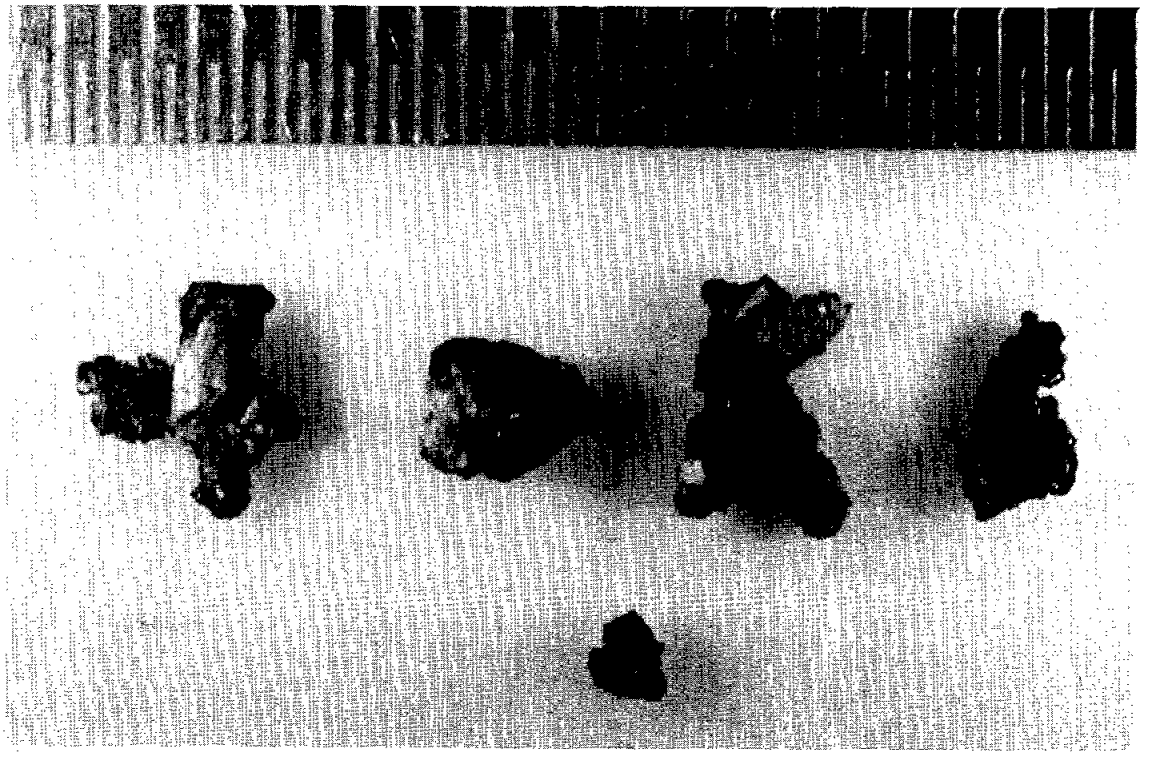
61223,0 2-4 mm 8.61 grams

Although this sample was listed as 2-4 mm in particle size, it included abundant fine dust. When it was sieved to remove the dust, it produced three size fractions: 2-4 mm, 1-2 mm, and <1 m.

The particles in the 2-4 and 1-2 mm fractions were dusted and handpicked into subsamples of separate lithologies. After the initial handpicking, similar lithologies in the two size fractions were combined to make the following samples.

61223,36
Glass-bonded agglutinates
5 fragments; 0.086 grams

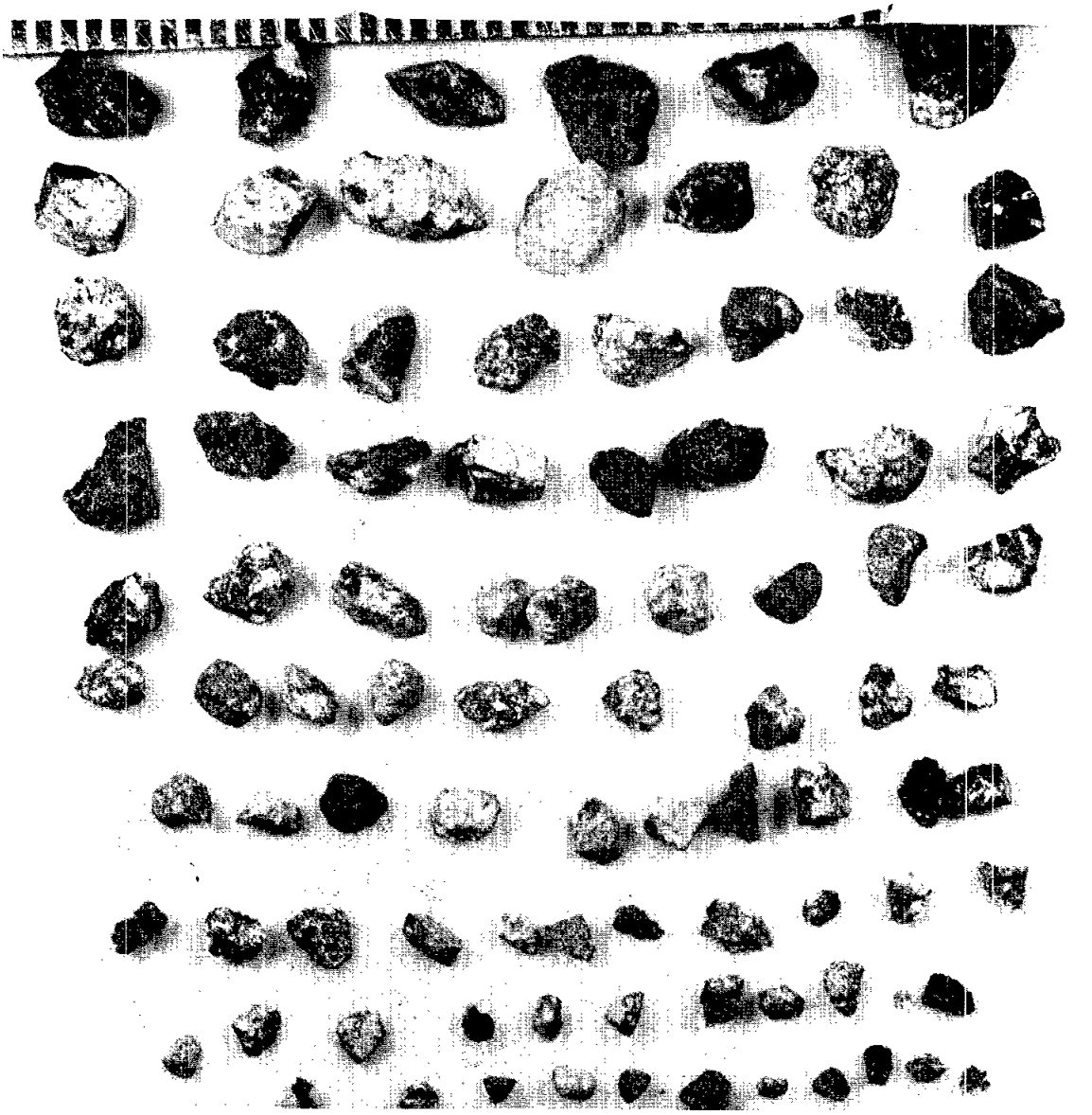
Irregular, vesicular masses of dark brown glass incorporating dust, mineral fragments, and clods of soil



