67075
Crushed Ferroan Anorthosite
219 grams

Figure 1: Tray full of 67075. NASA S 72-37541. Cube is 1 inch.

Figure 2: 67075 before pickup. AS16-106-17319.

LMP Look at this rock right here, John. Pure white. Yeah, it's really shocked whatever it is. It looks like chalk, Tony, it's so shocked. It's about pebble size and it's broken open, let's make it 5 cm long, broken open. Hey, John. Can I get a bag from you. I picked up that white - -
CDR I'll get it for you.
LMP Thank you. That white shocked rock. It's broke in two. There's two pieces of it. Partially documented.

Introduction
Lunar sample 67075 is very friable (figure 1). The original PET description (LSPET 1973) was that of a crushed anorthosite with evidence of some flow (figure 3) and some recrystallization in the solid state (120 deg. triple junctions, figure 4). Detailed petrographic description showed that the sample may be a mixture of closely related anorthositic rocks from a layered

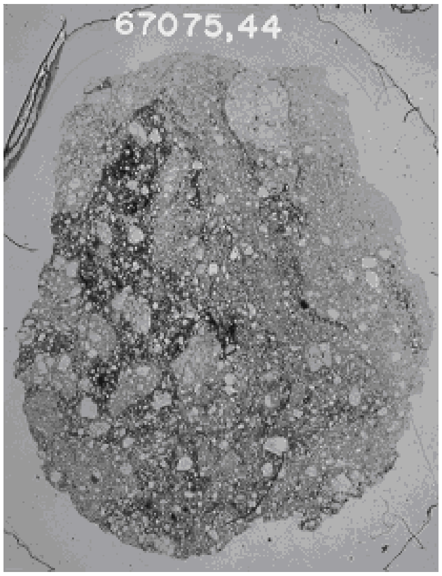

Figure 3: Thin section of one of the small fragments from the tray (figure 1). NASA S72-52492. This is about 1 cm.

Mineralogical Mode for 67075

	McCallum et al. 1975	Steele and Smith 1973	
Plagioclase	90 %	99	70
Pyroxene		1	
Olivine			30
Ilmenite			

igneous intrusion (McCallum et al. 1975). Chemical analyses show a range of Al_2O_3 (31-34%) and FeO (1-4%) contents. Ryder and Norman (1980) reported that 67075 was about 95% plagioclase.

67075 was originally collected as two broken parts of a conspicuous white rock on the lunar surface near the rim of North Ray Crater (Sutton 1991). During transit to Earth it broke into numerous pieces, such that lunar orientation and zap pits on original surface can no longer be discerned. It has proven difficult to date, but it has been shown to be 4.47 b.y. old, with about 50 m.y. exposure to cosmic rays (see below).

Petrography

Pecket and Brown (1973), Brown et al. (1973) and McCallum et al. (1975) all suggest that 67075 was assembled from genetically-related fragments of a layered plutonic anorthosite complex. This explanation can explain the pyroxene exsolutions and the range of compositions of mafic minerals (Ryder and Norman 1980). Nord et al. (1975) showed that 67075 was "lithified" or cemented by a mild shock-heating event – such as the North Ray Crater impact.

