# 77115

## Micropoikilitic Impact Melt Breccia
## 115.9 g, 6.5 x 5.5 x 3.5 cm

### INTRODUCTION

Sample 77115 was sampled as "blue-grey breccia" from the boulder at Station 7 (*see the section on the Station 7 Boulder, page 235*). It is a sample of the boulder matrix that incorporated the large white norite clast (77215). It contains obvious large lithic clasts, as seen in the hand specimen (Fig. 1), and has numerous small lithic and mineral clasts in the matrix. The texture and chemical composition of 77115 is similar to that of the black dike in 77075, although it is somewhat coarser grained. Schmitt had observed that these rocks are closely related in origin (see discussion in 77075).

Sample 77115 is a grey, vuggy, very fine-grained, fragment-laden, crystalline-matrix breccia containing abundant xenoliths (clasts). It consists of two parts: a grey, fine-grained matrix making up most of the rock and a thin layer that is part of a brown granular breccia clast (Minkin et al., 1978). Chao et al. (1975) state that 77115 is "not a breccia in a normal sense, but is a crystalline rock, formed by crystallization of a fragment-laden melt." The probable origin of impact melt breccias has been explained by Simonds (1975) and Onorato et al. (1976).

### PETROGRAPHY

The fine-grained matrix of 77115 (Fig. 2) consists largely of an interlocking network of anhedral and lath plagioclase surrounded by pyroxene in a micropoikilitic texture generally typical of the matrix of the other impact melt rocks from Apollo 17 (i.e., 76035, 72435, 73155, etc.). The plagioclase and pyroxene form a subophitic-topoikilitic intergrowth in which the maximum grain size of pyroxene oikocrysts is approximately 25-30 µm and of matrix plagioclase is less than 15 µm (McGee et al., 1980).

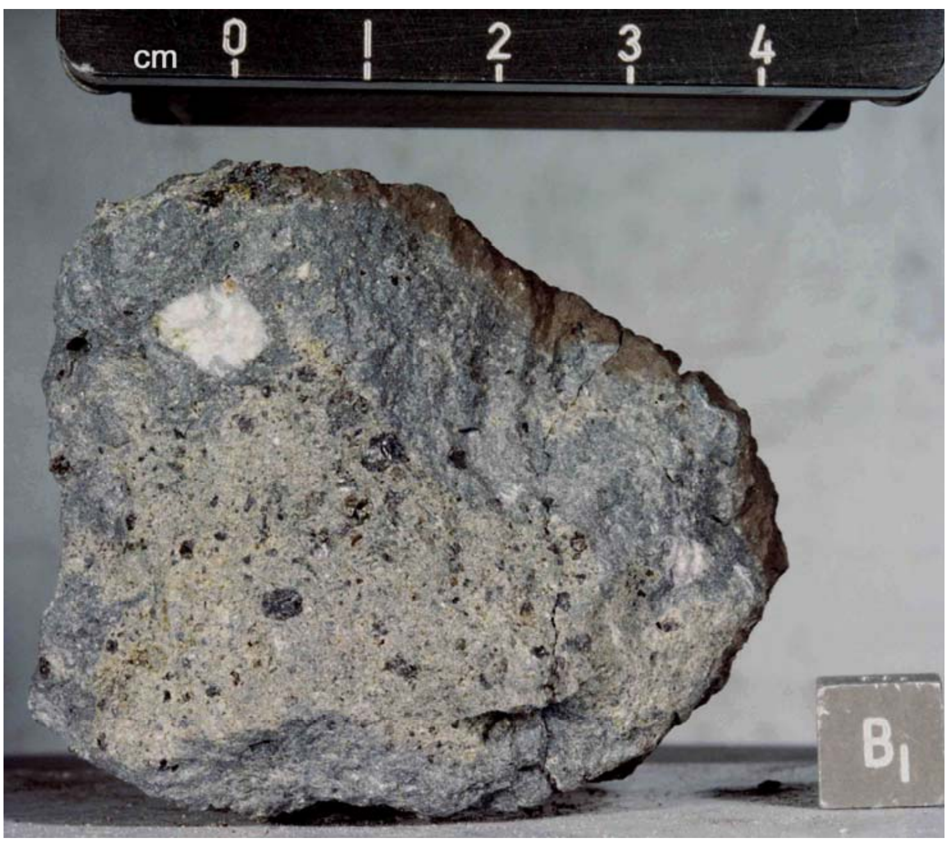


Figure 1: Photograph of broken surface of 77115. Note the dark clasts as well as the large white clast. S73-24122.

