THE BOULDER

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Abstract. The external morphologies of Boulder 1, Station 2, and of the four samples taken from it by the Apollo 17 crew, are briefly described. The boulder is a polymict breccia, containing the following principal materials as clasts: gray competent breccias (GCBx), black competent breccias (BCBx), anorthositic breccias (AnBx), pigeonite basalt (PB), coarse norite (CN). All are enclosed in a matrix of light-colored friable breccia (LFBx).

1. Introduction

The Apollo 17 LM landed on the smooth, dark floor of a narrow valley that strikes radially across the south-east rim of the Serenitatis basin. The valley is generally interpreted as a graben bounded by two large upland horsts (North Massif and South

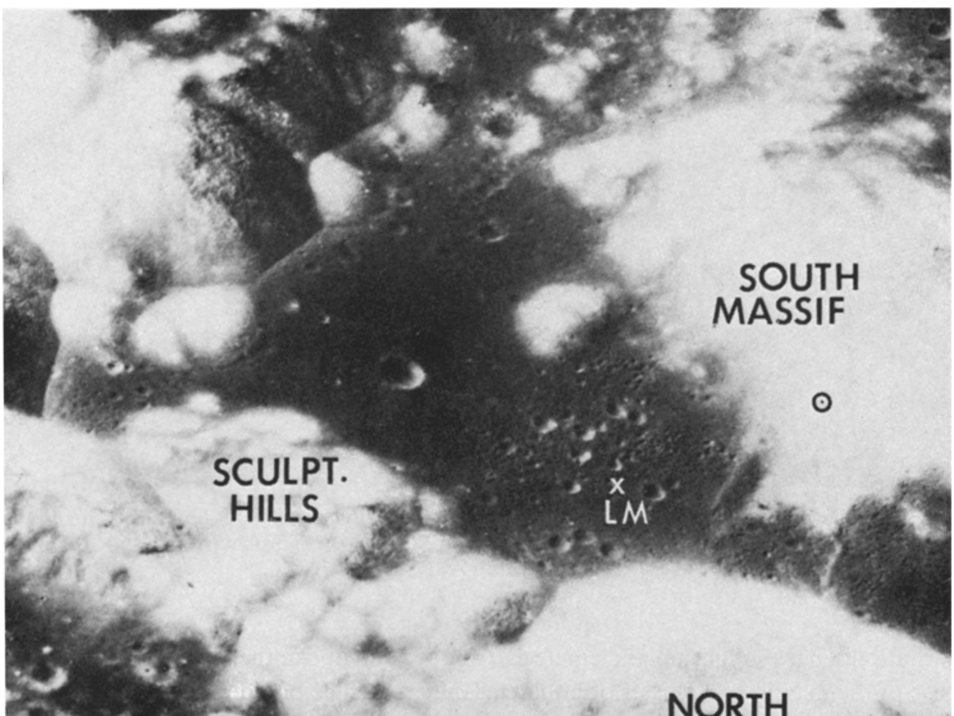

Fig. 1. The Valley of Taurus-Littrow, looking south. Width of field, 30 km. Circle indicates Station 2; note the apron of light-colored landslide debris extending from Station 2 out onto the valley floor.

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Massif) and the domical Sculptured Hills (Figure 1; AFGIT, 1973). The two massifs are not structurally or topographically symmetrical. At the foot of South Massif is a thick apron of upland material, presumably deposited by an avalanche that slid down the scarp and out over the dark valley floor. In the brilliant light of the lunar day, the astronauts described roughly horizontal strata in North Massif and gently tilted layers in South Massif. Near the summit of South Massif a contact, dipping 10–15° to the west, appeared to separate the predominant tan-gray material of the mountainside from a blue-gray layer near the summit. Near the contact are groups of boulders that have evidently come to rest along a gentle break in slope.

