68416 BASALTIC IMPACT MELT 179 g

INTRODUCTION: 68416 is a subophitic-ophitic impact melt which is fairly homogeneous but contains a few large plagioclase xenocrysts (Fig. 1). It is similar in chemistry and petrography to, but slightly coarser-grained than, 68415, which was taken from the same boulder (see 68415, Fig. 2). Its Rb-Sr isotopics agree well with those of 68415 but an Ar-Ar age of 4.00 ± 0.05 b.y. (Kirsten et al., 1973) is older.

68416 was sampled a few centimeters from 68415 and its orientation is known. It is pale gray and tough like 68415. Zap pits are present on its rounded, lunar exposed face.

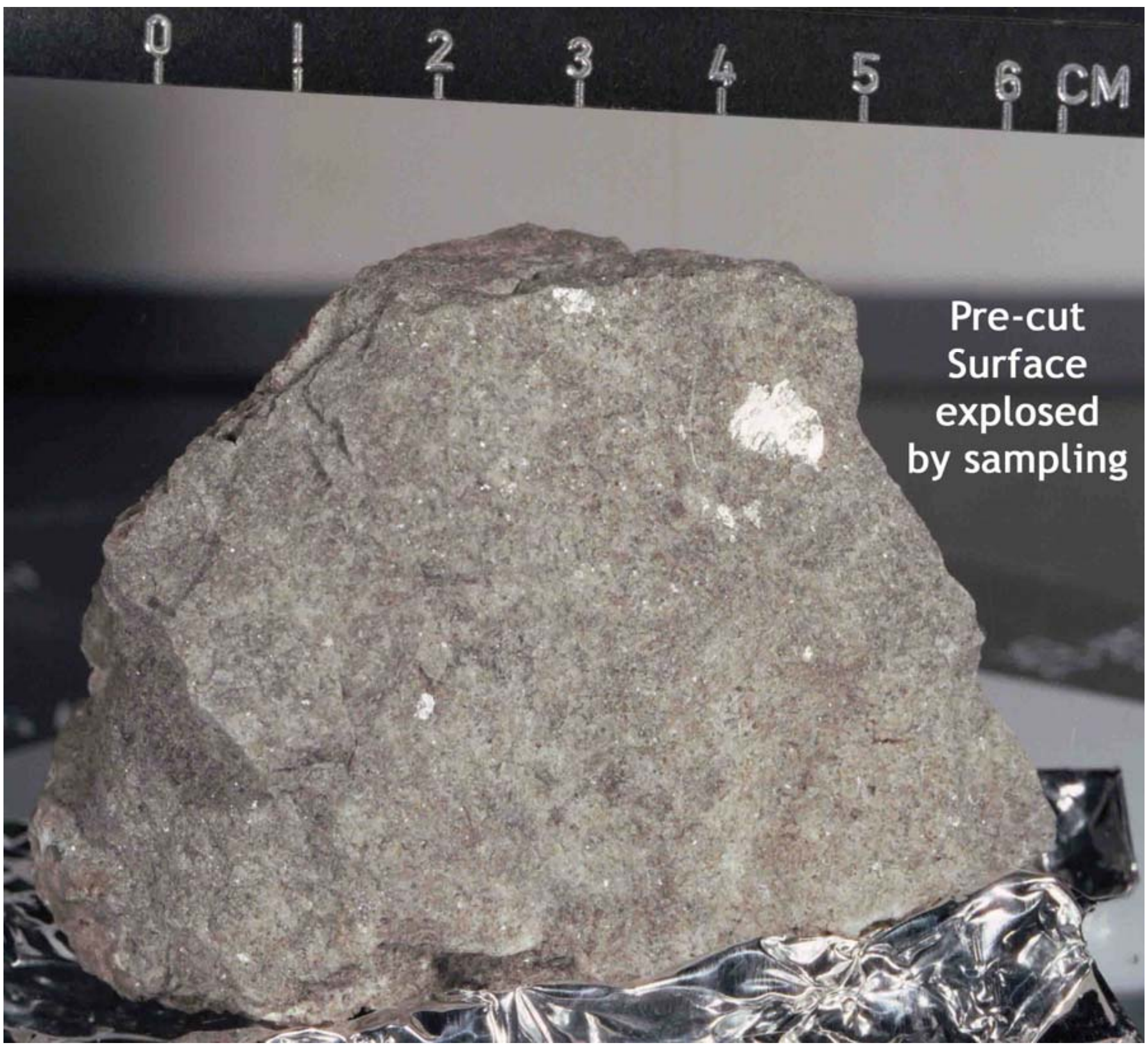

FIGURE 1. S-72-37533.

PETROLOGY: Petrographic descriptions with microprobe data are given by Brown et al. (1973), Hodges and Kushiro (1973), and Vaniman and Papike (1981). Juan et al. (1973) give a petrographic description with compositions of mineral phases deduced from the optical characteristics. Misra and Taylor (1975) report analyses of metal grains, and Englehardt (1978, 1979) briefly notes the ilmenite paragenesis. Nash and Haselton (1975) used the data of Hodges and Kushiro (1973) to calculate the silica activity as a function of temperature.

68416 has a subophitic-ophitic texture (Fig. 2) which is slightly coarser-grained than 68415. Brown et al. (1973) note a weak preferred orientation of plagioclase laths and the presence of phenocrysts, and Juan et al. (1973) report anhedral-subhedral megacrysts which have wavy extinction, but note an absence of any preferred orientation. Published modes have 73-79% plagioclase, 16-20% pyroxene, and 2-4.5% olivine. Other reported phases include ilmenite, ulvospinel, troilite, cristobalite, Fe-metal, and mesostasis glass. Misra and Taylor (1975) note that schreibersite is present but is less common than in 68415.