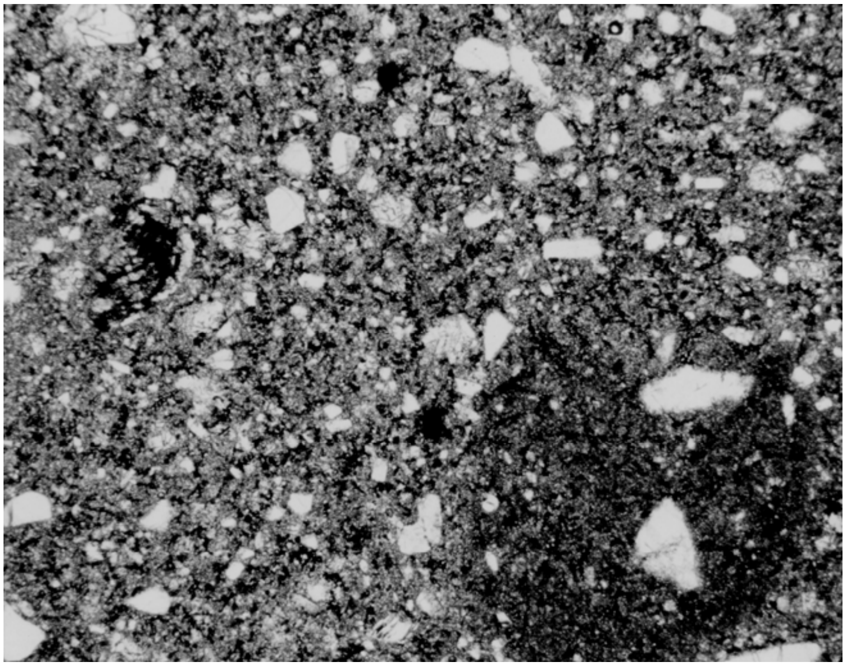

Figure 2: Photomicrograph of thin section 77115,60, showing the crystalline matrix with partially dissolved clasts. Field of view is 3 x 5 mm.

Chao et al. (1975) reports the modal mineralogy of the matrix of 77115 (Table 1). The matrix has ~60% plagioclase, ~30% pigeonite, and ~6% olivine, with minor amounts of augite, phosphate, troilite, mesostasis, and metallic iron. Equant grains of olivine are scattered throughout the matrix. Clusters of ilmenite platelets mold against grains of plagioclase and pyroxene and poikilitically enclose plagioclase, olivine, and pyroxene. Small amounts of a K-rich mesostasis and associated small grains of phosphate minerals, metallic iron, troilite, and ilmenite occur interstitially. Some pyroxene and plagioclase occur as euhedral crystals in the vugs. The grain size of the plagioclase, pyroxene, and ilmenite in the matrix ranges from 1 µm to about 30 µm, with most grains about 5-10 µm. Olivine grains are generally larger, about 6-8 µm across.

In the matrix, plagioclase is $An_{85-88}$, low-Ca pyroxene ranges from $Wo_{4-13}En_{66-77}Fs_{19-21}$, and minor amounts of high-Ca pyroxene range from $Wo_{30-40}En_{46-50}Fs_{14-16}$
Olivine is $Fo_{66-72}$

77115 contains a large variety of lithic clasts, and according to Chao et al. (1975), the clast population appears different from that of 77135 (which is from the breccia that surrounds the 77115 lithology). Figs. 3 and 4 are photomicrographs of a small compound lithic clast in thin section 77115,11, illustrating a small anorthosite clast within a larger granulated noritic clast.

Chao et al. (1975) and Huebner (1976) reported diffusively rimmed xenocrysts in 77115. This occurs where the enclosed mineral clast has a composition different from The matrix. Thornber and Heubner (1980) and Sanford and Heubner (1979 and 1980) discuss cation diffusion and cooling rates for 77115. They use chemical gradients in olivine (Fig. 5) to calculate a cooling rate of 10-25 °C/hr. from 1230 °C to 1180 °C and <7 °C/hr. below 1180 °C.

Thornber and Heubner (1980) have also performed an experimental study of the phase equilibria relations of a melt with the composition of 77115 (Fig. 6).