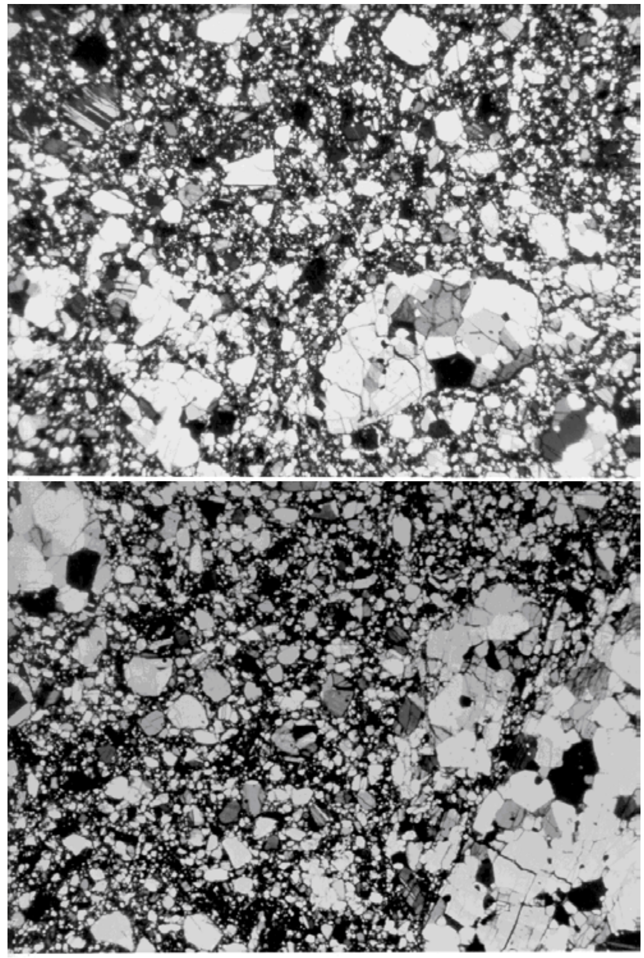

Figure 4 a,b: Thin section photomicrographs of 67075 with cross polarized light. NASA S72-42278 and NASA S72-42274. About 2.5 mm across.

In addition to calcic plagioclase, 67075 has minor olivine, low-Ca pyroxene, high-Ca pyroxene and traces of Cr-spinel, ilmenite, Fe-Ni metal, troilite and silica. Plagioclase occurs in grains up to 2 mm in size.

McCallum and O'Brien (1996) used low-Ca, high-Ca pairs to calculate cooling rates and the depth of burial of 67075 (14 km).

Mineralogy

Olivine: Brown et al. (1973) and McCallum et al. (1975) reported Fe-rich olivine (Fo_{44-55}). Smith and Steele (1975) determined trace elements in olivine.

Pyroxene: Steele and Smith (1973), Brown et al. (1973), Dixon and Papike (1975), McCallum et al. (1975) and others studied the exsolution of pyroxene fragments in 67075, including the inverted pigeonite (figures 5 and 6).

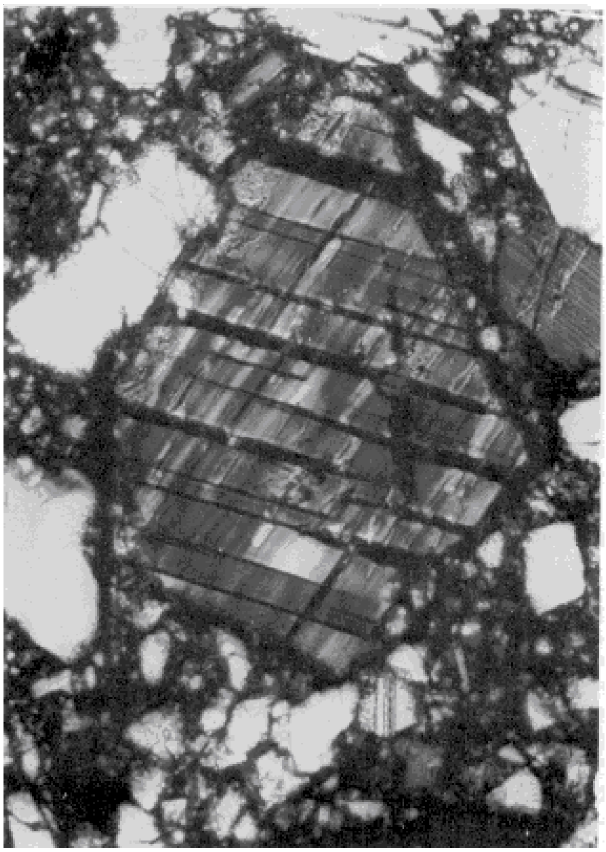

Figure 5: Photomicrograph of pigeonite crystal with coarse exsolution of augite lamellae in 67075,48. Crystal is 200 microns long (this is figure 1 in Brown et al. 1973a).