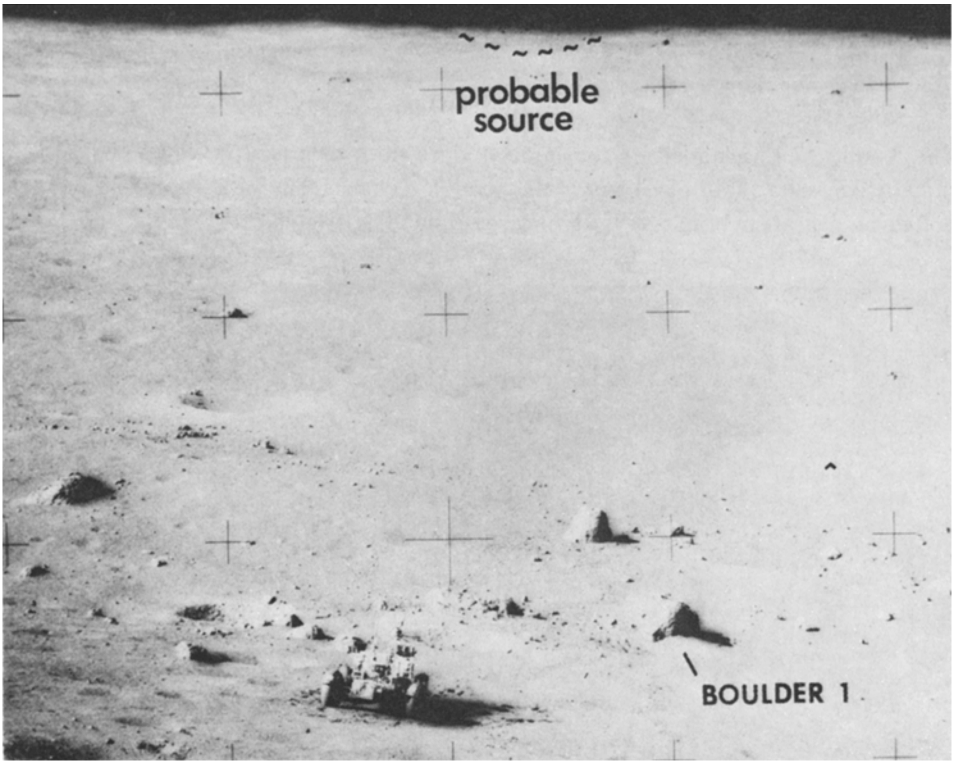

Fig. 2. A view of Apollo 17 Station 2 showing the northeast-facing slope of South Massif and the boulder field near the summit from which Boulder 1 was probably derived. (NASA photograph AS17-138-21072.)

Station 2 lies on light uplands material, about 50 m above the break in slope at the base of the massif, in a cluster of boulders (Figure 2). The boulders probably came to rest on the light deposit after rolling from the upper portions of the massif (Wolfe *et al.*, 1974), and are presumed to represent lithologies from the upper part of the stratified massif. Boulder 1 is one of three boulders sampled at Station 2; in the field its light blue-gray color appeared to match that of blue-gray materials observed near the top of the west portion of the South Massif (Schmitt, 1973). The geological setting of the Boulder is described in detail by Wolfe (1975).

2. Boulder Morphology

Boulder 1, Station 2 is a 2-m boulder with a uniquely foliated structure (Figure 3). It was observed to be embedded in the regolith, projecting 1 m above the soil line, with a well-developed fillet on the uphill side; no track was detected.

Differential erosion of hard and soft materials has sculptured the surface of the boulder in five crudely parallel layers, studded with resistant knobs ranging in diameter from 1 to 15 cm. An imposed cleavage, expressed partly as closely-spaced shear

Fig. 3. The southeast face of Boulder 1 as it appeared before sampling. The boulder is about 2 m wide and 1 m from the top to the soil line. The boulder's crudely layered and knobby morphology was unique among Apollo 17 rocks and boulders. (NASA photograph AS17-138-21030.)

planes and partly as open cracks, cross-cuts the boulder in a direction normal to the layering. The surface of the boulder is rough and grainy and has a light, spotty patina of the type that develops on friable materials as they constantly shed small particles. All of these features give the boulder a rough-hewn texture unlike that of any other rock seen or photographed at the Apollo 17 site (Figure 3). Designating it Boulder 1, the astronauts took specimens from four different layers of the southeast face (Figure 4). All the specimens are complex polymict breccias of non-mare rocks.