## MINERAL CHEMISTRY

Chao et al. (1975) report the compositions of pyroxene, olivine, and plagioclase. McGee et al. (1980) have carefully studied the composition (Fig. 7) and microstructures in the pyroxenes from the different lithologies of the Station 7 Boulder, including 77115. They measured exsolution lamellae in pigeonite -20-25 µ1n wide in pyroxenes in 77115 and 77135 as compared with -10 µm wide for 77075 dike rock, leading McGee et al. to conclude that the 77075 dike crystallized more rapidly and cooled through the solidus more rapidly than did the enclosing rocks 77115 and 77135.

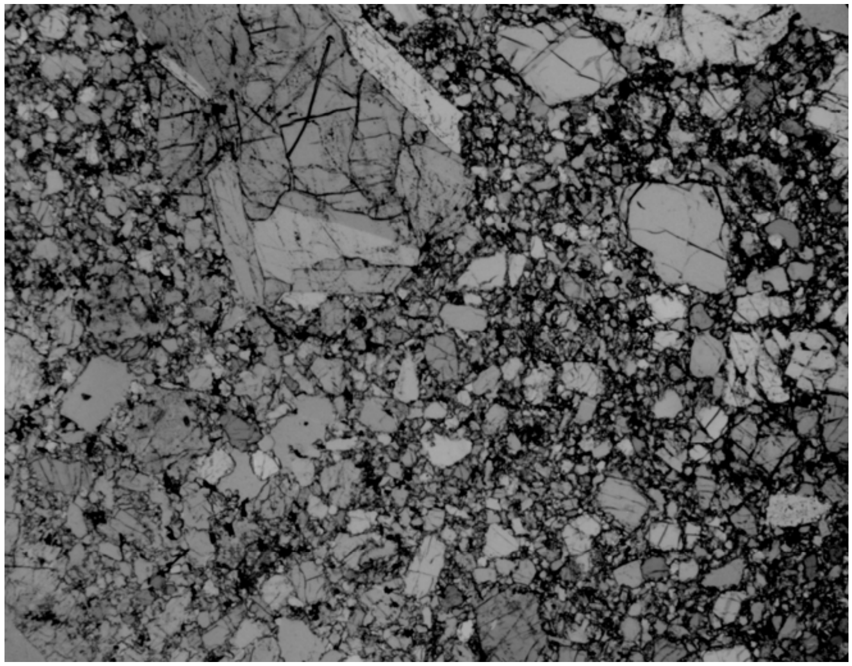

Figure 3: Photomicrograph of an "anorthositic" clast in thin section 77115,11. Field of view is 3 x 5 mm.

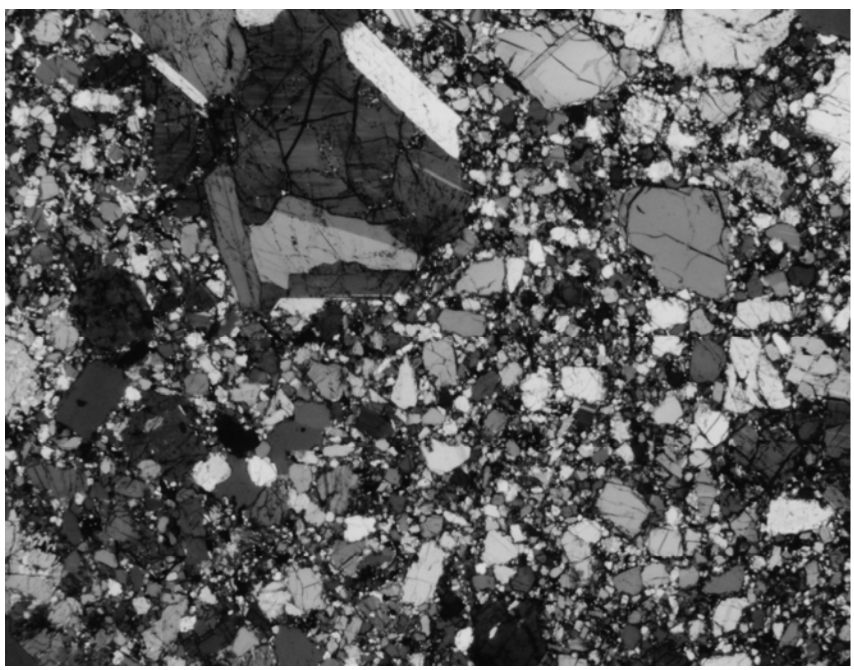

Figure 4: Cross-polarized view of same area as Fig. 3.