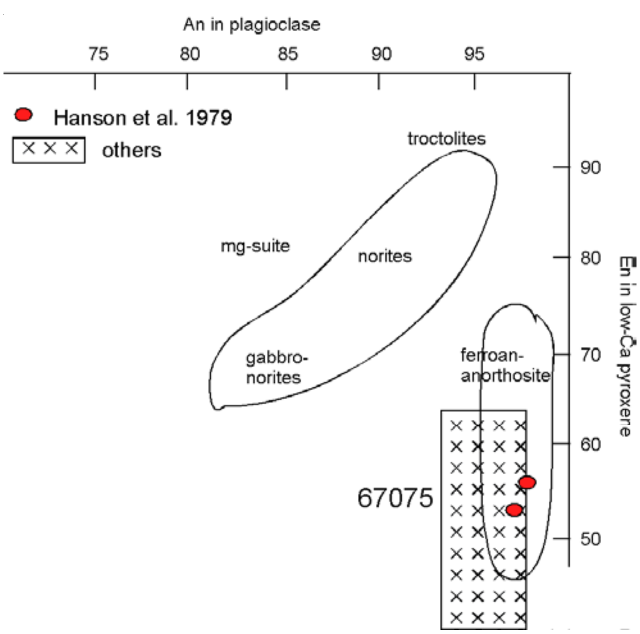

Figure 7: Field of plagioclase and pyroxene composition of clasts in 67075. Pyroxene and plagioclase have not been studied as pairs in 67075.

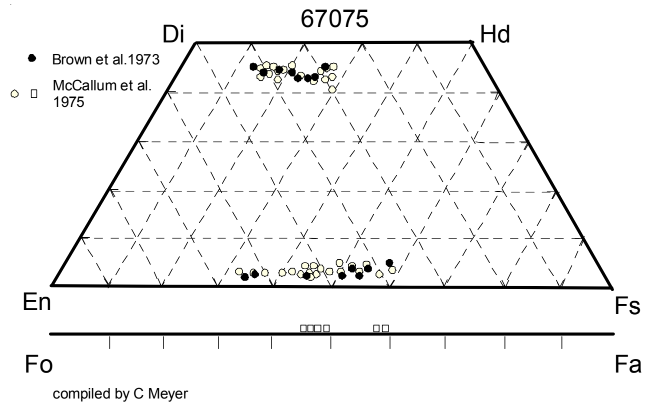

Figure 6: Pyroxene and olivine composition in 67075. Pyroxene is exsolved, but also present as individuals (data from Dixon and Papike 1975, McCallum et al. 1975 and Brown et al. 1973a).

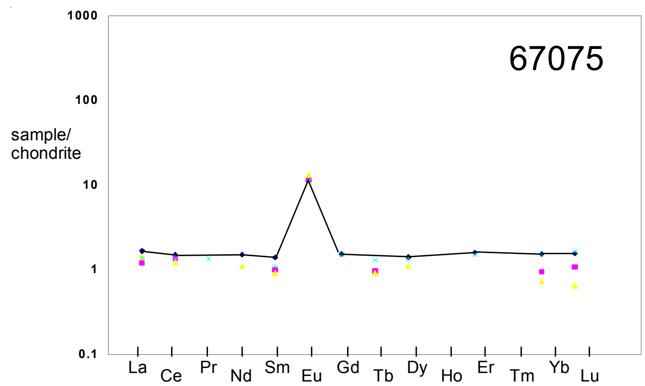

Figure 8: Normalized rare-earth-element diagram for 67075 (isotope dilution data by Hubbard et al. 1974 is connected). Additional data by Wanke et al., Haskin et al., Lindstrom et al.(table 1) are plotted as colored dots.

Plagioclase: Brown et al. (1973), Steele and Smith (1973), Dixon and Papike (1975) and McCallum et al. (1975) reported calcic plagioclase (An_{93-97}) in 67075. Meyer et al. (1974), Meyer (1979), Hansen et al. (1979) and Steele et al. (1990) studied the trace element content of plagioclase (An_{97}). Gose et al. (1975) studied cation ordering.

Chromite: El Goresy et al. (1973) reported two distinct occurrences of spinel: primary Ti-chromite and breakdown of ulvospinel. Okamura et al. (1976) studied spinel lamallae exsolved from augite.