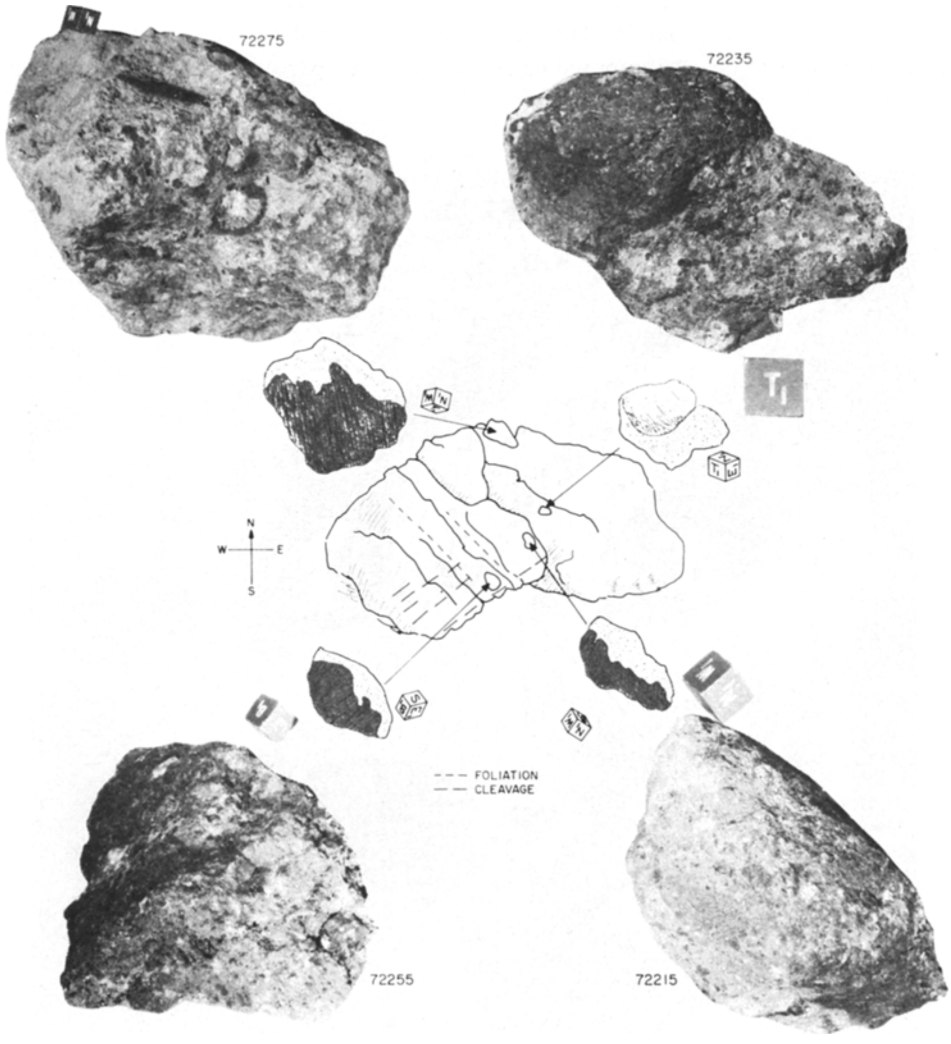

Fig. 4. Sketch of Boulder 1 *in situ*, showing the foliation, cleavage, and locations from which the samples were taken. The photographs show the four specimens approximately as they were positioned on the boulder. The lunar orientation of the boulder, and hence of the specimens, is indicated by the compass directions. The cubes give the conventional orientations assigned to the specimens in the Lunar Receiving Laboratory. The lunar and laboratory orientations are *not* the same.

3. Specimen 72275

Specimen 72275, from the top of the boulder, is predominantly of light gray friable matrix material, and encloses several coherent knobs and one conspicuous black-rimmed white clast (Marble Cake clast). En route from the Moon, the specimen broke into four main pieces with a total weight of 4423 g, plus innumerable chips and fines (Figure 5). The exposed surface of the specimen has a thin, patchy, brown patina, zap pits, and splashes of black glass covering both the matrix and the Marble Cake clast. An opposite face, which was tilted downward toward the body of the boulder,