S-80-39156

61223,37
Aphanites
88 particles; 1.455 grams

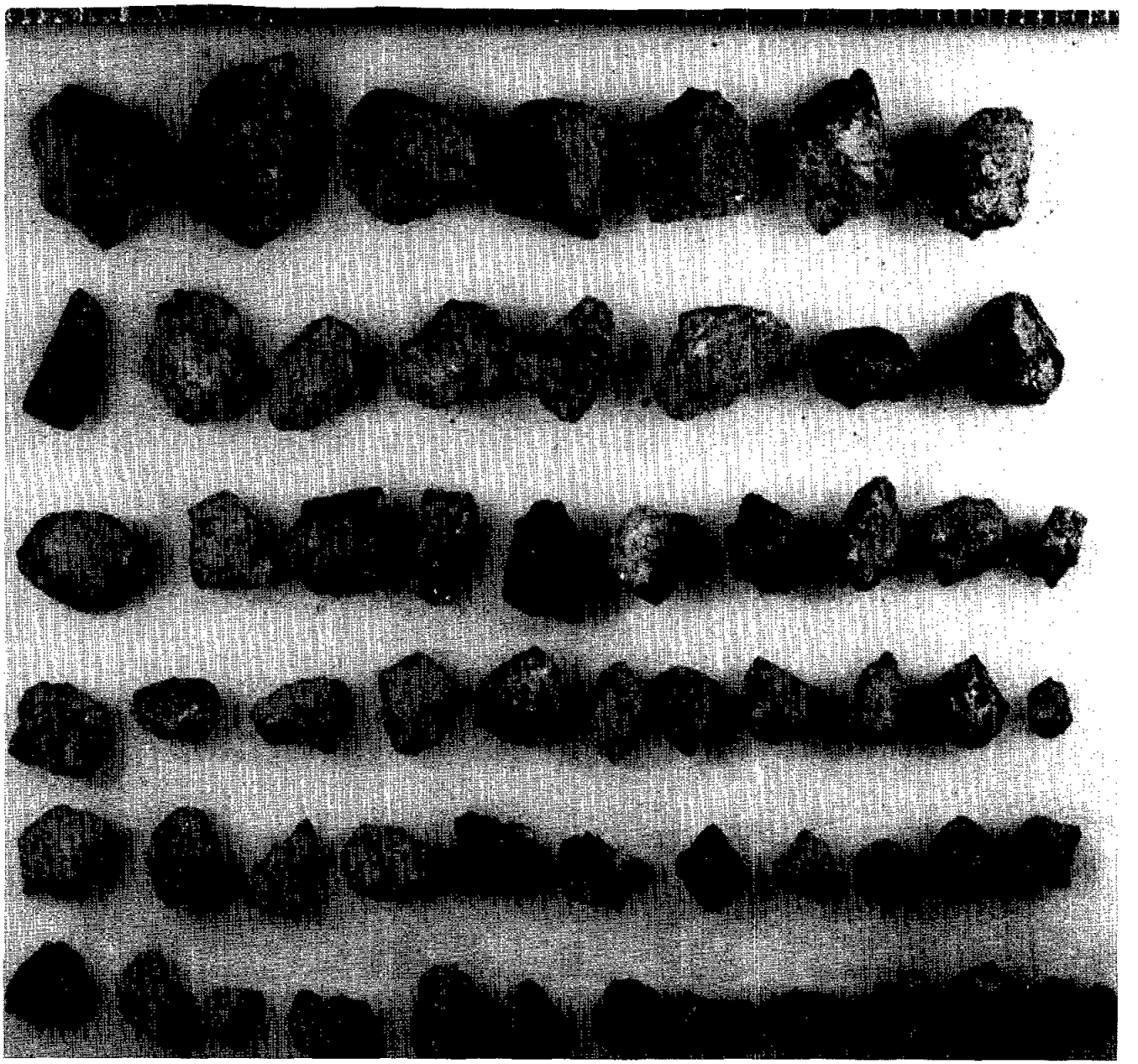
Coherence: Tough, with conchoidal fracture
Shape: Rounded to angular; blocky
Surface: Exterior surfaces smooth to granular, partially coated with white dust; fresh fractures mostly smooth; sparse pin-hole vesicles on some fragments.
Color: Medium to dark gray
Character: Aphanitic to very fine-grained with a few visible inclusions; typical impact-melt microbreccias.



S-80-42640

61223,38
Aphanites
60 particles; 1.227 grams

Coherence: Tough, with smooth to conchoidal fracture
Shape: Rounded to angular
Surface: Many surfaces partially or wholly coated with white dust; a few sparse pin-hole vesicles
Color: Dominantly light gray; ranging from off-white to medium gray
Character: Nondescript particles that are probably highly feldspathic, impact-melt microbreccias. They grade in color and texture toward the materials of 61223,37.

