**Introduction**

64435 has a thick shiny black glass coat on one side (figure 1) and numerous micrometeorite pits on the other (figure 2) as if it had once been an impact bomb that had its glass coat eroded away on the unprotected side. 64435 is an oriented lunar sample that has been studied for cosmic ray induced activity. It contains clasts of plutonic igneous rocks (ferroan anorthosite clan) with “inverted” pigeonite.

**Petrography**

The majority of 64435 is a fine-grained grey impact melt that has not been described. It is found to be very aluminous in composition ($\text{Al}_2\text{O}_3 = \sim31\%$). Ryder and Norman (1980) noted that the plagioclase microlites in the matrix were often in alignment, as if by flow (figure 3). James and Flohr (1985abs) and James et al. (1989) studied a large (5x2x1 cm) coarse-grained white composite clast (CTA-A-FTA) made up of coarse troctolitic anorthosite and fine troctolitic anorthosite (see below).
Figure 2: Flip side of 64435 (see figure 1). NASA S72-39676. Cube is 1 cm. Note the abundant micrometeorite craters.

Additional data can be found in notes by Brian Mason (unpublished), Kempa and James (1982abs), Lindstrom (1984abs), James (1987abs) and the catalog by Ryder and Norman (1980).

**Significant Clasts**

*Troctolitic Anorthosite, 239:* This clast (figures 9 and 10) is coarse grained (1-4 mm) consisting of ~81% plagioclase (An97), 15% olivine (Fo71.5), 2-3% orthopyroxene (Wo1.5En74.5) and 1% augite (Wo45En45) (James et al. 1989). Noteworthy is that the pyroxene in this clast has the texture of “inverted pigeonite” indicating a slow cooling of the igneous body – as in a pluton!

*Anorthosite, 210A:* Clast (210A) is about 98% plagioclase (An98), 1% orthopyroxene (WoEn28) and 1% augite (Wo44En39). Plagioclase is shocked (James et al. 1989).

*Fine-grained Troctolitic Anorthosite, 207:* James et al. (1989) found that the area surrounding the coarse grained clasts (above) was a fine-grained granulite with the mineralogy of a troctolitic anorthosite. It is composed of about 85% plagioclase (An97.8) and 12% mafic minerals (olivine Fo70.6 and pyroxene (Wo1.3En72.75 and Wo45En45).
Anorthosite: Laul and Schmitt (1974) provide an analysis – may be same as composite clast studied by James et al. (above).

Mineralogy
Olivine: Olivine is very “mafic” (Fo72).

Pyroxene: The composition of pyroxene in the portions of the composite white clast are replotted in figure 4. Noteworthy is the presence of inverted pigeonite (figure 2c in James et al. 1989).

Plagioclase: All of the plagioclase in 64435 is very calcic (An90-98). The plagioclase is highly shocked.

Opaques: James et al. (1989) determined the composition of ilmenite and chromite.

Glass: See et al. (1986) and Morris et al. (1986) included 64435 in their study of “large glass objects”.

Metallic Iron: Hewins and Goldstein (1975) reported the Ni and Co in metal grains.

Chemistry
Taylor et al. (1974abs), Laul and Schmitt (1974abs) and Hubbard et al. (1974) determined the chemical composition of the melt rock (figure 6). The anorthosite clast studied by Laul and Schmitt (1974) may be the same as the composite clast studied by James et al. (1989). The composition of the shiny black glass coat (figure 1) has been measured by Morris et al. (1986), See et al. (1986), Laul and Schmitt (1974) and Ebihara et al. (1992).

The average compositions of the three portions of the composite white clast that was carefully studied by James et al. (1989) are summarized in table 1 and figure 6 (see their paper for specific details). The portions of the white clast are all related to ferroan anorthosite (figure 5).

Radiogenic age dating
64435 has not been dated, but Nunes et al. (1974, 1977) and Rosholt (1974) have determined the U, Th and Pb
Figure 5: Composition of plagioclase and pyroxene in clasts in 64435.152 (from James et al. 1989).

Cosmogenic isotopes and exposure ages
Fruchter et al. (1978) determined the cosmic-ray-induced activity of $^{26}$Al and $^{53}$Mn for an interior shielded chip and calculated exposure ages 1.3 and 1.7 m.y. Bogard and Gibson (1975) calculated the exposure age as 0.6 and 0.7 m.y. from $^{21}$Ne and $^{38}$Ar data by Bogard et al. (1973). Bhandari (1977) calculates 0.5 m.y. from $^{26}$Al data (Bhandari et al. 1976).
Table 1. Chemical composition of 64435.