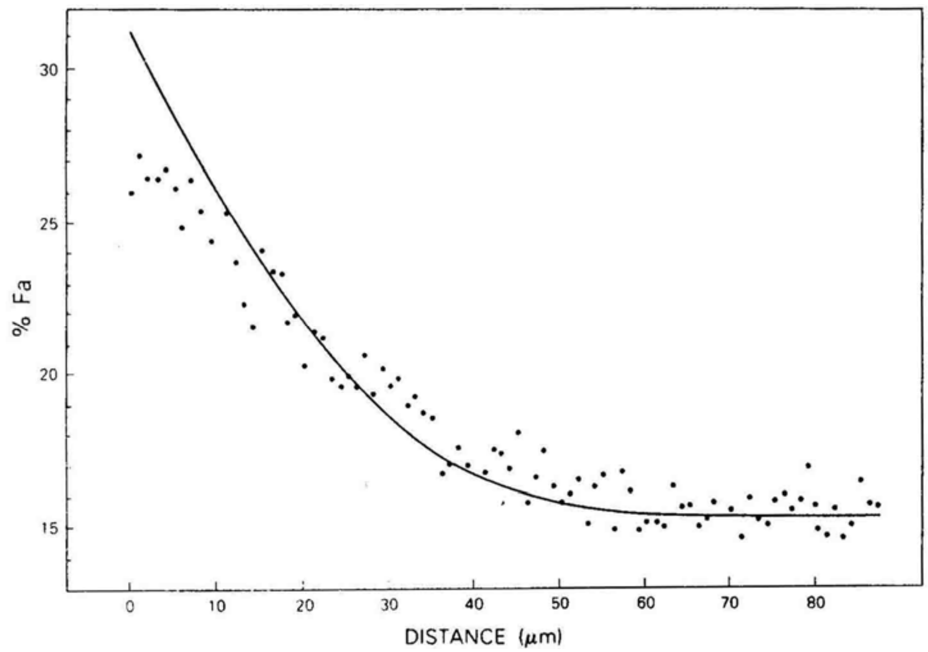


Figure 5: Composition gradient at edge of olivine xenocryst in 77115. From Sanford and Huebner (1979).

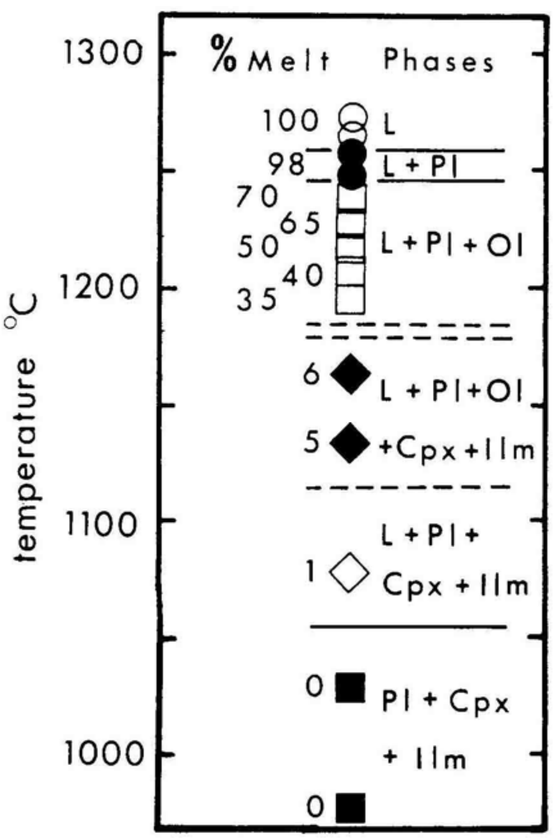


Figure 6: Phase relationships from experimental study by Thornber and Huebner (1980).

