Figure 1: This boulder of vesicular basalt from a small crater on rim of Steno Crater had a significant fillet. It was found to have been exposed to cosmic rays and micrometeorite bombardment for ~110 m.y. Samples 71055 and 71035, 71036 and 71037 were chipped from the top knobs of this boulder. NASA surface photo AS17-136-20739.
Figure 2: Three views of 71055. NASA photos S73-16172, 16164, 16168. Top is exterior surface.

Lunar Sample Compendium
C Meyer 2007
Introduction

Lunar basalts 71055 and 71035, 71036 and 71037 were all chipped from top of a small boulder (0.5 m) in small blocky crater (10 m) on rim of larger Steno Crater (figure 1). All samples are the same kind of high-Ti basalt. The crystallization age (of 71055) was determined by Rb-Sr as $3.64 \pm 0.09$ b.y. The cosmic ray exposure age was found to be 110 m.y.

Orientation of these samples was documented by photography (figure 35 in Wolfe et al. 1981). Thus, they have been in the Sun for 110 m.y. Sample 71036 was returned under vacuum and has been kept in a freezer since 1972. Although it has not been studied, it is the same lithology (basalt) as the other pieces of this boulder.

Soil samples 71040 (259 g) and 71060 (506 g) and assorted small rock fragments were scooped from the
shadow area behind the boulder – but this shadow would not have been “permanent”. They were returned “in vacuum” in ALSRC#1.

Petrography
Neal and Taylor (1993) summarize what is known about each of the samples of this basaltic boulder. Dymek et al. (1975) give a detailed petrologic description of 71055 and Warner et al. (1979) studied 71037. 71036 has not received attention, probably because it is another sample of the same material (it has been kept in a freezer since the mission).
Warner et al. (1979) describe 71037 as a fine-grained, high-Ti basalt. Due to low trace element content they grouped 71037 with “Type B Apollo 17 basalts”.

These samples are all very vesicular; up to 30% (figures 1, 2, 7, 9, 10). Vugs extend up to 12 mm. The texture is described as “plagioclase-poikilitic” (Neal and Taylor 1993). Average grain size is 1 – 2 mm with seriate grain size distribution.

**Mineralogy**

**Olivine**: Olivine in 71055 occurs as rounded cores of larger pyroxene and is Fo$_{75-68}$ (Dymek et al. 1975).

**Pyroxene**: According to Dymek et al. (1975), pyroxene in 71055 is “highly complex, both chemically and texturally. The largest grains (up to 2 mm), typically composite, are composed of pale-pink (Al- and Ti-poor) to dark-pink (Al- and Ti-rich) regions arranged in parallel bands, in a radiating spehulitic pattern, or forming an hourglass structure”. Pyroxene crystals are
found to have a wide range of chemical zoning (figure 6). Sung et al. (1974) found substantial Ti+3 in pyroxene.

**Plagioclase:** Large grains of plagioclase (up to 1.5 mm) poikilitically enclose pyroxene (Dymek et al. 1975). Other plagioclase forms elongate sheaves intergrown with pyroxene (figure 5). Plagioclase composition is An_{77-84}.

**Ilmenite:** Elongated blades of ilmenite in 71055 have been studied by Dymek et al. (1975), von Englehardt (1979) and Muhich et al. (1990). Taylor et al. (1992) have shown how to separate the ilmenite.

**Chemistry**
Tables 1 – 4 and figures 12 and 13 show that the chemical composition of 71055, 71035 and 71037 are typical of Apollo 17 basalts. Additional data for Zr and Hf are given in Garg and Ehman (1976) and Hughes and Schmitt (1985). Moore et al. (1974), Gibson et al. (1976), Moore and Lewis (1976) and Sill et al. (1974) determined C, S and N.

**Radiogenic age dating**
Tera et al. (1974) determined the age of 71055 by precise Rb-Sr isochron (figure 13). Murthy and Coscio (1976) merely quote Tera et al. Chen et al. (1979) and Taylor and Chen (1979) tried, but could not date 71055 by U-Th-Pb. Nyquist et al. (1976) determined the whole rock Rb and Sr isotopic composition of 71035, but did not obtain an isochron.

**Cosmogenic isotopes and exposure ages**
Rancitelli et al. (1974) determined the cosmic-ray-induced activity of 71035 (144 g). ^{22}Na was 92 dpm/kg, ^{26}Al = 79 dpm/kg, ^{46}Sc = 87 dpm/kg, ^{54}Mn = 164 dpm/kg, and ^{56}Co = 279 dpm/kg. Arvidson et al. (1976) determined the cosmic ray exposure age by Kr-Kr analysis as 110 ± 7 m.y.
Other Studies
Brecher (1974) magnetic properties
Mayeda et al. (1975) oxygen isotopes
Watson et al. (1974) magnetics
Trice et al. (1974) elastic properties
Usselman et al. (1975) experimental
O’Hara and Humphries experimental
Taylor et al. (1992) ISRU benification

Processing
71036 was returned in a sealed rock box (ALSRC #1) and placed in a freezer (-20 C). It has not been studied. A small slab was sawn from 71055 (figure 14).

Summary of Age Data for 71055

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<th>Method</th>
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<td>U/Pb</td>
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Tera et al. 1974
Chen et al. 1979
Tilton and Chen 1979
Caution: Old decay constant used.

Figure 13: “Picture worth a 1000 words” (Tera et al. 1975).
Table 1. Chemical composition of 71055.