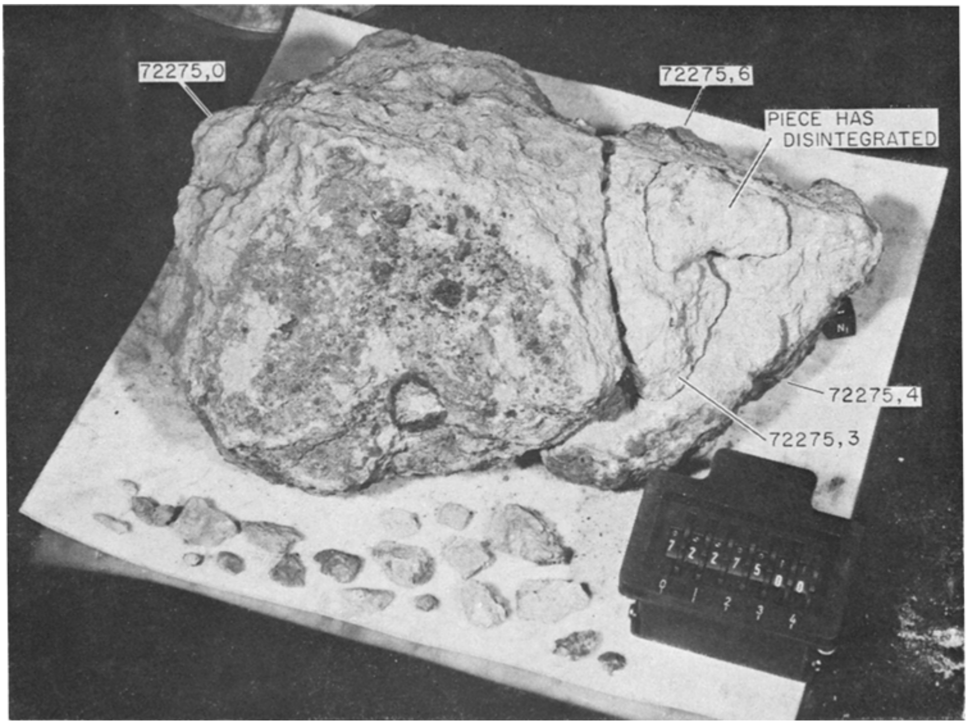

Fig. 5. A reassembly of the five documented pieces of 72275, photographed at the Lunar Receiving Laboratory in January 1973. Twenty undocumented chips are shown in the foreground. (NASA photograph s-73-16077.)

is coated with a very fine-grained (1.5 μ) powdery material that is delicately layered and ripple-marked (Figure 6). The ripples are an uncommon lunar minitopography suggestive of the passage of a dust cloud over the rock surface, which may formerly have been one wall of a small fissure in the boulder. The rippled dust has approximately the same bulk composition as the boulder matrix. Further details of composition and mineralogy are given in Marvin (1974).

The matrix of 72275 is a porous aggregate of angular mineral and lithic fragments ranging in size up to 0.1 mm. The macroscopically visible components are predomi-