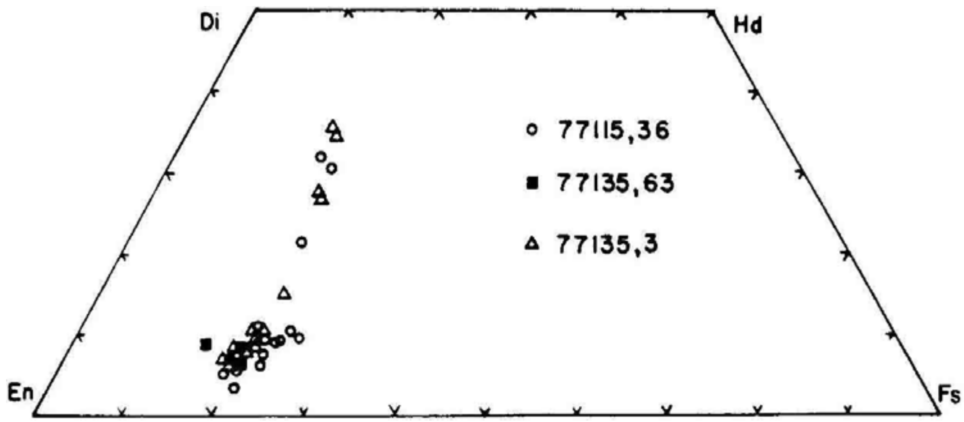


Figure 7: Pyroxene composition in 77115 matrix. From McGee et al. (1980).

Bersch et al. (1991) have precisely determined the compositions of olivine in 77115. Engelhardt (1979) has reported the composition of the ilmenite. Hansen et al. (1979) report the trace element content of plagioclase. Warren and Kallemeyn (1993) report that an uncommonly magnesian Cr-spinel is present in the troctolitic anorthosite clast.

## WHOLE-ROCK CHEMISTRY

Winzer et al. (1974) reported the chemical composition of 77115 (Table 2 and Fig. 8). Note the high trace element and phosphate content of the Aroctolite" clast. Ebihara et al. (1991) report the trace compositions of siderophile and volatile elements (Table 3). Fruchter et al. (1975) report K, U, and Th contents.

## SIGNIFICANT CLASTS

Chao et al. (1975) discuss a brownish-grey xenolith that is found as a thin veneer on the surface that was attached to the boulder (presumably why it broke this way). This clast is a recrystallized breccia with a bimodal; grain-size distribution (but not cataclastic) containing millimeter-size clasts of granulated clinopyroxene set in a matrix of smaller, slightly fractured yellow-green olivine ($FO_{69}$) and colorless to light grey plagioclase.

Warren and Kallemeyn (1993) have restudied the "troctolite" clast in 77115 that was originally reported by Winzer et al. (1974). Warren and Kallemeyn conclude that this clast should be properly called a troctolitic anorthosite and be classified as a member of the "alkalic suite." This unusual clast has very high REE abundance (Fig. 8). In this clast, plagioclase is An95, olivine is Fogg, and pyroxene is $WO_{1.7}En_{88}Fs_{10}$.

## RADIOGENIC ISOTOPES

Stettler et al. (1978) have restudied the ages of 77115 and confirmed their results of 1974. They have determined a pronounced intermediate temperature plateau at 3.90 ± 0.03 b.y. (Fig. 9). This is a problematical puzzle because this rock was observed to be continuous with the dike rock (77075), which has been dated by the same laboratory at 3.97 ± 0.03 b.y. Possibly the enclosure of 77115 within the "green-grey" breccia 77135 (age 3.89 b.y.) has reset the age of 77115 without resetting the age of 77075.

Nakamura et al. (1976) have determined a Rb-Sr isochron (Table 4) with an imprecise "age" of 3.75 ± 0.20 b.y. (Fig. 10).

Nunes et al. (1974) have reported U-Th-Pb data for 77115 (Table 5).

## MAGNETIC STUDIES

Cisowski et al. (1983) have determined the thermal remanent magnetization of 77115. Hale et al. (1978) also attempted (unsuccessfully) to determine the magnetization of this sample.

## PROCESSING

The initial processing and distribution of 77115 is outlined in Butler and Dealing (1974). It was studied by the international consortium led by E.C.T. Chao (see final report by Minkin et al., 1978). Detailed description of the splits is given in open-file report 78-511.

The largest remaining piece of 77115 is 76 g. Twenty-eight thin sections of 77115 have been prepared.