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<th>reference</th>
<th>Miller74</th>
<th>Brunfelt74</th>
<th>Boynton75</th>
<th>Rose 74</th>
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<tr>
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<td>14.36 (a)</td>
<td>14.51 (a)</td>
<td>13.41 (b)</td>
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<td>Al2O3</td>
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<td>9.31 (a)</td>
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<td>18.52 (a)</td>
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<td>0.26 (a)</td>
<td>0.26 (a)</td>
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Sc ppm   95 (a) 82 (a) 87 (b) 94 (a) 80 (d)
V ppm    129 (a) 88 (b) 364 (d)
Cr ppm   2790 (a) 2640 (a) 2805 (a) 2800 (a) 2805 (d)
Co ppm   21.6 (a) 22 (a) 51 (b) 26 (a) 18 (d)
Ni ppm   <10 (a) 43 (b) 2 (d)
Cu ppm   4.4 (a) 31 (b)
Zn ppm   3 (a) 1.9 (d)
Ga ppm   3 (a) 8.1 (b) 4.27 (d) 22 (d)
Ge ppm   3.3 (d) 2.4 (d)
As ppm   <1.5 (d)
Se ppm   0.9 (a) 0.9 (b) 0.362 (c)
Sr ppm   104 (a) 170 (b) 121 (c)
Y ppm    69 (b)
Zr ppm   223 (b)
Nb ppm   27 (b)
Mo ppm   27 (b)
Ru ppm   27 (b)
Rh ppm   27 (b)
Pd ppm   27 (b)
Ag ppm   27 (b)
Cd ppm   27 (b)
In ppm   27 (b)
Sn ppm   27 (b)
Sb ppm   27 (b)
Te ppm   27 (b)

Cs ppm   0.07 (a)
Ba ppm   39 (a) 315 (b) 62.4 (c) 63 (d)
La ppm   4.67 (a) 4.6 (a) 4.6 (d)
Ce ppm   13.4 (a) 22 (a) 15.6 (c) 23 (a) 13 (d)
Pr ppm   17 (c) 33 (d)
Nd ppm   7.05 (a) 6.1 (a) 6.72 (c) 6 (d)
Sm ppm   14.9 (a) 1.8 (a) 1.36 (c) 1.5 (a) 1.3 (d)
Eu ppm   1.74 (a) 2 (a) 2.1 (a) 1.6 (d)
Gd ppm   14.3 (a) 13 (c)
Tb ppm   7.74 (c) 0.87 (d)
Ho ppm   0.089 (a)
Er ppm   0.089 (a)
Tm ppm   0.089 (a)
Yb ppm   0.089 (a)
Lu ppm   0.089 (a)
Hf ppm   0.089 (a)
Ta ppm   0.089 (a)
W ppm    0.089 (a)
Re ppm   0.089 (a)
Os ppm   0.089 (a)
Ir ppm   0.089 (a)
Pt ppm   0.089 (a)
Au ppm   0.089 (a)
Th ppm   0.089 (a)
U ppm    0.089 (a)

Technique: (a) INAA, (b) microchemical, (c) IDMS, (d) RNAA
Table 2. Chemical composition of 71035.

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Sc ppm 87  
V 2669  
Cr 19  
Ni 0.41  
Cu 130  
Zn  
Ga  
Ge ppb  
As  
Se  
Rb 0.41  
Sr 130  
Y  
Zr  
Nb  
Mo  
Ru  
Rh  
Pd ppb  
Ag ppb  
Cd ppb  
In ppb  
Sn ppb  
Sb ppb  
Te ppb  
Cs ppm 66.3  
Ba 5.77  
La 18.7  
Ce  
Pr  
Nd  
Sm  
Eu 1.5  
Gd 12.1  
Tb 13.6  
Dy  
Ho  
Er  
Tm  
Yb 7.71  
Lu 1.14  
Hf 7  
Ta  
W ppb  
Re ppb  
Os ppb  
Ir ppb  
Pt ppb  
Au ppb  
Th ppm  
U ppm  

Table 3. Chemical composition of 71037.

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<td>S %</td>
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<table>
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Sc ppm 85  
V 73  
Cr 2121  
Co 20  
Ni  
Cu  
Zn  
Ga  
Ge ppb  
As  
Se  
Rb  
Sr  
Y  
Zr  
Nb  
Mo  
Ru  
Rh  
Pd ppb  
Ag ppb  
Cd ppb  
In ppb  
Sn ppb  
Sb ppb  
Te ppb  
Cs ppm 66.3  
Ba 6.1  
La 21  
Ce  
Pr  
Nd  
Sm  
Eu 1.54  
Gd  
Tb 1.9  
Dy 13  
Ho  
Er  
Tm  
Yb 7.4  
Lu 1.02  
Hf 7  
Ta 1.7  

W ppb  
Re ppb  
Os ppb  
Ir ppb  
Pt ppb  
Au ppb  
Th ppm  
U ppm  

techniques: (a) XRF, (b) INAA, (c) IDMS
Figure 14: Group photo after cutting slab from 71055. Small cube is 1 cm. NASA S73-34148. This is the top, exposed lunar surface.
References


O’Hara M.J. and Humphries D.J. (1975) Armalcolite crystallization, phenocryst assemblages, eruption conditions and origin of eleven high titanium basalts from Taurus Littrow. LS VI, 619-621.


### Table 4

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<th>Technique</th>
<th>U ppm</th>
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<th>Rb ppm</th>
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