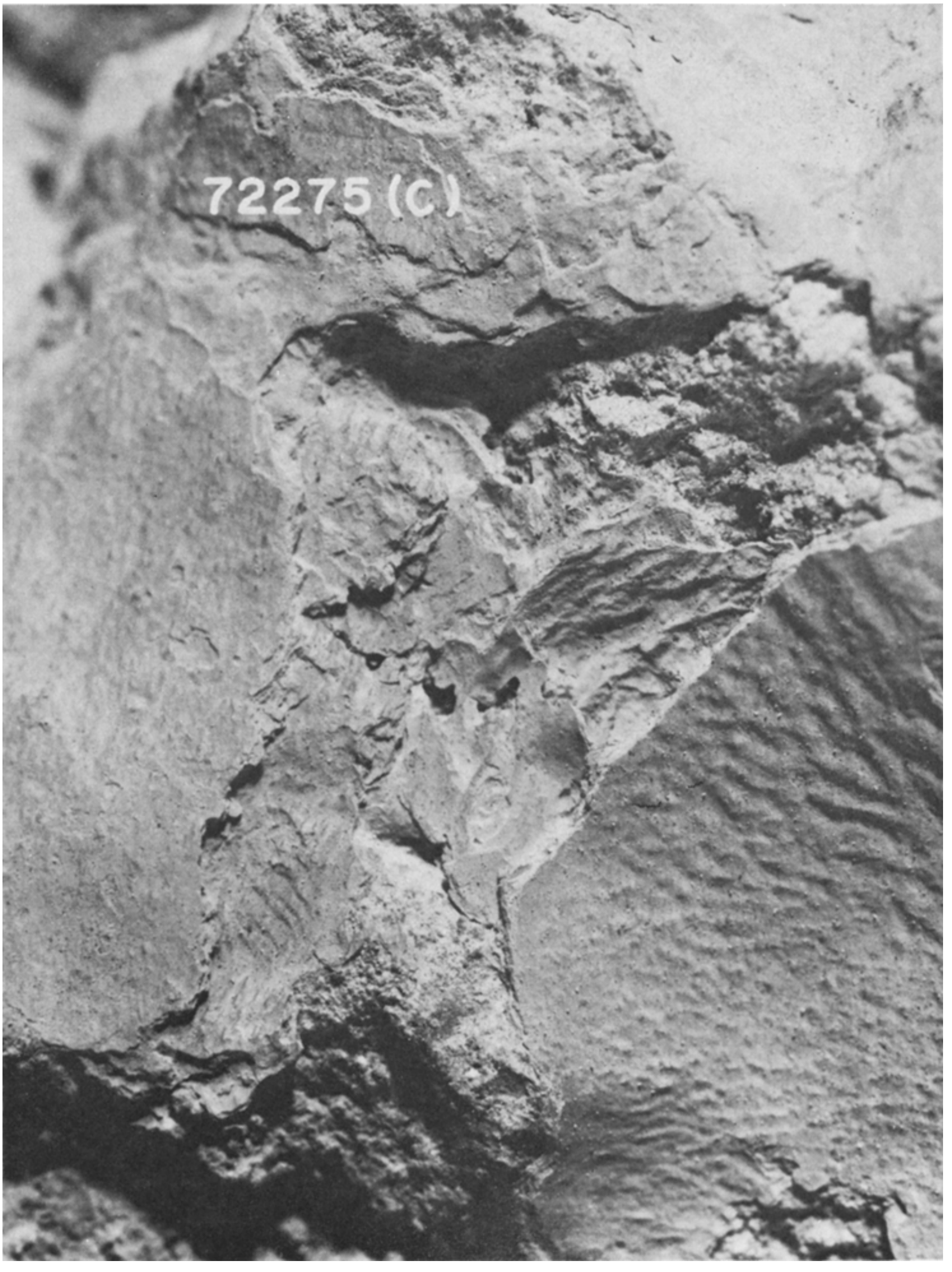

Fig. 6. The deposit of delicately layered, ripple-marked material on one surface of 72275. The chipped area (center) exposes layers with different orientations of the ripple pattern. The coarsest ripples (right center) have a wavelength of $\sim 125\ \mu$. (NASA photograph S-73-26509.)

nantly fragments of plagioclase. Less abundant constituents are brown or yellow pyroxenes, sparse grains of pink or amber spinel, and tiny specks of metallic iron or iron sulfide. This light friable breccia matrix is hereafter designated LFBx.

The most conspicuous clasts of 72275 are of four varieties:

(1) Gray competent breccias (abbreviated GCBx in the present series of articles). These occur as dark-gray, aphanitic, sub-angular to rounded clasts ranging in size from about 1 mm to 3 cm. Such clasts are ubiquitous and very coherent. Under high magnification they are seen to be angular microbreccias in various stages of recrystallization. Two prominent clasts of this type are exposed on the surface of a slab that was cut through 72275 (Figure 7a). One of them (Clast # 2) was subdivided and distributed to Consortium members. The other one, which remains undisturbed, has an almost spiral form and sits in a groundmass of its own debris, looking as though it had been crushed and rotated *in situ*.

(2) Black competent breccias (BCBx). These are dark-gray to black aphanitic materials with a sub-vitreous luster that contrasts markedly with the dull gray of Clast # 2 and the other gray competent breccia clasts. Minute white angular inclusions in the black materials indicate that they are microbreccias. In some instances, the black microbreccias occur as small isolated masses within the gray friable matrix, but for the most part they are closely associated with white anorthositic breccias (Figure 7b). This association, along with their darker color and higher luster, appeared to set the black competent breccias apart from the more common gray ones. Under the microscope, however, the differences between the two are not obvious, and the BCBx and GCBx appear to be essentially the same type of rock in various stages of recrystallization.

(3) Anorthositic breccias (AnBx). Clasts of this material are white or light-gray, with textures ranging from coarsely cataclastic to fine-grained and granular. Many of the smaller (1–4 mm) clasts consist wholly of feldspar: the larger ones often contain 20–35% of yellow mafic silicates and are rimmed or interlayered with black competent microbreccias (BCBx). The 2-cm Marble Cake clast is the largest of its kind in 72275 (Figure 7b). The dark 'rim' of Marble Cake is actually interlayered with the white 'core', which is itself a complex microbreccia of a unique ilmenite-KREEP-rich norite and several other light-colored rock-types (Ryder *et al.*, 1975; Marvin *et al.*, 1974).

(4) Pigeonite basalt (PB). Basaltic clasts with felty white plagioclase laths and yellow pyroxenes are conspicuous in 72275. Clots of the crystalline basalt (which proved to be pigeonite basalt; see Ryder *et al.* (1975)) lie within zones consisting entirely of crushed basaltic debris strung out into lenses and bands and interfingered with the light gray matrix. The crushing and shearing of pigeonite basalt framents, as well as of some of the gray aphanitic materials (such as Clast # 3; Figure 7a), clearly took place after aggregation of the boulder matrix. The pigeonite basalts always occur in close association with the light-gray matrix (LFBx); they are never included in the gray or black microbreccias (GCBx or BCBx). The distinction between these two associations is of crucial importance in interpreting the history of the boulder.

