77075

Impact Melt Dike in Cataclastic Norite
172.4 g; 4 x 4 x 4 cm, 1.2 x 1.5 x 1.5 cm, 1 x 1 x 0.5 cm (3 fragments)

INTRODUCTION

Sample 77075 was sampled from one of the dark dikes within the large, "off-white" clast in the boulder at Station 7 (see the section on the Station 7 Boulder, page 235). The dike material is a fragment-laden melt rock with a matrix texture and chemical composition similar to that of 77115, but with a finer grain size. Friable white cataclastic norite (equivalent to samples 77077 and 77215) is attached to the black dike. Sample 77076 and piece 19 of 77215 are also from the same dark dike. The dark dike was about 3 cm thick (Minkin et al., 1978)

PETROGRAPHY

Sample 77075 consists of three pieces that fit together (Fig. 1). The dark dike material is a fragment-laden, micropoikilitic impact melt breccia that is a fine-grained equivalent of the boulder sample 77115. Schmitt (in Schmitt and Cernan, 1973) observed that the dike material was continuous with the "blue-grey, matrix-rich breccia" (represented by 77115) that surrounds the off-white norite clast that the dike cuts (Fig. 2). Indeed, the chemistry, age, mineralogy, and texture of the thin sections all confirm this field observation (or is it the other way around?). The white material attached to the sides of 77075 is the same noritic material as that of 77215 and is part of the large, "off-white" boulder clast.

Chao et al. (1974) and Minkin et al. (1978) have described 77075. Megascopically, the dark vein in 77075 is aphanitic with scattered small xenoliths of calcic plagioclase, pyroxene, and olivine. The matrix is holocrystalline with very fine grain size (Fig. 3). The average grain size of the matrix of 77075 is 5-10 µ1n, with poikilitic pyroxene averaging 10-20 µm (McGee et al., 1980). The principal minerals in the matrix are calcic plagioclase (An_{89-92}), pigeonite, and olivine (Fo_{74-78}). Orthopyroxene xenocrysts have a uniform composition of $Wo_{3-4}En_{66-69}$ Fs_{28-30}. Augite was not observed in the matrix of the dike material in 77075. The dense, dark dike has a sharp boundary with the porous, noritic microbreccia.

McGee et al. (1980) have studied the microstructures in the pyroxenes from the different lithologies of the Station 7 Boulder, including the 77075 dike. They measured exsolution lamellae that were ~10 µm wide in pigeonite compared with 20-25 µm wide in pyroxenes in 77115 and 77135, leading McGee et al. to conclude that the 77075 dike