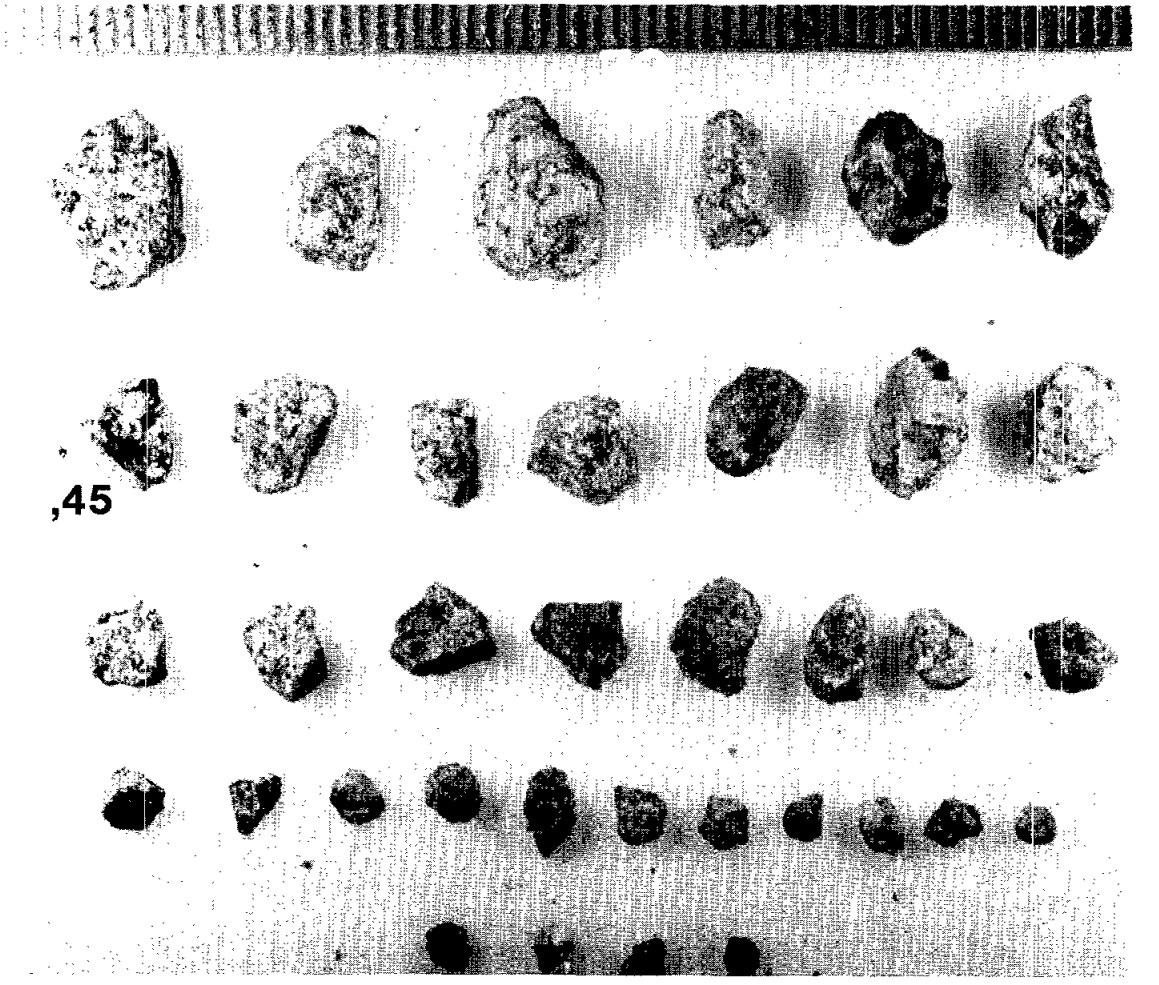


S-80-39155

61223,39
Gray crystallines
36 fragments; 0.442 grams

Coherence: Very coherent with smooth to hackly fracture
Shape: Rounded to angular
Surface: Sugary, with sparse vesicles ranging in size from less than 0.1 to 1 mm; partially coated with white dust
Color: Medium to light gray; mottled
Character: Fine-grained crystallines which are visibly polymineralic in contrast to the aphanites of 61223,38

Note: One particle in this group was recognized as the coarse eucrite-like gabbro being searched for. That one was renumbered 61222,45 and is described in a later section.



S-80-39154

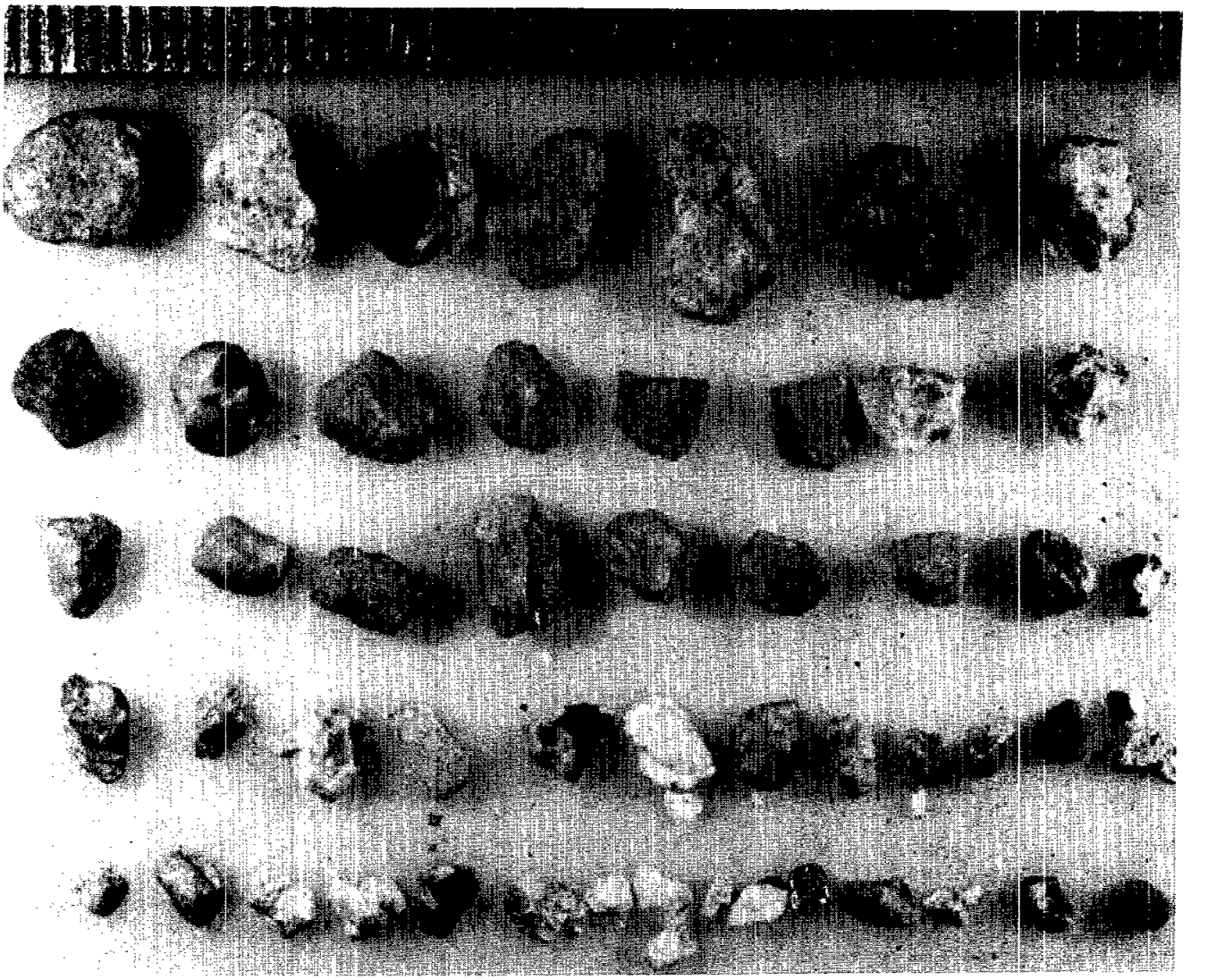
61223,40
Yellow crystallines
27 particles; 0.355 grams

Coherence: Moderately to strongly coherent
Shape: Rounded to subangular
Surface: Some particles very smooth, others rough and grainy
Color: Yellowish
Character: These particles have a dominantly yellowish tinge that distinguishes them from the gray crystallines of 61223,39 and from the gray aphanites. They are fine-grained, polymineralic materials with probable bulk compositions of gabbroic anorthosites.

S-80-39348

61223,41
Anorthosites
50 particles; 0.462 grams

Coherence: Very friable to strongly coherent; some grains crumbling spontaneously
Shape: Rounded to angular
Color: White to grayish white, chalky to translucent; some particles have veinlets or surface patches of dark glassy material.
Character: These white particles, of many shapes and textures, range from aphanites to sugary crystallines. A few have sparse grains of pink spinel, metal, or yellow mafics; none contain more than 2% of accessory minerals.



S-80-39153

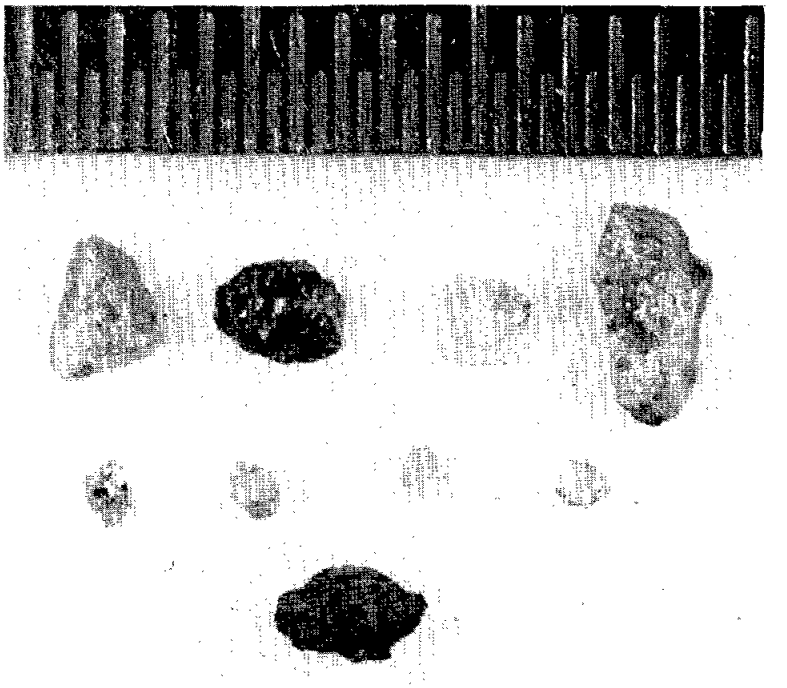
61223,42
Glassy fragments
9 particles; 0.088 grams