<table>
<thead>
<tr>
<th>reference weight</th>
<th>Taylor74 matrix</th>
<th>Hubbard74 matrix</th>
<th>Laul 74 glass</th>
<th>anor.</th>
<th>Morris 86 glass</th>
<th>Ebihara92 glass</th>
<th>James 89 ave</th>
<th>ave</th>
<th>ave</th>
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<tr>
<td>SiO2 %</td>
<td>44.5 (d)</td>
<td>44.55 (e)</td>
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<td>TiO2</td>
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<td>0.2 (e)</td>
<td>0.5 (a)</td>
<td>0.1 (a)</td>
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<td>Al2O3</td>
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<td>30.25 (e)</td>
<td>32.1 (a)</td>
<td>24.5 (a)</td>
<td>35.5 (a)</td>
<td>24.43</td>
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<td>FeO</td>
<td>3.13 (d)</td>
<td>3.42 (e)</td>
<td>3 (a)</td>
<td>8 (a)</td>
<td>0.61</td>
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<td>MnO</td>
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<td>0.04 (e)</td>
<td>0.105 (a)</td>
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<td>MgO</td>
<td>3.38 (d)</td>
<td>3.83 (e)</td>
<td>3 (a)</td>
<td>8 (a)</td>
<td>9.4 (a)</td>
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<td>CaO</td>
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<td>17.16 (e)</td>
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<td>13.3 (a)</td>
<td>19 (a)</td>
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<td>Na2O</td>
<td>0.39 (d)</td>
<td>0.34 (e)</td>
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<td>K2O</td>
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<td>0.066 (e)</td>
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<td>0.02</td>
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<td>P2O5</td>
<td>0.03 (e)</td>
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**Sc ppm** 7 (d) 5.2 6.9 0.9 (a) 7.7 (a) 3.67 0.433 4.3 (a)
**V** 22 (d) 15 20 4 (a)
**Cr** 498 (b) 438 1163 5.7 (a) 1194 (a) 494 12.9 340 (a)
**Co** 26 (d) 7 100 1.3 (a) 80 (a) 13.5 0.332 7.04 (a)
**Ni** 56 (d) 1800 (a) 1508 (c) 35 <3 16 (a)
**Cu** 4 (d) 11.2 (c)
**Zn**
**Ga**
**Ge ppb** Reimold 84 1750 (c) 2.68 (c)
**As**
**Se**
**Rb** 0.39 (d) 0.638 (b) 2.24 (b) 146 (b)
**Sr**
**Y** 4.53 (d) 100 (a)
**Zr** 17 (d) 11.2 (b) 100 (a)
**Nb** 1.38 (d)
**Mo**
**Ru**
**Pd ppb** 76.8 (c)
**Ag ppb** 12.1 (c)
**Cd ppb** 71 (c)
**In ppb** 101 (c)
**Sn ppb**
**Sb ppb** 5.6 (c)
**Te ppb** 68.3 (c)
**Cs ppm** 0.02 (d) 108 (c) 0.032 0.045 0.049 (a)
**Ba** 28 (d) 21.1 (b) 20 90 9 (a) 141 (a) 8 6 9 (a)
**La** 1.54 (d) 1.32 (b) 1.5 9.6 0.16 (a) 11 (a) 0.336 0.129 0.392 (a)
**Ce** 3.99 (d) 4.06 (b) 4 24 (a) 25.6 (a) 19.5 (c) 0.81 0.259 1.13 (a)
**Pr** 0.47 (d)
**Nd** 1.95 (d) 2.35 (b) 3 15 0.4 (a) 14.4 (c)
**Sm** 0.53 (d) 0.681 (b) 0.7 4.3 0.086 (a) 4.59 (a) 0.146 0.0402 0.157 (a)
**Eu** 0.68 (d) 0.759 (b) 0.76 0.91 0.69 (a) 1 (a) 2.902 (c) 0.681 0.698 0.716 (a)
**Gd** 0.72 (d) 0.842 (b)
**Tb** 0.13 (d) 0.2 0.8 0.03 (a) 1.07 (a) 0.86 (c) 0.038 0.0099 0.042 (a)
**Dy** 0.8 (d) 1.03 (b) 0.8 5.1 0.2 (a)
**Ho** 0.19 (d)
**Er** 0.53 (d) 0.66 (b)
**Tm** 0.087 (d)
**Yb** 0.53 (d) 0.611 (b) 0.58 2.8 0.06 (a) 3.53 (a) 2.96 (c) 0.158 0.0258 0.189 (a)
**Lu** 0.082 (d) 0.095 (b) 0.082 0.43 0.008 (a) 0.44 (a) 0.408 (c) 0.028 0.0026 0.032 (a)
**Hf** 0.52 (d) 0.41 3.2 0.03 (a) 3.27 (a) 0.063 0.0064 0.125 (a)
**Ta** 0.017 (d) 0.035 0.02 (a) 0.45 (a) 0.014 0.004 0.019 (a)
**W ppb**
**Re ppb** 5.82 (c)
**Os ppb** 62.9 (c)
**Ir ppb** 50 (a)
**Pt ppb** 57.2 (c)
**Au ppb** 21.9 (c)
**Th ppm** 0.23 (d) 0.218 (b) 0.25 1.1 (a) 2.84 (a)
**U ppm** 0.12 (d) 0.062 (b) 0.1 0.4 0.02 (a) 0.35 (a) 0.372 (c)

**technique:** (a) INAA, (b) IDMS, (c) RNAA, (d) ssms, (e) XRF
Figure 8: Group photo of first slab 64435. NASA S73-17790. Cubes are 1 cm.

Figure 9: Photo of first slab cut from 64435 showing coarse troctolitic anorthosite, 239 and anorthosite, 210A clasts (near cube). Also see same clasts on opposite face of 152 (figure 10). Cube is 1 cm.
Other Studies
Charette and Adams (1977)  spectra
Huffman et al. (1974)  Mossbauer
Huffman and Dunmyre (1975)  Mossbauer
Nagata et al. (1974)  magnetics
Cisowski et al. (1976)  magnetics
Schwerer and Nagata (1976)  gas release
Gibson and Moore (1975)  nitrogen, methane
Gibson and Andrawes (1978)  rare gas content
Bogard et al. (1973)  tracks, crater counts
Bhandari et al. (1976)  C
Moore et al. (1973)  
Gripe and Moore (1974)  
Moore and Lewis (1976)  

Processing
Two adjacent slabs have been cut from 64435: one in 1973 and the second in 1983. Portions of the first slab were to be studied by a consortium led by Brian Mason (results published in Ryder and Norman 1980). The second slab included the large white composite clast (,152 CTA-A-FTA) studied in detail by James et al. (1989), but portions of this large clast also outcrop on ,15 and ,11.
References for 64435


Ryder G and Norman M.D. (1980) Catalog of Apollo 16 rocks (3 vol.). Curator’s Office pub. #52, JSC #16904