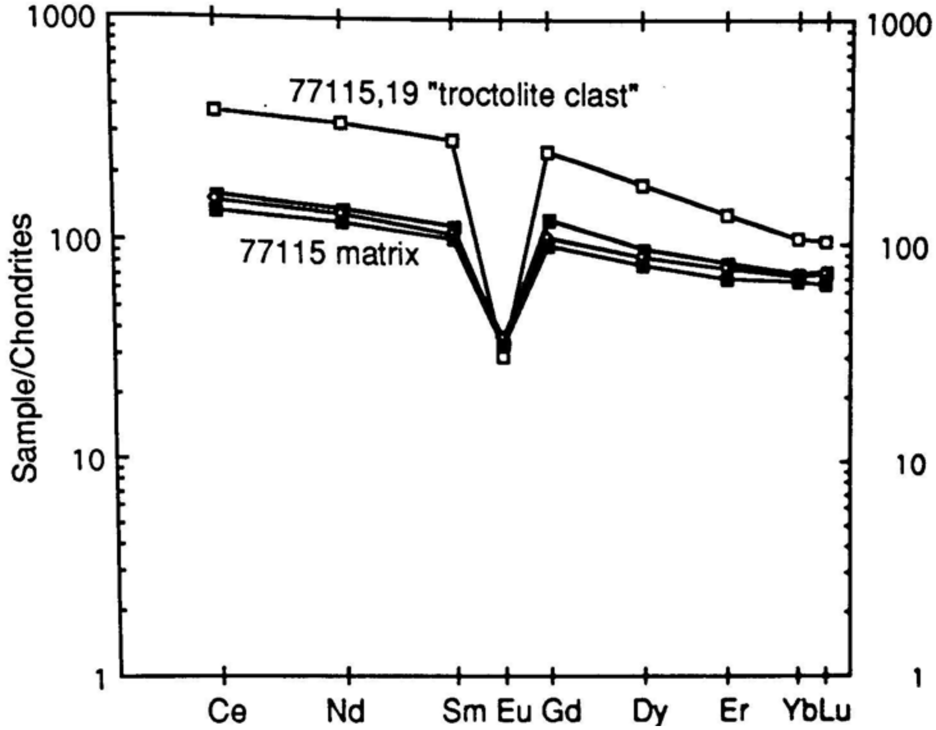


Figure 8: Normalized rare earth element composition of 77115 matfix and clast. Data from Winzer et at. (1974) and Warren and Kallemeyn (1993).

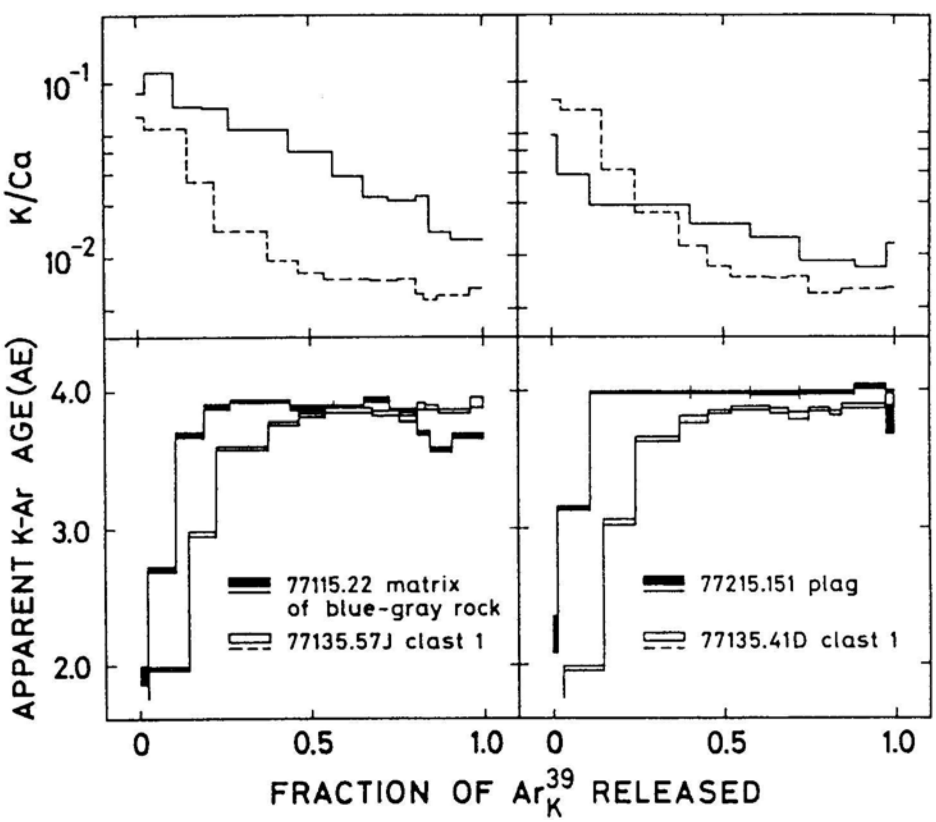


Figure 9: $^{39}$Ar $^{40}$Ar thermal release pattern for 771.15. From Stettler et al. (1978).