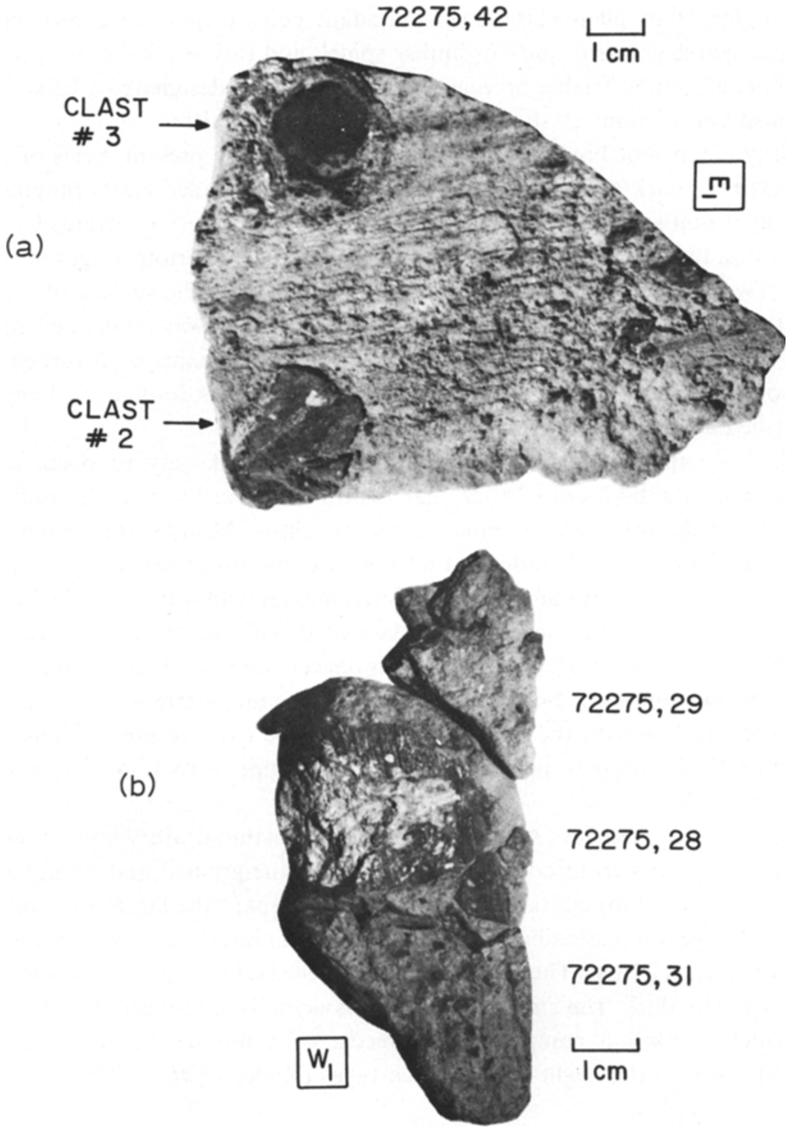

Fig. 7. (a) The slab cut from 72275, showing two large clasts of gray competent breccia. Both clasts are surrounded by small fragments of their own crushed debris. Clast #3 appears to have been sheared and rotated *in situ*. (b) A sawed surface of the Marble Cake clast and two pieces of adjacent matrix.

4. Specimen 72235

Specimen 72235 (62 g) consists of a coherent knob of interlayered dark gray to black (BCBx) and white breccias (AnBx), with a piece of adherent light-gray friable matrix similar to that of 72275. (The name Dying Dog was given to this specimen for reasons that are apparent in Figure 8.) Both the dark and the light layers of the knob appear

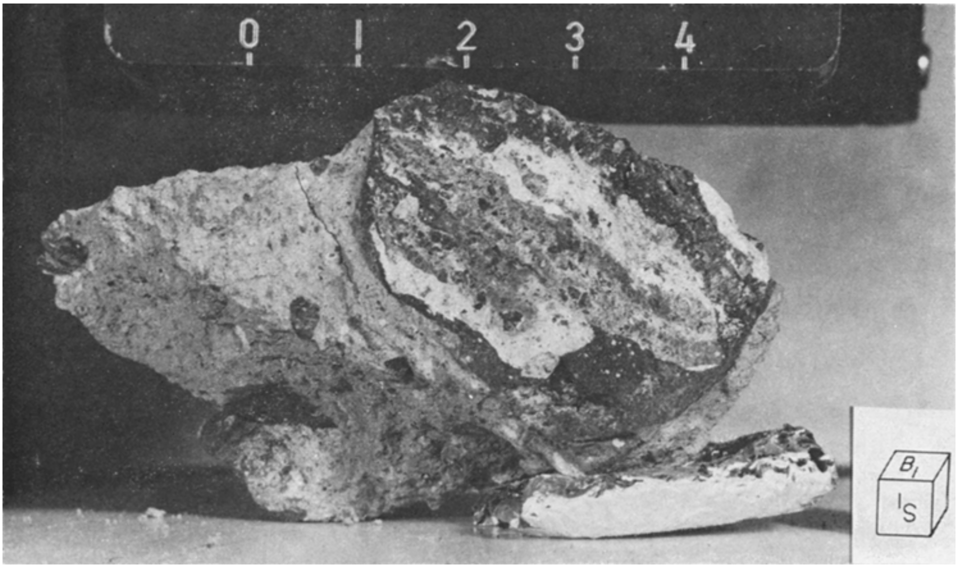

Fig. 8. 72235, the 'Dying Dog'. The large clast of black and gray competent breccias interlayered with anorthositic breccias (right) lies in a friable matrix similar to that of 72275 (left).