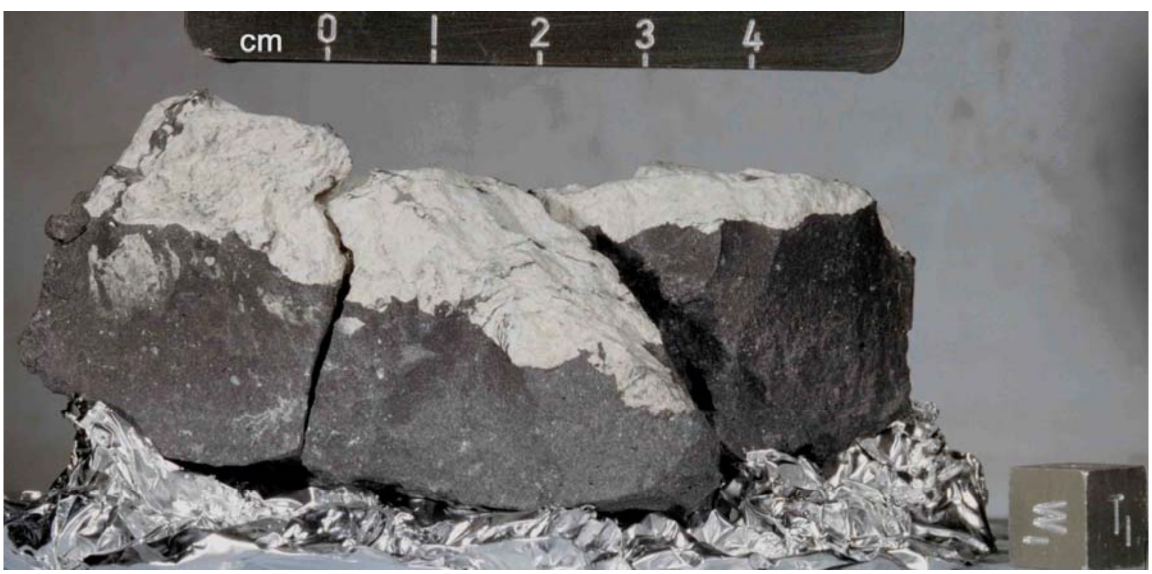

Figure 1: Photograph of 77075. Scale is 1 cm. S73-24005.

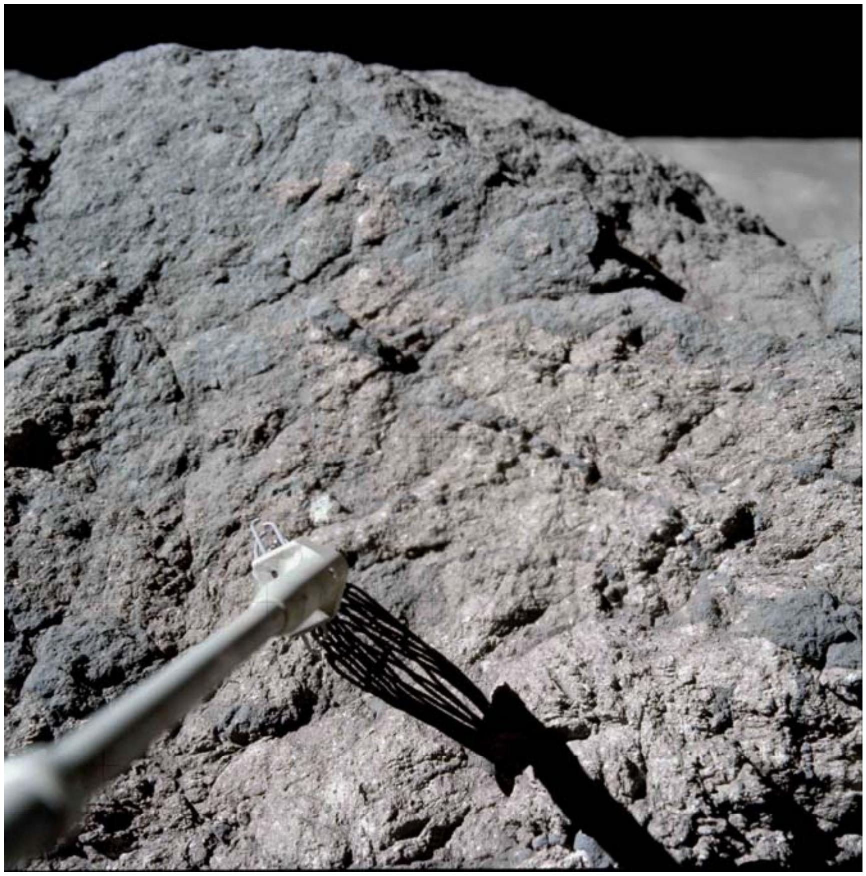

Figure 2: Closeup photograph of the boulder at Station 7. The vein through the off-white norite clast can be clearly seen through the brown patina. Schmitt observed that this vein (77075) is continuous with the surrounding breccia (77115). AS17-146-22327.