Chemistry

The chemical analyses of splits of 67075 show a slight variation in mafic mineral content but similar REE

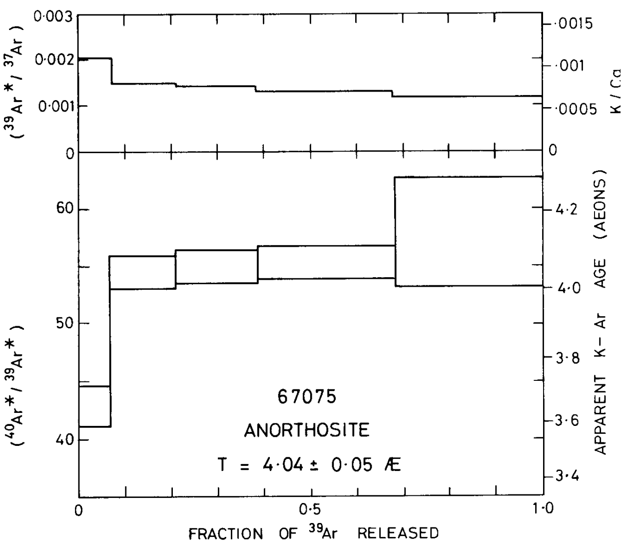

Figure 9: Apparent age and K/Ca as a function of 39Ar release from cataclastic anorthosite 67075 (coarse plagioclase). Turner et al. 1973.

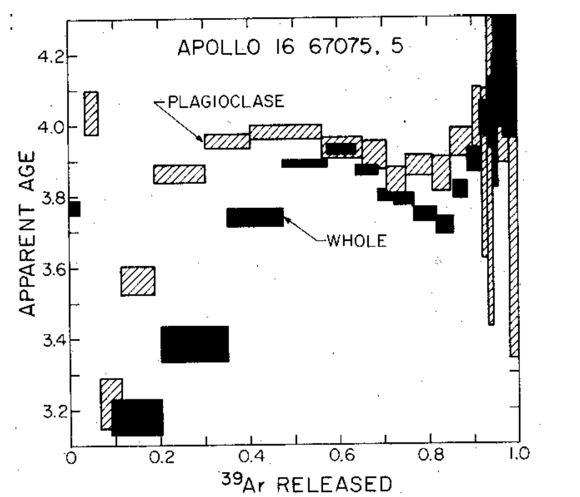

Figure 10: Ar release diagram for plagioclase and whole rock splits of 67075 (Huneke et al. 1977abs).

content (Haskin et al. 1973, Hubbard et al. 1974, Scoon 1974, Wanke et al. 1975 and Lindstrom et al. 1981)(figure 8). The analysis by Hertogen et al. (1977) showed a very minor meteoritic siderophile content.

Moore et al. (1973) reported only 5 ppm carbon, while Jovanovic and Reed (1976) reported minor halogens.

Radiogenic age dating

67075 was dated by the $^{39}Ar/^{40}Ar$ plateau technique as 4.04 ± 0.05 b.y. (figure 9)(Truner et al. 1973). Huneke et al. (1977) could not obtain a good plateau, but the plagioclase may be 3.95 b.y. (figure 10).

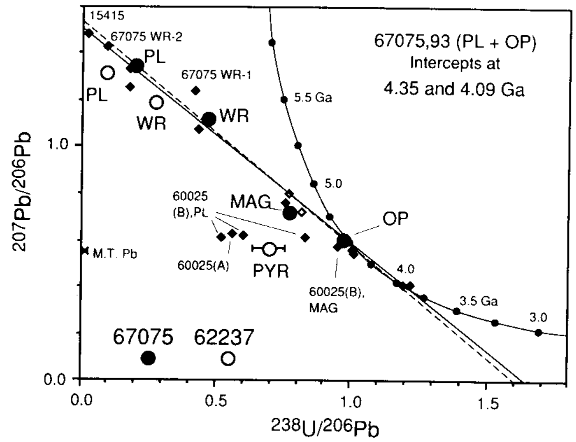

Figure 11: U/Pb isochron diagram showing data for 67075 (from Premo et al. 1989).

Silver (1973abs) noted excess Pb in 67075 that was apparently "unsupported" by the U and Th. Oberli et al. (1979abs) obtained Pb isotope values closer to the isochron defined by the cataclysm. Lead isotopes in 67075 were again studied by Premo et al. (1989) who found that the data defined two intercepts with Concordia at 4.09 and 4.35 b.y. (figure 11).

Nyquist et al. (2010 and 11) found concordant Rb/Sr and Nd/Sm ages at 4.47 ± 0.07 b.y. (figure 12 a,b).