Plagioclase glass (8 fragments)

Coherence: Tough, brittle, with smooth to conchoical fracture; (some particles may be transparent plagioclase and/or maskelynite instead of melted anorthosite).
Shape: Angular to rounded; bleby
Color: Mostly colorless and transparent with a high luster; a few grains darkened by minute inclusions
Character: Fragments of colorless glass occur in all size fractions of this Apollo 16 soil; including one 1-cm particle (61224,2). Previous analyses (e.g. Ridley et al., 1973) show that at least two varieties are present with compositions clustering at An_{95} and An_{81}.

Ropy Glass (1 fragment; bottom in figure)

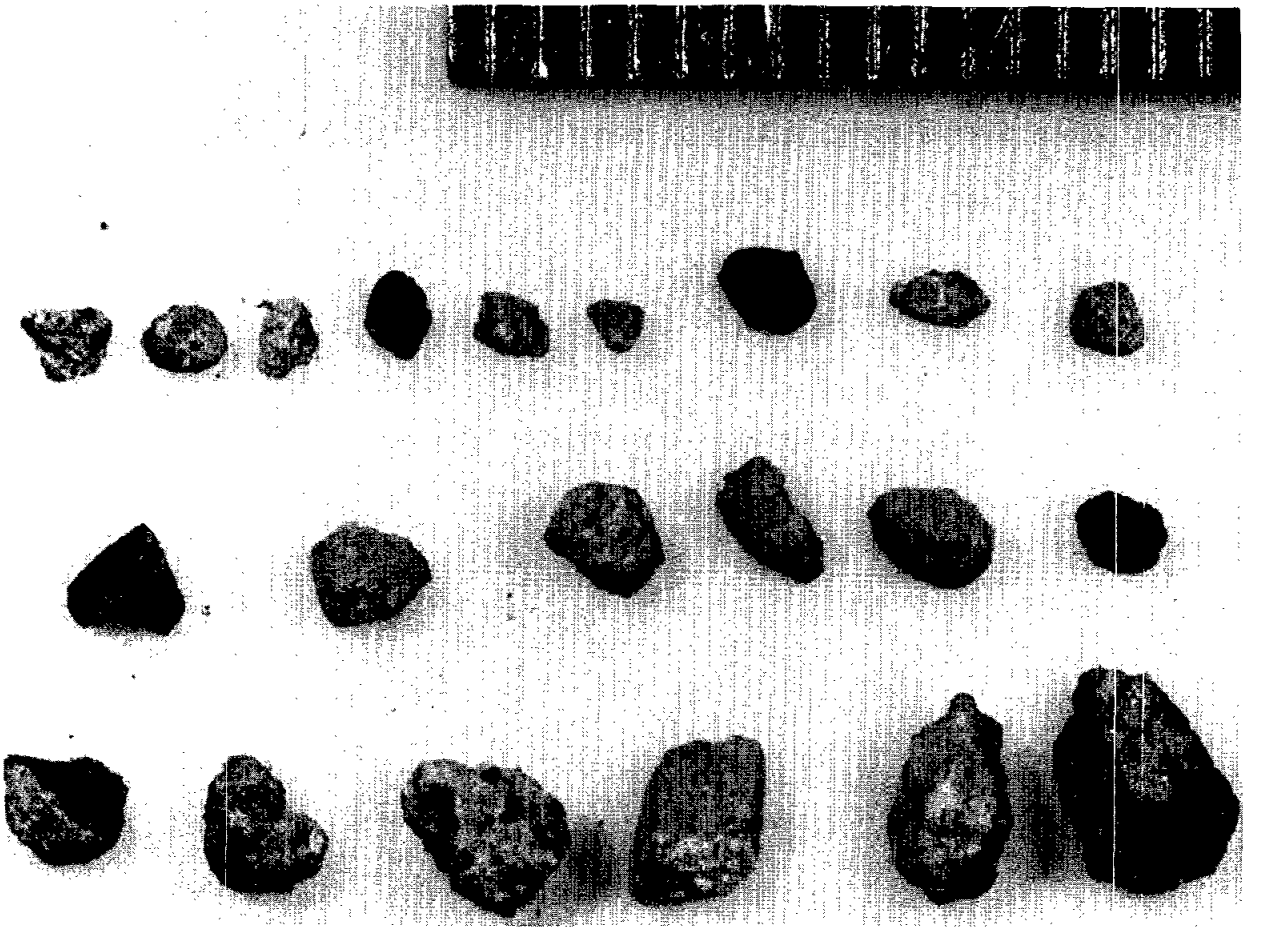
This elongate, ropy pellet, coated with fine white dust, is the only one of its kind observed in the 2-10 mm fractions of this soil. A small fracture at one end shows that the interior is probably light brown. Its twisted character is reminiscent of the ropy KREEP glasses of Apollo 14; however, no guess at its composition is justified.



S-80-39347

61223,43
Matrix clods
21 particles; 0.212 gram

Coherence: Friable to coherent
Shape: Angular, blocky; some broken pellets
Surface: Mostly smooth; some coating with white dust
Color: Medium to very light gray
Character: Clods of microbreccia that resemble the average matrix of typical Apollo 16 light matrix breccias more than they do any class of clasts; some are just cohesive enough to survive gentle handling, others are strongly coherent