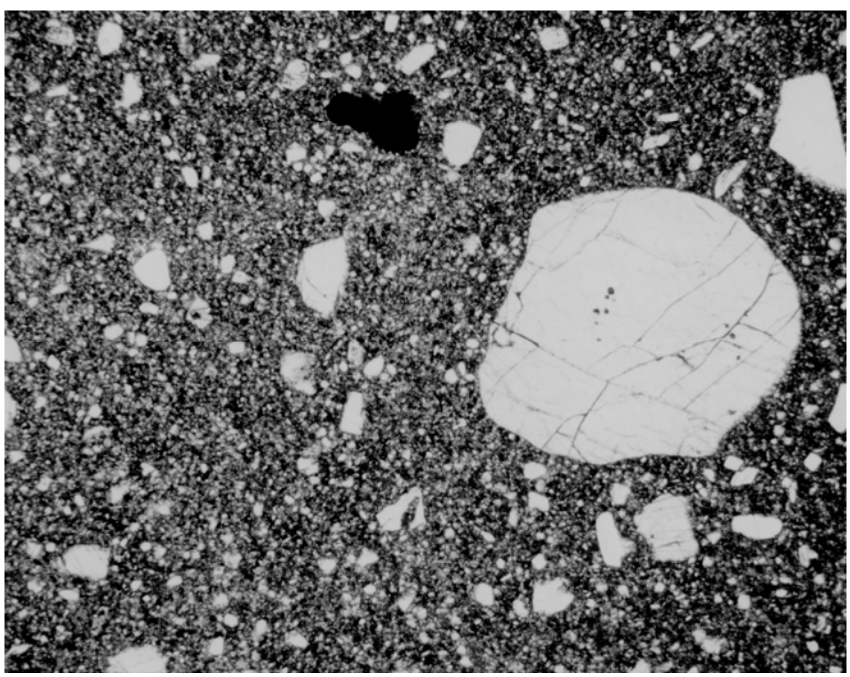

Figure 3: Photomicrograph of 77075,11, showing the poikilitic texture of the dike material. Rounded olivine xenocryst is included. Field of view is 3 x 4 mm.

crystallized and cooled through the solidus more rapidly than did the enclosing rocks 77115 and 77135. Presumably, the relatively rapid cooling of the dike rock also inhibited precipitation of matrix augite and resulted in coprecipitation of ilmenite and pigeonite. The abundant population of cooler, unmelted fragments in 77075 probably contributed to the rapid initial cooling rate and favored fine grain size by providing a high initial density of nuclei. Rapid quenching of the dike rock by injection into a cooler clast, 77215, probably also contributed to the faster cooling time (McGee et al., 1980). Sanford and Heubner (1980) have also discussed the cooling rate for the dark dike in 77075.

Warren and Wasson (1978) find that chemical composition of the white noritic portion of 77075 is "extremely similar" to the composition of the same lithology on 77077 and 77215, which are from the same sample location on the boulder at Station 7. All three rocks are the same crushed norite (Fig. 4). The plagioclase in the norite is An_{90-92}, the orthopyroxene is $Wo_{4-5}En_{65-70}Fs_{26-30}$. Bersch et al. (1991) have precisely determined the composition of pyroxene in the white, noritic portion of 77075. Fig. 5 shows that the white portion of 77075 plots within the Mg-norite suite of lunar rocks.

WHOLE-ROCK CHEMISTRY

Winzer et al. (1974) have reported the chemical composition of the dark vein in 77075, and Warren and Wasson (1988) have reported the composition of the white norite material (Table 1 and Fig. 6). The composition of the dark dike is the same as for the continuous boulder matrix 77115 and similar to many other lunar impact melt breccias. The attached white norite is the same composition as 77215.

Morgan et al. (1974x) determined the trace siderophile and volatile elements in the dark dike material and found that it had high Ir (Table 2), while Warren and Wasson (1978) found that the siderophile elements were very low in the white, noritic portion of 77075 (Table 1).