Cosmogenic isotopes and exposure ages

Turner et al. (1973) reported a ^{38}Ar exposure age of 46 m.y., Marti et al. (1973) reported the ^{81}Kr exposure age of 48.5 ± 5.5 m.y. and Hohenberg et al. (1978) calculated 50.2 and 49 m.y. exposure ages.

Other Studies

Lightner and Marti (1974) and Drozd et al. (1977) reported the isotopic composition of Xe.

Weeks et al. (1973) studied the paramagnetic resonance of Fe^{3+}, Ti^{3+} and Mn^{2+} in plagioclase.

Processing

67075 was returned in Teflon bag #384 is SCB7. There are 17 thin sections

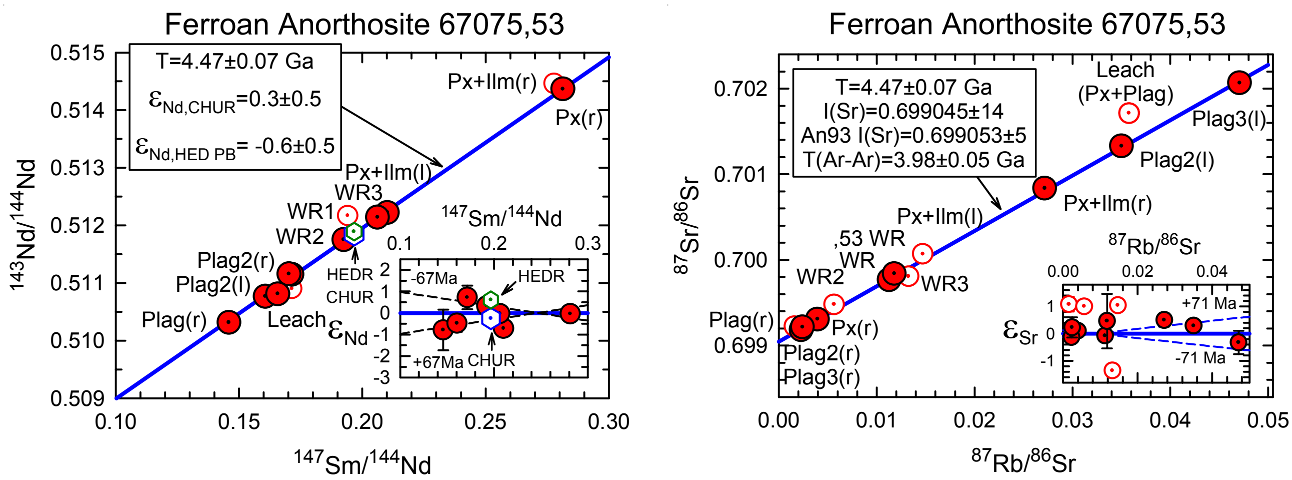

Figure 12 a, b: Interanl isochrons determined for 67075 (Nyquist et al. 2011).

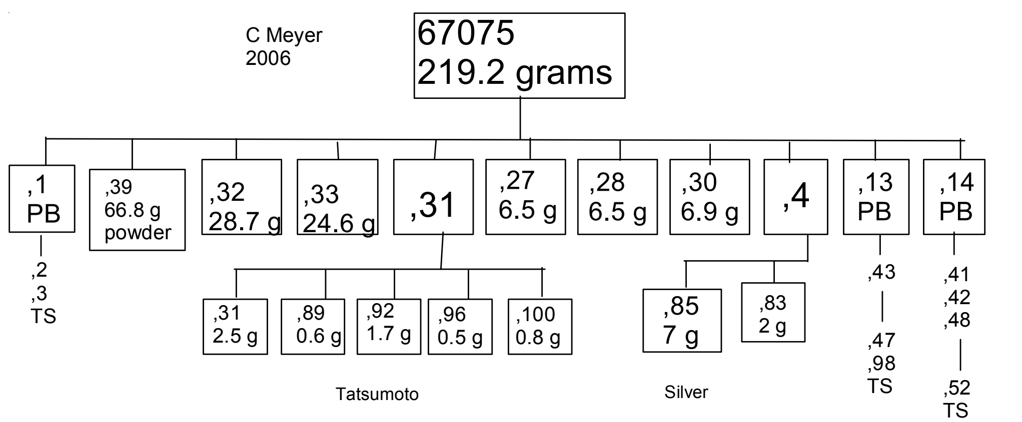

Table 2. Composition of 67075 cont.