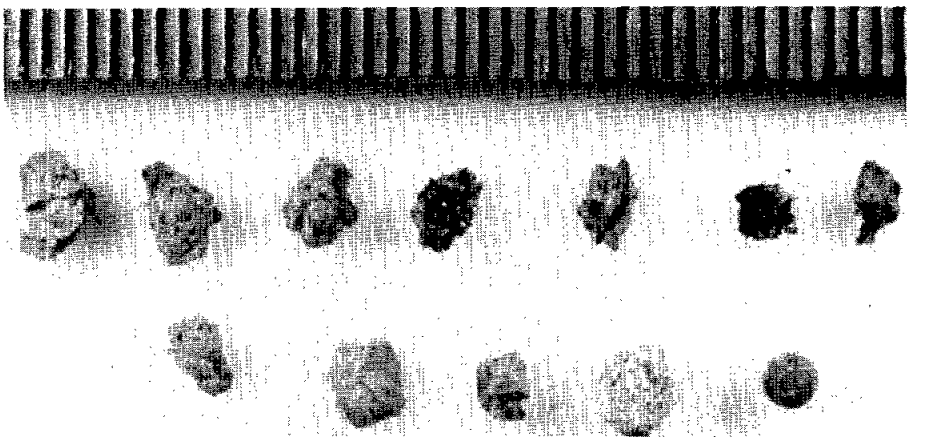


S-80-42636

61222,0 1 to 2 mm fraction

61222,33
Melted soil products
12 particles; 0.031 grams

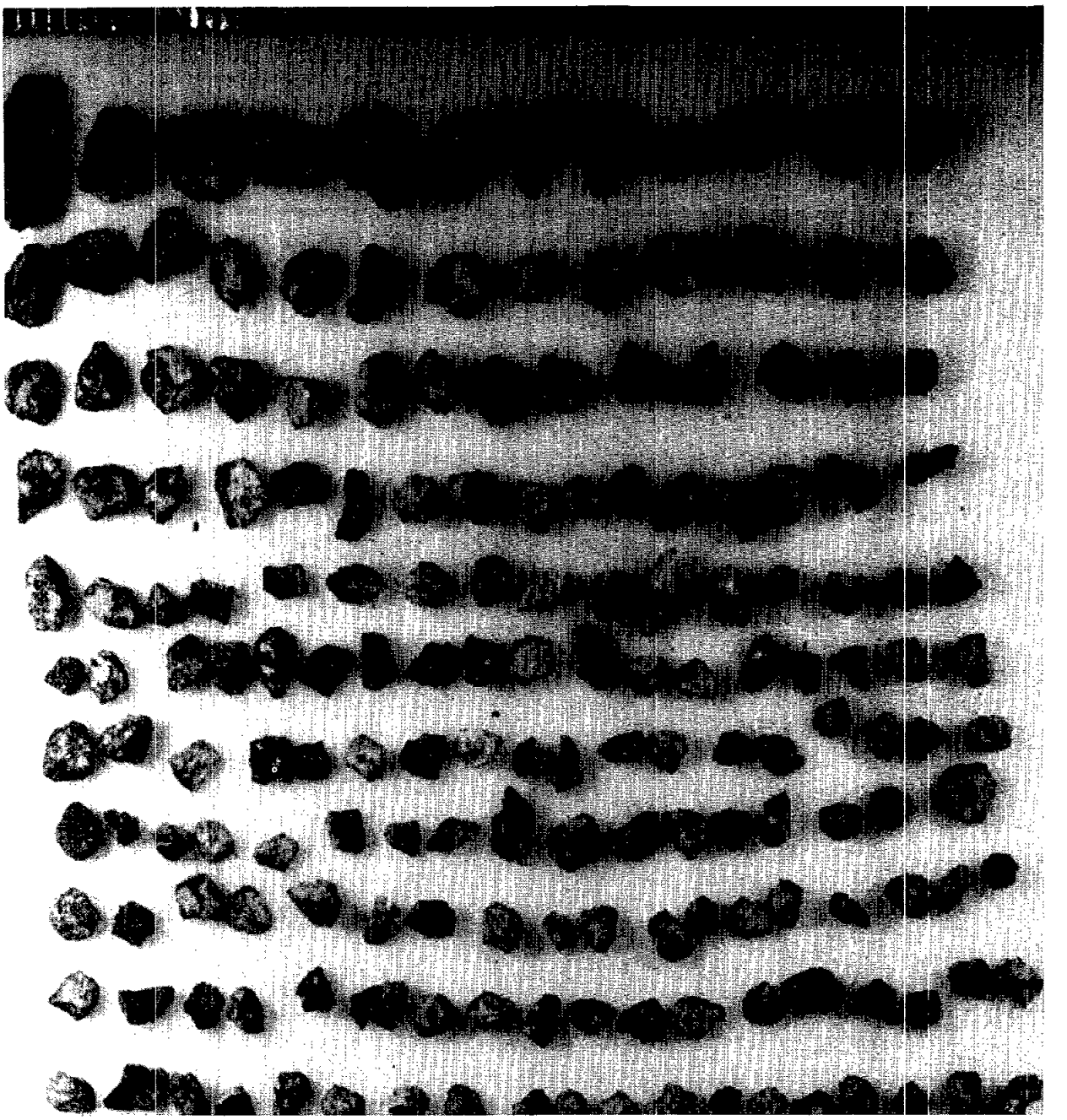
2 agglutinates of lustrous brown, vesicular glass with adhering soil grains
1 glassy bomblet with a rough, dust-coated surface
4 broken, jagged fragments of ropy glass with dust-coated surfaces
4 masses of glass in rounded, lobate forms; unbroken and coated with dust
1 glass spherule; light gray, with a pitted and frosted surface



S-80-40454

61222,34
Aphanites
179 particles; 0.638 grams

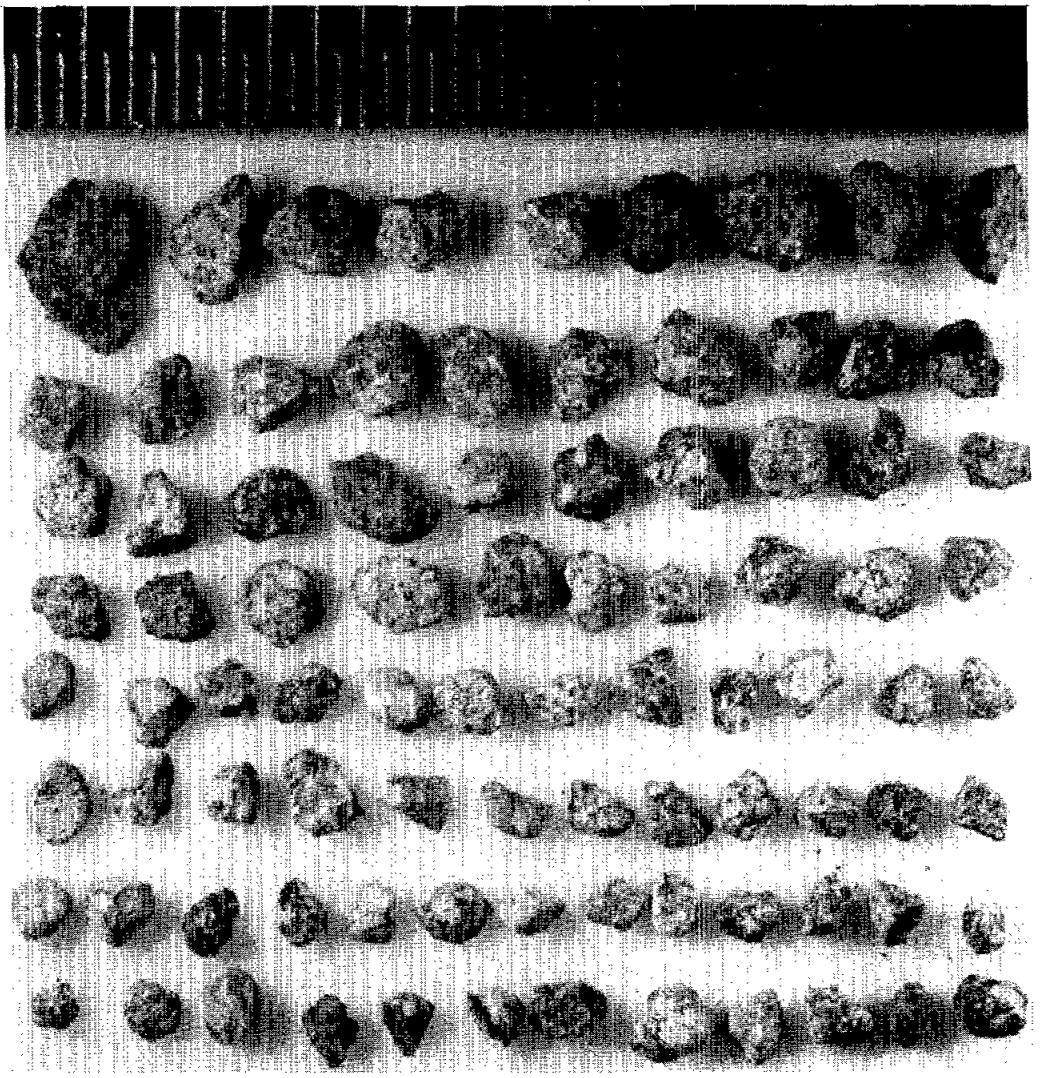
Dark gray angular to rounded fragments of tough, aphanitic material with a smooth fracture. This material occurs as hard, rounded pellets that break into blocky fragments; many have sparse pin-hole vesicles. These particles are probably impact-melt microbreccias.