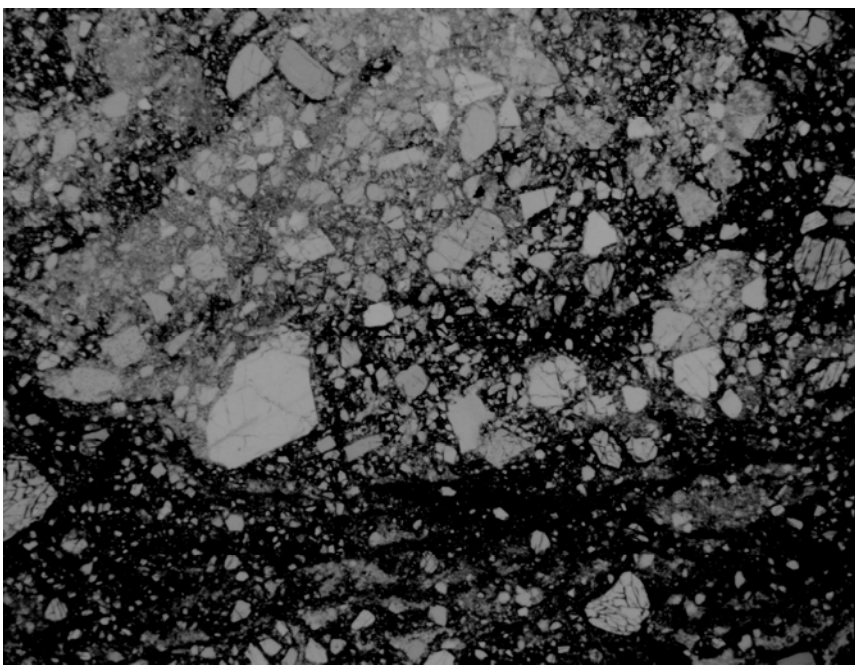

Figure 4: Photomicrograph of 77075 white norite material. Field of view is 3 x 4 mm.

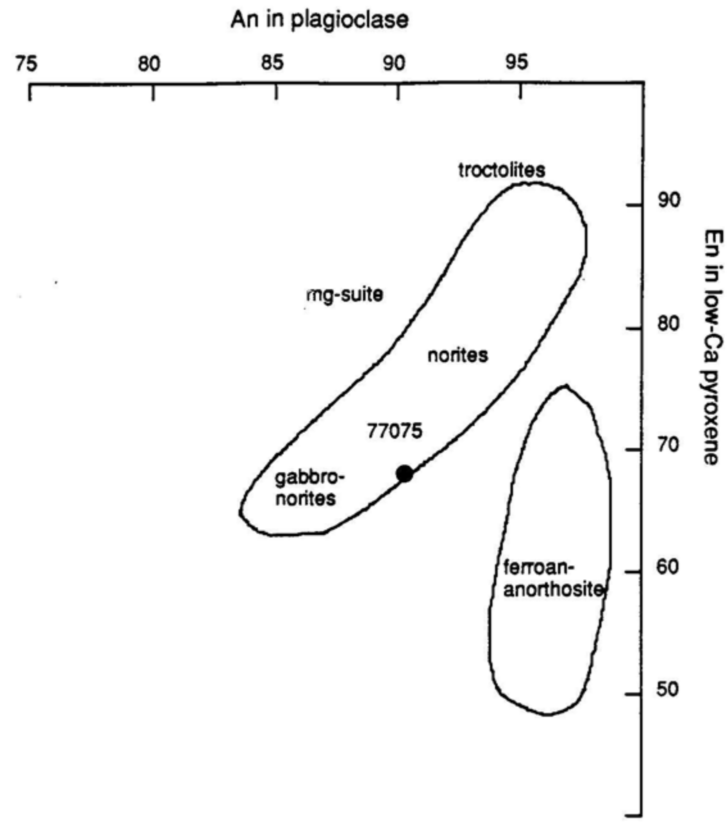

Figure 5: Plagioclase and pyroxene composition of the white portion of 77075. Fields from James and Flohr (1975).