	U ppm	Th ppm	K2O %	Rb ppm	Sr ppm	Nd ppm	Sm ppm	technique
Premo 89	0.00618	0.0156						idms
Nyquist et al. 1976				0.499	158			idms
				0.593	145			idms
Wanke 75	0.0052		0.014	0.67	127		0.16	RNAA
Oberli 79	*1.852*	*13.67*						idms

Table 1. Chemical composition of 67075.

reference	LSPET73		Hertogen77		Hubbard74		Lindstrom81		Haskin 73		Scoon 74		Wanke 75	
weight							132 mg							
SiO2 %	44.9	(a)							45.5		44.42	(e)	45.35	(d)
TiO2	0.09	(a)							0.05		0.11	(e)	0.1	(d)
Al2O3	31.54	(a)					32.1	(d)	34.2		31.73	(e)	31.18	(d)
FeO	3.41	(a)					2.94	(d)	1.07		3	(e)	3.95	(d)
MnO	0.06	(a)					0.046	(d)	0.017		0.04	(e)	0.06	(d)
MgO	2.42	(a)					2.3	(d)	0.47		2.35	(e)	3.13	(d)
CaO	18.09	(a)					18	(d)	19.9		18.12	(e)	17.11	(d)
Na2O	0.26	(a)					0.28	(d)	0.34		0.27	(e)	0.26	(d)
K2O	0.01	(a)			0.016	(c)			0.0233		0.03	(e)	0.014	(d)
P2O5											0.04	(e)	0.02	(d)
S %	0.01	(a)									0.01	(e)		
sum														
Sc ppm							4.73	(d)	1.89	(d)			7.68	(d)
V														
Cr	420	(a)			372	(c)	351	(d)	119	(d)	457	(e)	560	(d)
Co							6.42	(d)	1.63	(d)			7.34	(d)
Ni			<4	(b)					1	(d)				
Cu													13.2	(d)
Zn			6.36	(b)					<1	(d)			15	(d)
Ga									3.14	(d)			2.33	(d)
Ge ppb			3.2	(b)										
As													2	(d)
Se			3.1	(b)										
Rb	0.8	(a)	0.4	(b)	0.593	(c)			0.63	(d)			0.67	(d)
Sr	144	(a)			145	(c)	162	(d)					127	(d)
Y	2.5	(a)												
Zr					7.06	(c)								
Nb														
Mo														
Ru														
Rh														
Pd ppb			<0.4	(b)										
Ag ppb			0.25	(b)										
Cd ppb			0.43	(b)										
In ppb			0.48	(b)										
Sn ppb														
Sb ppb			0.071	(b)										
Te ppb			<5	(b)										
Cs ppm			0.03	(b)					0.037	(d)			0.03	(d)
Ba					8.85	(c)	6	(d)					13	(d)
La					0.393	(c)	0.285	(d)	0.33	(d)			0.32	(d)
Ce					0.891	(c)	0.82	(d)	0.75	(d)			0.8	(d)
Pr													0.12	(d)
Nd					0.664	(c)			0.5	(d)				
Sm					0.209	(c)	0.145	(d)	0.135	(d)			0.16	(d)
Eu					0.65	(c)	0.646	(d)	0.73	(d)			0.63	(d)
Gd					0.301	(c)							0.3	(d)
Tb							0.035	(d)	0.033	(d)			0.047	(d)
Dy					0.343	(c)			0.226	(d)			0.33	(d)
Ho														
Er					0.255	(c)							0.24	(d)
Tm														
Yb					0.251	(c)	0.155	(d)	0.117	(d)			0.25	(d)
Lu					0.038	(c)	0.026	(d)	0.0157	(d)			0.04	(d)
Hf					0.12	(c)	0.064	(d)	0.055	(d)			0.12	(d)
Ta													0.011	(d)
W ppb													0.015	(d)
Re ppb			0.02	(b)									0.2	(d)
Os ppb			0.3	(b)										
Ir ppb			0.319	(b)										
Pt ppb														
Au ppb			0.048	(b)									0.66	(d)
Th ppm					0.023	(c)								
U ppm			0.0206	(b)	0.013	(c)							0.0052	(d)

technique: (a) XRF, (b) RNAA, (c) IDMS, (d) INAA, (e) classical wet

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