S-80-40453

61222,35
Aphanites
88 particles; 0.318 grams

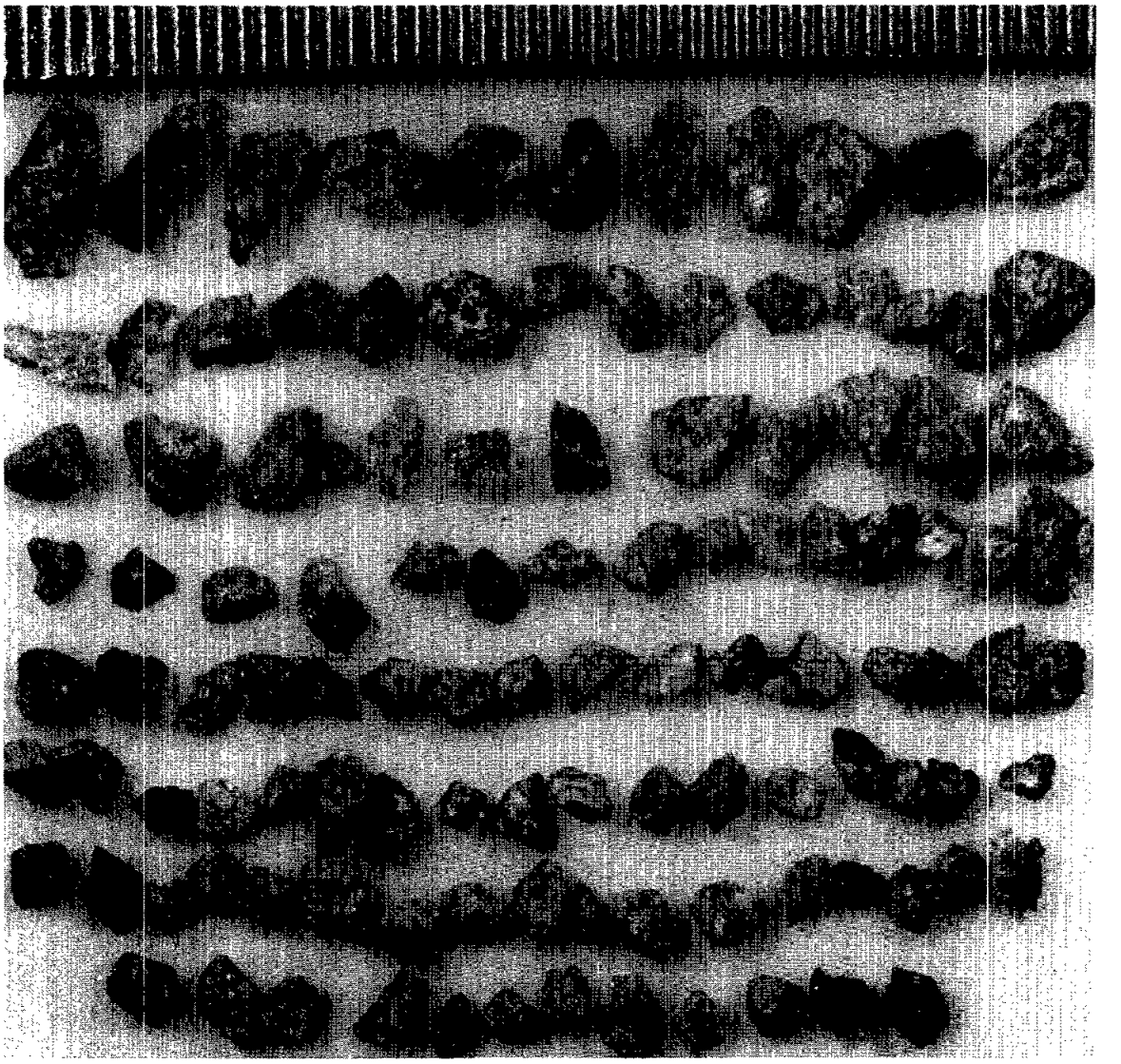
Light gray, rounded to subangular, coherent particles, partially coated with white dust; probably impact-melt microbreccias. These aphanites are distinguished from those of 61224,34 and ,36 solely by their dominantly light gray color.



S-80-40452

61222,36
Aphanites and very fine-grained crystallines
114 particles; 0.383 grams

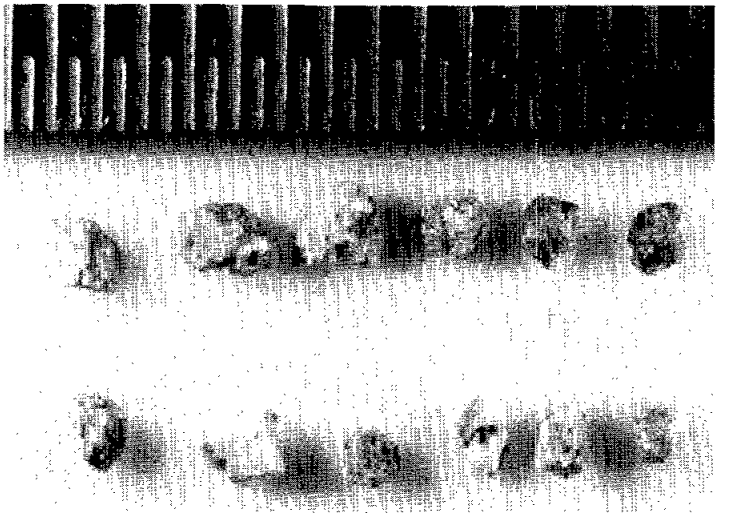
Yellowish, rounded to angular, coherent particles that appear to be polymineralic; they are probably gabbroic anorthosites in bulk composition.