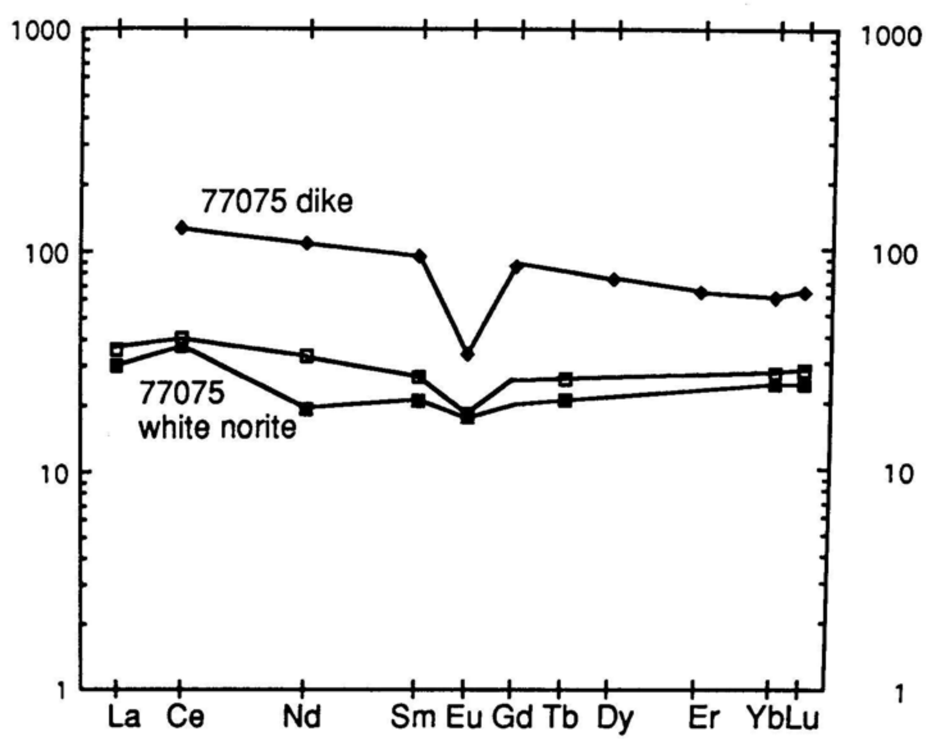

Figure 6. Normalized rare earth element plot for 77075. The data from the dike are from Winzer et al. (1974), and the data for the white norite material are from Warren and Wasson (1978).

SIGNIFICANT CLASTS

The white material attached to 77075 is the same material as the cataclastic norite in 77077 and 77215.

RADIOGENIC ISOTOPES

Stettler et al. (1974) determined ages of 3.99 ± 0.03 b.y. and 3.96 ± 0.08 b.y. by the ^{39}Ar- ^{40}Ar plateau technique (Fig. 7). Stettler et al. (1978) reported an age of 3.98 ± 0.03 Ky. for a third split of the dark dike and concluded that the age was 3.97 t 0.04 Ky. (weighted average of three analyses).

Nakamura and Tatsumoto (1977) have determined an internal Rb-Sr "isochron" for the matrix of 77075 dike material after separating as many of the xenocrysts as possible (Table 3). They obtained an age of 4.18 ± 0.08 b.y. (Fig. 8). However, this apparent "isochron" may be misleading because the mineral splits may have included small plagioclase xenocrysts.

Nunes et al. (1974) have reported U-Th-Pb data (Table 4), and Nakamura and Tatsumoto (1977) have determine&a Sm-Nd "isochron" (Table 5).

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Stettler et al. (1974) obtained an exposure age of about 25.5 m.y. by the Ar method.

PROCESSING

The initial processing and distribution of 77075 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). A detailed description of the splits is given in open-file report 78-511.

Sample 77075 has five thin sections. The three largest pieces are: ,13 (57 g); ,14 (41 g); and ,15 (53 g).

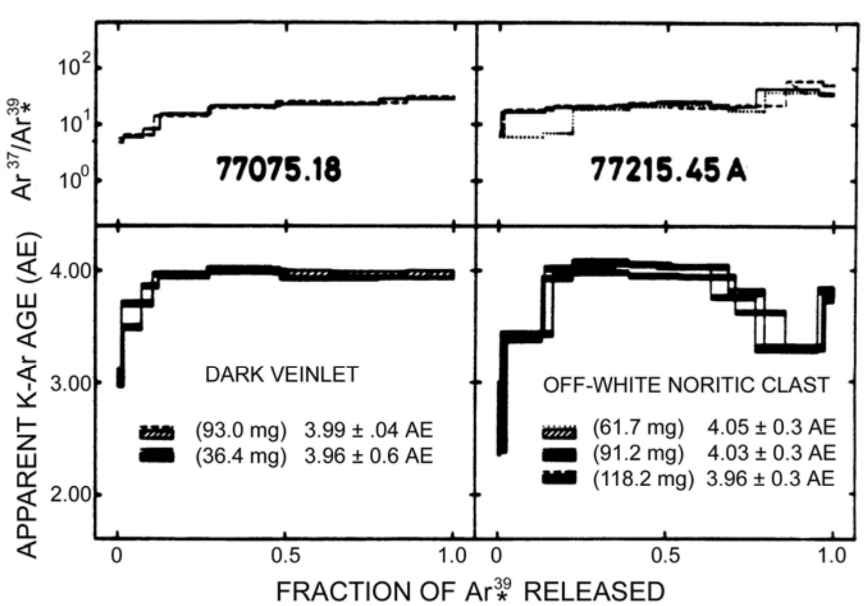

Figure 7: Ar-Ar plateau data for two splits of 77075. From Stettler et al. (1974).