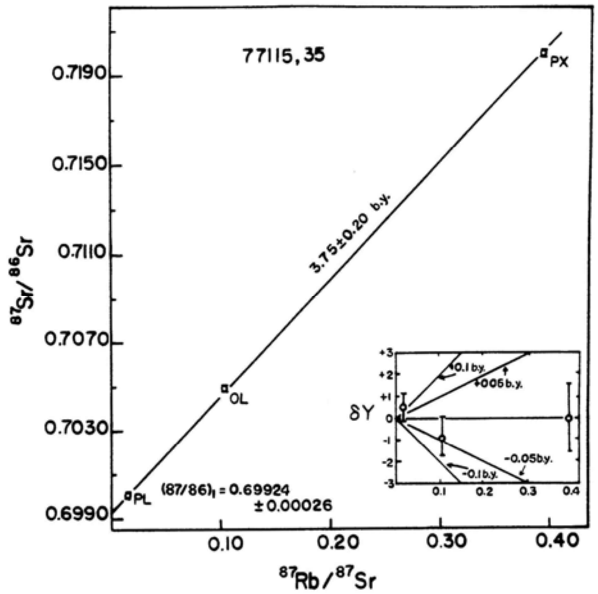


Figure 10: Rb-Sr isochron for 77115. From Nakamura et al. (1976).

**Table 1: Mineral modes far 77115. ***
From Chao et al. (1975).

| | 77115,52 | Matrix † | 77115,53 | Matrix † | 77115,56 | Matrix † | Average | Average matrix † |
|---|---|---|---|---|---|---|---|---|
| Plagioclase | | | | | | | | |
| (A) Matrix, anhedral and laths | 46.3 | 59.2 | 49.3 | 61.4 | 50.2 | 61.1 | 48.6 | 60.5 |
| (B) Xenocrysts | 10.5 | – | 13.3 | – | 11.2 | – | 11.7 | – |
| Clinopyroxene | | | | | | | | |
| (A) Matrix | 24.7 | 31.6 | 22.4 | 27.9 | 22.4 | 27.2 | 23.2 | 28.9 |
| (B) Xenocrysts | 2.6 | – | 1.5 | – | 0.7 | – | 1.6 | – |
| Olivine | | | | | | | | |
| (A) Matrix, granular | 4.5 | 5.7 | 5.3 | 6.6 | 5.5 | 6.7 | 5.1 | 6.3 |
| (B) Xenocrysts | 3.8 | – | 2.4 | – | 3.4 | – | 3.2 | – |
| Orthopyroxene xenocrysts | 3.5 | – | 1.5 | – | 1.8 | – | 2.3 | – |
| Ilmenite | 2.0 | 2.6 | 2.5 | 3.1 | 3.6 | 4.4 | 2.7 | 3.4 |
| K-rich material | 0.4 | 0.5 | 0.6 | 0.7 | 0.2 | 0.2 | 0.4 | 0.5 |
| Phosphate | 0.1 | 0.1 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| Ni-Fe material | 1.4 | – | 0.9 | – | 0.7 | – | 1.0 | – |
| Troilite | 0.2 | 0.3 | 0 | 0 | 0.2 | 0.2 | 0.1 | 0.2 |
| Fe metal | TR. | TR. | TR. | TR. | TR. | TR. | TR. | TR. |
| Total | 100.0 | 100.0 | 99.9 | 100.0 | 100.1 | 100.0 | 100.1 | 100.0 |

*Normalized after subtracting voids and xenoliths.
†Normalized after subtracting xenocrysts.
Done in reflected and transmitted light by C. L. Thompson.