S-80-40451

61222,37
Polymineralic crystallines
11 particles; 0.039 grams

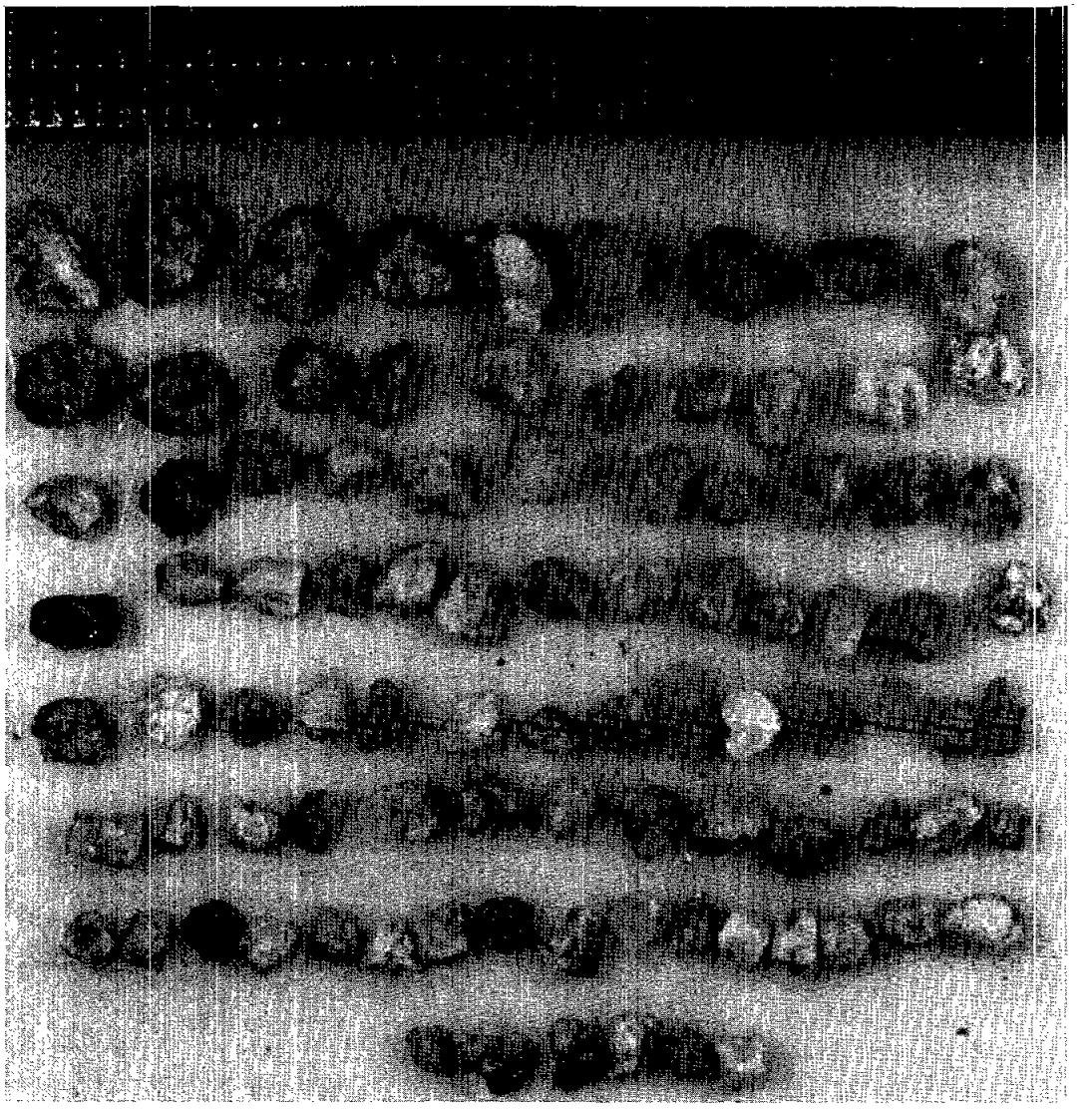
Light-colored, fine-grained friable to very coherent, anorthositic materials with visible accessory minerals including pink spinels and yellow pyroxenes; virtually no opaques.



S-80-40450

61222,39
Anorthosites
92 particles; 0.274 grams

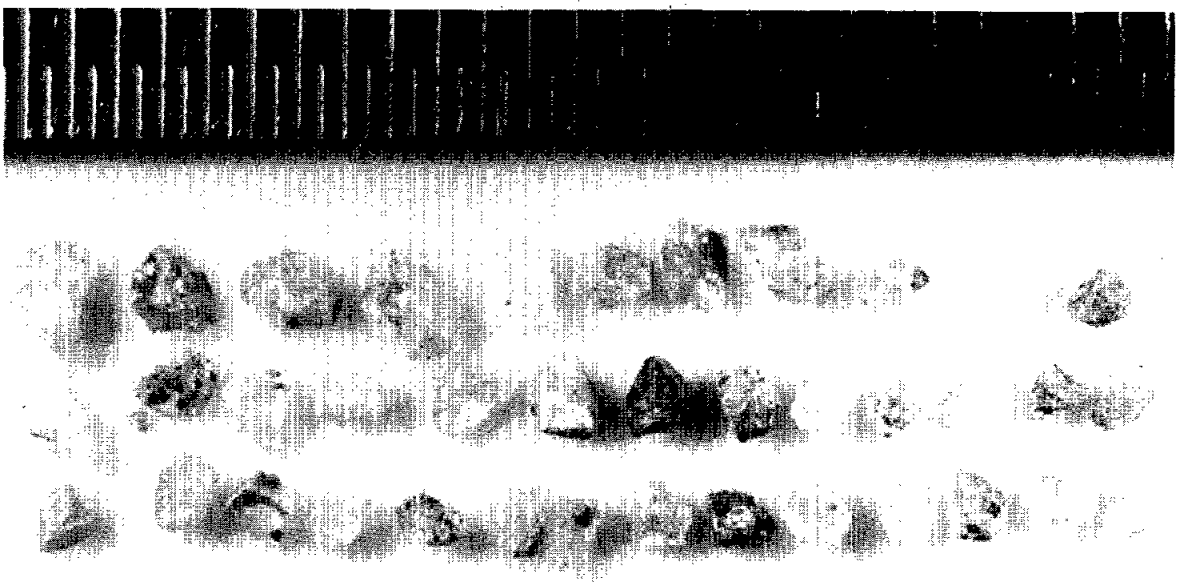
White chalky to translucent fragments in all shapes and degrees of coherence. A few have traces of accessory minerals such as pink spinels or yellow mafics but these never exceed 1%.



S-80-40448

61222,40
Feldspar glass
38 particles; 0.111 grams

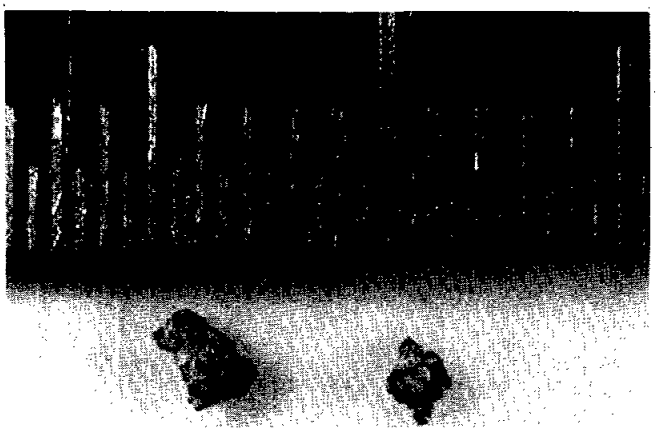
Transparent, vitreous, angular fragments of a distinctive type found in all size fractions of this soil. Some pieces contain minute dark inclusions; a few are shot through with what appear to be chalky blebs. As noted in the description of 61223, 3 previous analyses have shown this soil to contain 2 compositions of glass: An_{95} and An_{81}.