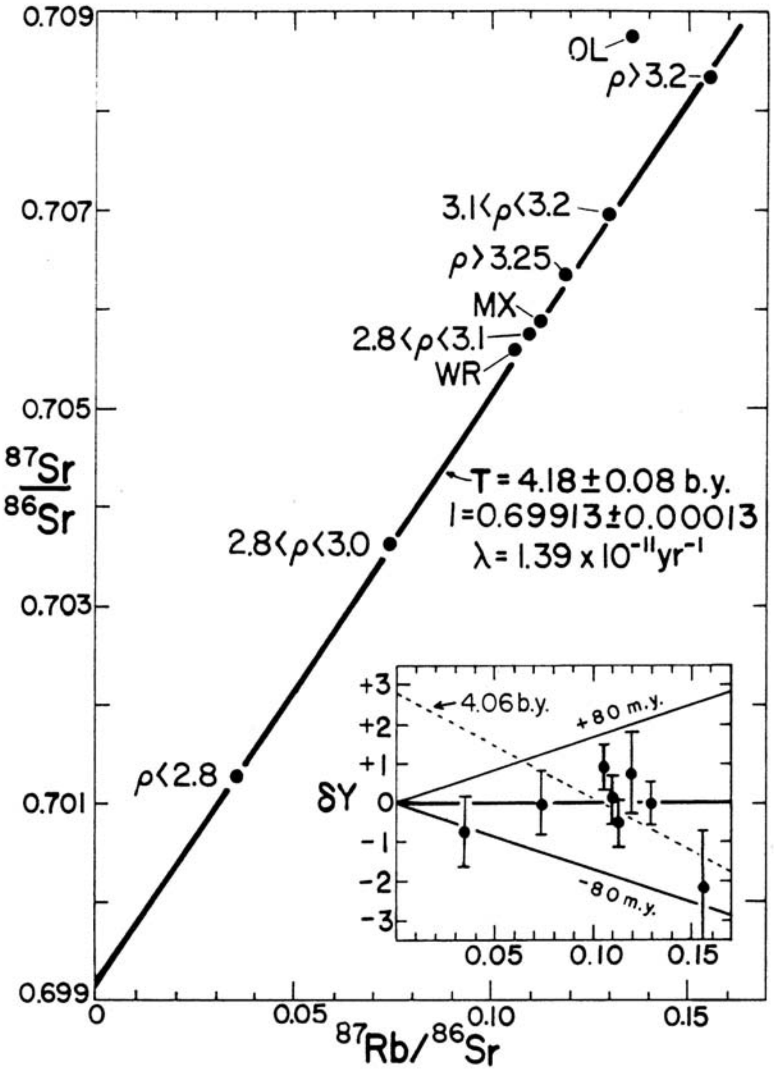

Figure 8. Rb-Sr isochron for dark dike material from 77075. From Nakamura and Tatsumoto (1978).

Table 1: Whole-rock chemistry of 77075.
a) Winzer et al. (1974); b) Warren and Wasson (1978)