**Table 2: Whole-rock chemistry of 77115.**
From Winzer et al. (1974).

| Split<br>Technique | ,69<br>AA, IDMS<br>matrix | ,70<br>AA, IDMS<br>matrix | ,71<br>AA, IDMS<br>matrix | ,19<br>AA, IDMS<br>"troctolite"<br>clast | ,19<br>AA, IDMS<br>chilled<br>margin |
|---|---|---|---|---|---|
| $SiO_2$ (wt%) | 47.1 | 47.1 | 47.2 | 41.8 | 46.6 |
| $TiO_2$ | 1.31 | 1.23 | 1.34 | 0.17 | 1.15 |
| $Al_2O_3$ | 17.35 | 18.86 | 17.55 | 16.78 | 18.63 |
| $Cr_2O_3$ | 0.17 | 0.16 | 0.18 | 0.04 | 0.19 |
| FeO | 8.90 | 8.39 | 9.51 | 6.08 | 8.44 |
| MnO | 0.11 | 0.11 | 0.11 | 0.06 | 0.11 |
| MgO | 12.33 | 10.98 | 12.43 | 23.54 | 11.96 |
| CaO | 10.79 | 11.11 | 10.89 | 10.24 | 11.01 |
| $Na_2O$ | 0.66 | 0.69 | 0.67 | 0.31 | 0.67 |
| $K_2O$ | 0.26 | 0.32 | 0.24 | 0.08 | 0.25 |
| $P_2O_5$ | 0.33 | 0.31 | 0.31 | 0.53 | 0.37 |
| Nb (ppm) | | | | | |
| Zr | 538 | 524 | 477 | 160 | 549 |
| Hf | 12.9 | | | | |
| Sr | 170 | 180 | 167 | 134 | 176 |
| Rb | 6.82 | 8.82 | 6.35 | 1.24 | 6.10 |
| Li | 17.6 | 16.8 | 19.3 | 12.1 | 18.1 |
| Ba | 416 | 461 | 393 | 243 | 386 |
| Ce | 95.4 | 92.4 | 82.7 | 226 | 120 |
| Nd | 62.4 | 59.3 | 55.5 | 155 | 76.5 |
| Sm | 17.3 | 16.1 | 15.2 | 42.2 | 21.4 |
| Eu | 1.93 | 2.06 | 1.91 | 1.68 | 1.96 |
| Gd | 25.2 | 20.8 | 18.9 | 50.8 | 26.3 |
| Tb | | | | | |
| Dy | 22.7 | 21.4 | 19.5 | 44.2 | 28.6 |
| Er | 13.2 | 12.5 | 11.1 | 21.6 | 15.9 |
| Yb | 12.1 | 11.7 | 11.0 | 17.2 | 14.5 |
| Lu | 1.86 | 1.80 | 1.59 | 2.51 | 2.20 |

**Table 3: Trace element data for 77115. Concentrations in ppb.**
From Ebihara et al. (1991).

| | Sample 77115,38 (a) | Sample 77115,74 (b) |
|---|---|---|
| Ir | 8.62 | 7.15 |
| Os | 8.19 | 7.99 |
| Re | 0.894 | 0.715 |
| Au | 5.52 | 4.43 |
| Pd | 18.1 | 10.9 |
| Ni (ppm) | 332 | 287 |
| Sb | 3.01 | 1.99 |
| Ge | 512 | 462 |
| Se | 101 | 104 |
| Te | 5.48 | 6.15 |
| Ag | 11.8 | 1.21 |
| Br | | |
| In | 6.61 | 9.95 |
| Bi | 0.46 | 0.33 |
| Zn (ppm) | 2.19 | 2.34 |
| Cd | 4.15 | 16.3 |
| Tl | 3.51 | 1.83 |
| Rb (ppm) | 8.93 | 7.43 |
| Cs | 230 | 281 |
| U | 1480 | 1500 |

(a) Fine-grained impact melt breccia matrix
(b) Troctolitic anorthosite clast (?)

**Table 4: Rb-Sr composition of 77115,35.**
Data from Nakamura et al. (1976).

| Separate | Plag. | Olivine | "Pyroxene" |
|---|---|---|---|
| wt (mg) | 4.74 | 4.63 | 0.80 |
| K (%) | 0.078 | 0.0291 | 0.1129 |
| Rb (ppm) | 1.300 | 0.700 | 4.465 |
| Sr (ppm) | 243.6 | 19.6 | 32.81 |
| $^{87}Rb/^{86}Sr$ | 0.01543 | 0.1033 | 0.3942 |
| $^{87}Sr/^{86}Sr$ | $0.70002 \pm 4$ | $0.70491 \pm 6$ | $0.72000 \pm 11$ |

**Table 5: U-Th-Pb for '77115.**
From Nunes et al. (1974).

| Split | 77115,35 |
|---|---|
| wt (mg) | 192.4 |
| U (ppm) | 1.453 |
| Th (ppm) | 5.436 |
| Pb (ppm) | 3.116 |
| $^{232}Th/^{238}U$ | 3.87 |
| $^{238}U/^{204}Pb$ | 2415 |