S-80-40447

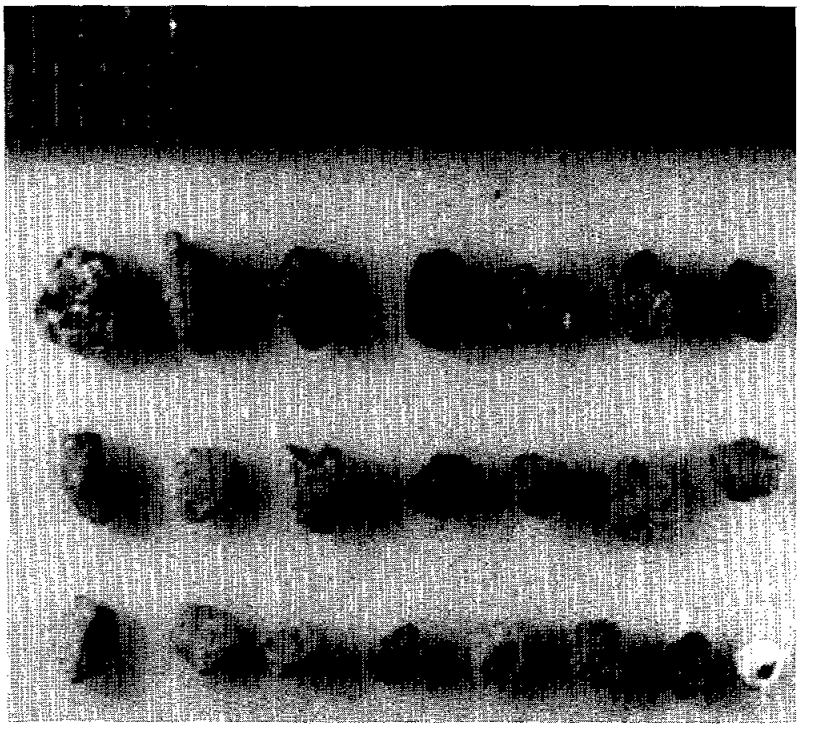
61222,41
Metal-rich grains
2 particles; 0.011 grams

Irregular particles, largely dust covered but with edges and corners of gleaming metal. They cling to forceps. They consist largely, if not entirely, of metal.



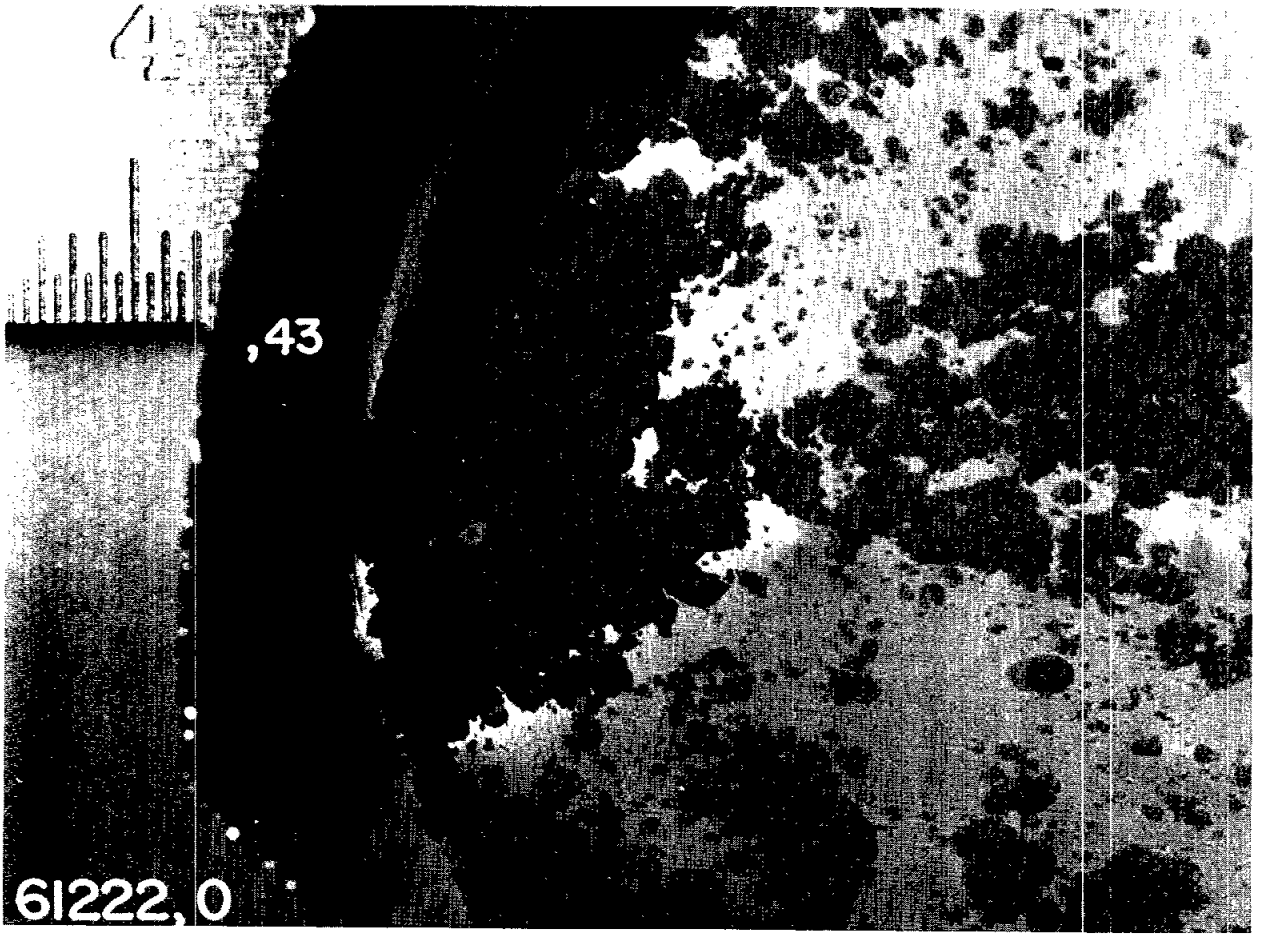
61222,42
Soil clods
22 particles; 0.058 grams

An assortment of small clods of average soil, ranging from rounded and friable to angular and coherent.



S-80-40446

61222,43
Fines: <1 mm
0.814 grams



S-80-40445

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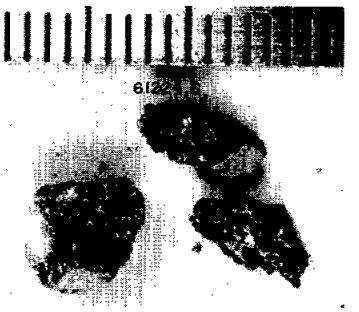
61224



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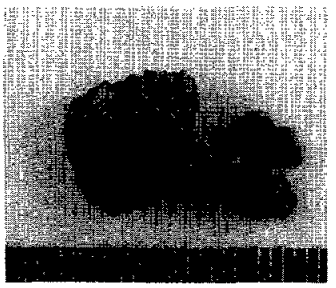

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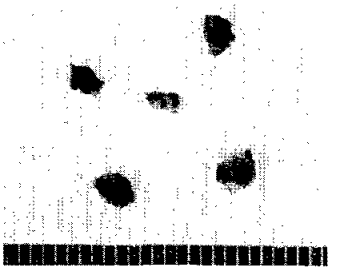

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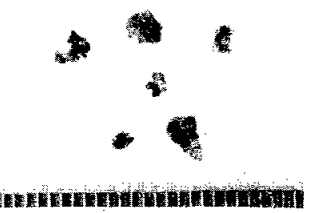

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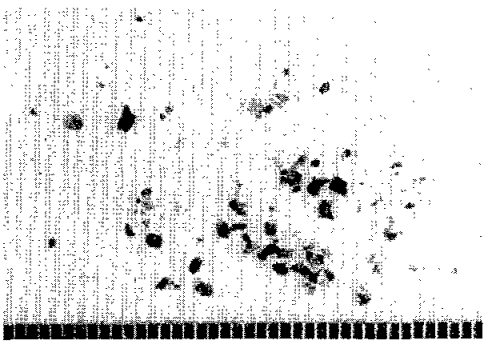

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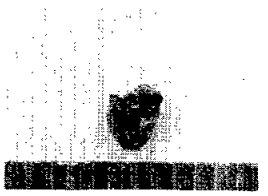

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