Split Technique	,21 (a) AA, IDMS dark vein	,27 (b) INAA white	,27 (b) INAA white
SiO_2 (wt%)	46.4	51.1	50.9
TiO_2	1.38	0.34	0.35
Al_2O_3	18.17	14.97	14.00
Cr_2O_3	0.17	0.38	0.41
FeO	9.31	10.67	10.16
MnO	0.11	0.17	0.18
MgO	12.57	12.9	13.78
CaO	10.55	8.82	8.82
Na_2O	0.65	0.38	0.36
K_2O	0.23	0.18	0.16
P_2O_5	0.26		
Nb (ppm)			
Zr	–	210	170
Hf	10.8	3.5	3.5
Ta		0.34	0.40
U		0.5	0.58
Th		1.57	1.8
Sr	165		
Rb	6.1		
Li	21.5		
Ba	333	160	158
Zn		3.25	3.31
Ni		6.1	<1.1
Co		33	25.9
Sc		16.6	16.5
La		7.2	8.3
Ce	74.3	22	24
Nd	47.5	8.5	15
Sm	13.4	3.0	3.9
Eu	1.84	0.98	1.01
Gd	16.4		
Tb		0.74	0.92
Dy	17.2		
Er	10.0		
Yb	9.53	3.9	4.4
Lu	1.5	0.59	0.68

Table 1: (Concluded).

Split Technique	,21 (a) AA, IDMS dark vein	,27 (b) INAA white	,27 (b) INAA white
Ga		4.03	4.1
Ge (ppb)		10.9	16.8
Ir		0.25	0.0084
Au		0.026	0.088

Table 2: Trace element data for dark dike in 77075. Concentrations in ppb.
From Morgan et al. (1974a).

	Sample 77075,19
Ir	8.89
Os	
Re	0.781
Au	5.09
Pd	
Ni (ppm)	286
Sb	1.92
Ge	532
Se	112
Te	6.3
Ag	1.2
Br	81
In	
Bi	0.34
Zn (ppm)	2.8
Cd	7.5
Tl	2.4
Rb (ppm)	6.4
Cs	270
U	1450

Table 3: Rb-Sr analytical data for 77075.
From Nakamura and Tatsumoto (1977).

Sample	Weight (mg)	K (%)	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$ [1]	$^{87}Sr/^{86}Sr$ [2]
Handpicked fraction						
Whole rock	22.75	0.1937	5.927	161.72	0.1060	0.70554 ± 4
Matrix	5.13	0.1996	5.978	153.49	0.1126	0.70583 ± 4
Olivine	0.62	0.0160	0.878	18.78	0.1352	0.70869 ± 8
Density separates of >74 µm fraction						
ρ<2.8 [3]	9.42	0.1132	2.604	211.24	0.0356	0.70123 ± 6
2.8<ρ<3.1	38.33	0.2090	6.274	165.35	0.1098	0.70571 ± 4
3.1<ρ<3.2	6.05	0.1834	6.079	135.35	0.1299	0.70690 ± 4
ρ>3.2	2.81	0.0961	3.554	66.25	0.1552	0.70827 ± 10
Density separates of <74 µm fraction						
2.8<ρ<3.0	0.9	0.1247	3.613	140.56	0.0743	0.70358 ± 6
ρ>3.25	0.75	0.0505	1.764	42.92	0.1189	0.70630 ± 8

[1] Uncertainties are estimated to be ≤0.3%.
[2] Uncertainties correspond to last significant figure and are 2σ mean.
[3] Combined with the ρ<2.8 separate of <74 µm fraction. Density is in g/cm^3.

Table 4: U-Th-Pb for 77075.
From Nunes et al. (1974).

Split	77075,22
wt (mg)	98.2
U (ppm)	1.425
Th (ppm)	5.299
Pb (ppm)	3.083
$^{232}Th/^{238}U$	3.84
$^{238}U/^{204}Pb$	2110

Table 5: Sm-Nd analytical data for 77075.
From Nakamura and Tatsumoto (1977).

Sample	Weight (mg)	Sm (ppm)	Nd (ppm)	$\frac{^{147}Sm}{^{144}Nd}$	$\left(\frac{^{143}Nd}{^{144}Nd}\right)^1$
$\rho<2.8$ [2]	9.42	10.23	37.59	0.1645 ± 2	0.511801 ± 37
$2.8<\rho<3.1$	38.33	15.18	53.04	0.1732 ± 1	0.512040 ± 19
Whole rock	22.75	14.10	49.00	0.1739 ± 1	0.512050 ± 19
$\rho>3.2$	2.81	6.58	22.86	0.1740 ± 4	0.512094 ± 40

[1] Normalized to $^{150}Nd/^{144}Nd$ = 0.236433. Errors correspond to last significant figures and are 2σ mean.
[2] Density is in g/cm^3.