to have been crushed and fluidized under confining pressure. Not only does the dark 'rim' material bend back to form interior layers, but little veinlets of it intrude the white layers and vice versa. Macroscopically, the large clast of 72235 resembles the Marble Cake clast of 72275. However, the white portion lacks fragments of ilmenite KREEP norite, but includes a coarse-grained clast of another unique variety of KREEP norite (Ryder *et al.*, 1975).

5. Specimen 72255

Specimen 72255 (461 g) occurred as a rounded mass with a firm, dark patina. Although it bears a superficial resemblance to 72275, it is a much more coherent rock that may well have been part of a single large clast in the boulder. 72255 is a polymict breccia with a matrix varying in color from medium-gray to light-gray. One zone (the vicinity of the east tip in Figure 9) is rich in chalky white lenses and stringers.

Numerous types of clasts are present, including gray aphanitic microbreccias (GCBx), white anorthositic clasts with or without thin black rims, and yellow to brown crystalline gabbroic clasts. The most conspicuous feature of the specimen is the Civet Cat clast, a 2-cm, wedge-shaped fragment with wispy white tabular to lenticular inclusions in a dark brownish-gray ground mass (Figure 9). The clast proved to be a coarse-grained KREEP-poor norite (abbreviated CN) with a relict plutonic texture visible through shock features. It is among the oldest of lunar rocks (4.17 ± 0.05 b.y.; Compston *et al.*, 1975) and has zero meteoritic component (Morgan *et al.*, 1975), indicating an origin beneath the regolith. The clast itself is the only one of its kind

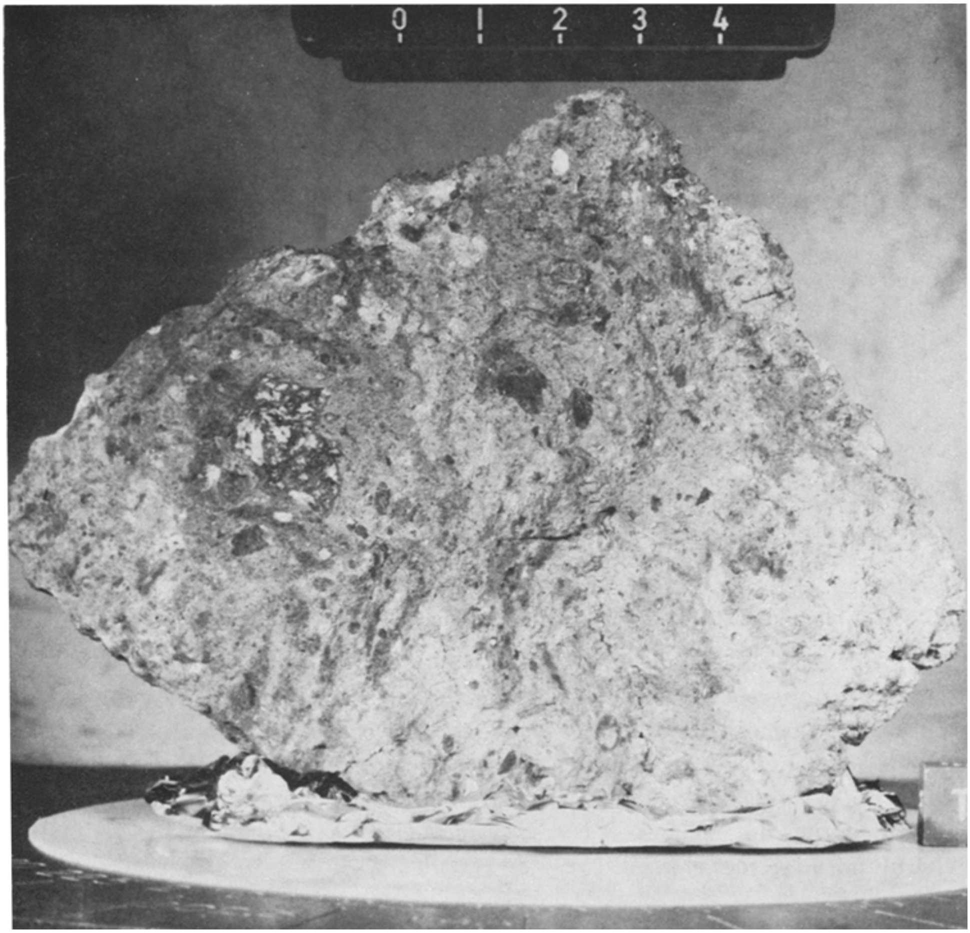

Fig. 9. The freshly fractured surface of 72255. The wedge-shaped black and white clast at left center is the Civet Cat clast, a KREEP-poor norite that is the oldest dated component of the boulder.

that is visible in hand specimen, but small fragments of this rock-type and of its distinctive pyroxenes occur in thin sections of all four boulder samples. Thus the ancient, deep-seated Civet Cat norite is an important component of the boulder.

6. Specimen 72215

Specimen 72215 (379 g) is of coherent material (mainly GCBx) with a rounded knob encrusted with anorthositic breccia at one end. The main mass consists of gray breccia ranging in color from light chalky to dark sugary gray (Figure 10). In the hand specimen, the dark sugary material, which is more coherent and of more uniform texture than the rest of the rock, appears as an irregular band through the matrix and a partial rim of the knob. However, under the microscope these various colors and

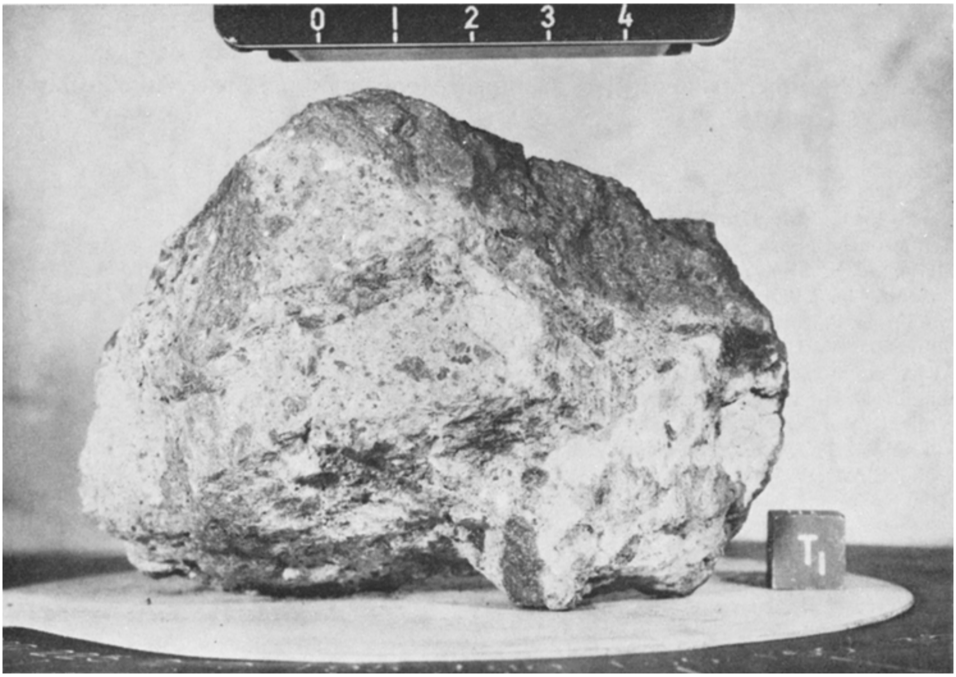

Fig. 10. 72215, a coherent specimen with irregular streaks and lenses of competent medium- and dark-gray breccias. A knob consisting mainly of GCBx, with a thin crust of white anorthositic breccia, occurs at the right-hand end of the specimen.

textures of breccia are virtually indistinguishable; everything from the light chalky matrix to the dark coherent knob looks about the same and is classed as GCBx. The anorthositic breccia of the knob contains several greenish clasts of coarse-grained poikilitic gabbroic anorthosite (Ryder *et al.*, 1975).

7. Outline of Macroscopic Observations

The foliated morphology of the boulder derives partly from post-aggregation shearing planes and partly from differential erosion of the friable matrix, which left behind prominent ridges and knobs of competent gray breccias. The boulder includes two lithologically distinct associations:

(1) Light-gray, friable, feldspar-rich matrix interfingered with crushed pigeonite basalt.

(2) Dark-gray to black competent microbreccias that are commonly interlayered with cataclastic anorthositic breccias. The dark microbreccias lack pigeonite basalts but include a range of clast-types, such as the Civet Cat norite and granitic fragments, not found within the light-gray matrix.

Any reconstruction of the boulder history must explain the incorporation of the dark polymict microbreccias within the matrix of crushed ANT rocks and pigeonite basalts.

Acknowledgement

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