Plagioclase phenocrysts and laths are mainly An_{95-98} with microlaths much more sodic (Fig. 3) (Hodges and Kushiro, 1973; Brown et al., 1973; and Vaniman and Papike, 1981). Pyroxene and olivine compositions are shown in Figure 4. Brown et al. (1973), Hodges and Kushiro (1973), and Vaniman and Papike (1981) all report similar compositions, and these papers and that of Juan et al. (1973) report the presence of rare orthopyroxene in contrast to 68415 for which no orthopyroxene has been reported. Brown et al. (1973) report that augite is more common than low-Ca pyroxene, also in contrast to 68415, but this feature is not apparent in the data of Hodges and Kushiro (1973) (Fig. 4) or Vaniman and Papike (1981). Metals contain 4-16% Ni (Fig. 5) (Misra and Taylor, 1975; Brown et al., 1973; and Hodges and Kushiro, 1973).

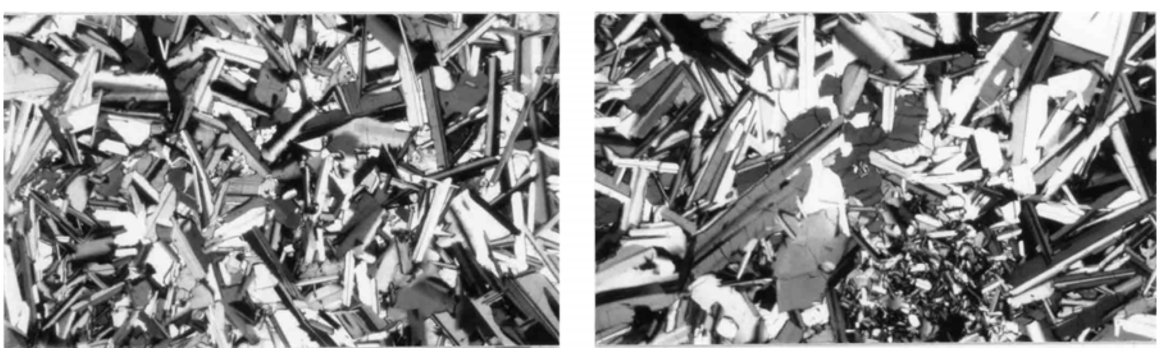

FIGURE 2. a) 68416,6, xpl. Width 2 mm. b) 68416,70, xpl. Width 2 mm.

EXPERIMENTAL PETROLOGY: Melting experiments at 5 kb pressure on 68416,21, a homogeneous powder, show phase relationships very similar to those of 68415. Plagioclase is the high temperature (>1400°C) liquidus phase, followed by spinel (1300-1250°C), then olivine (1250-1225ºC) (Hodges and Kushiro, 1973). The results are consistent with a plagioclase cumulate origin of 68416 or impact melting of a plagioclase cumulate. The silica activities in excess of 1, calculated by Nash and Haselton (1975) from the data of Hodges and Kushiro (1973), support the textural evidence that 68416 is a rapidly quenched, not an equilibrium, assemblage.

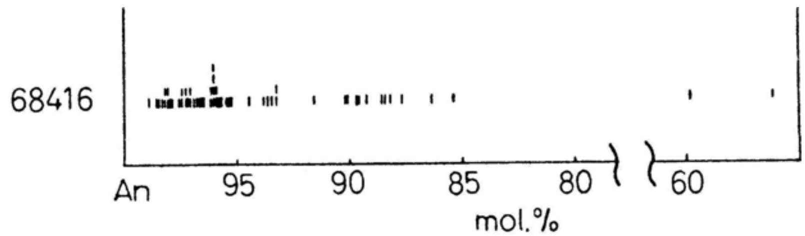

FIGURE 3. Plagioclase compositions; from Hodges and Kushiro (1973).

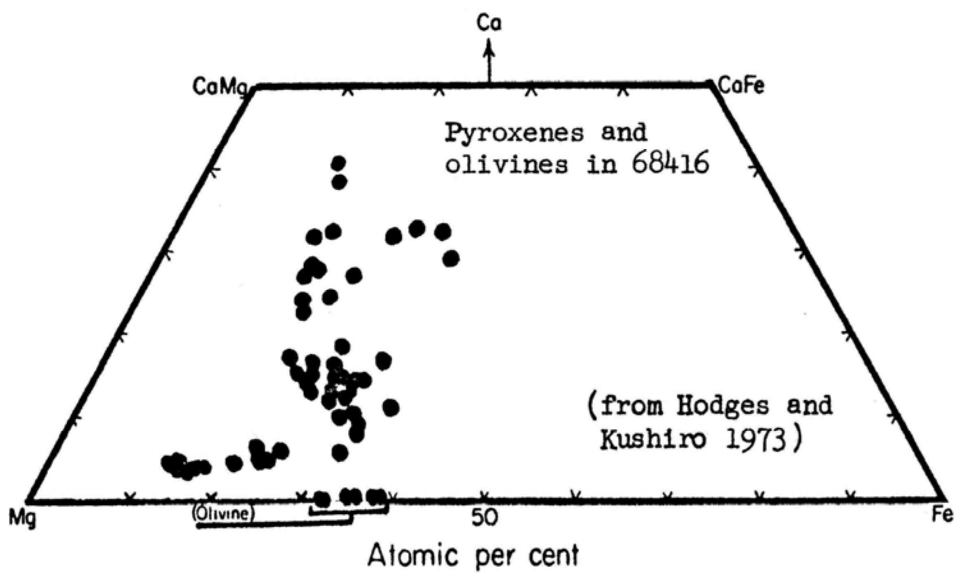

FIGURE 4. Mafic mineral compositions; from Hodges and Kushiro (1973).

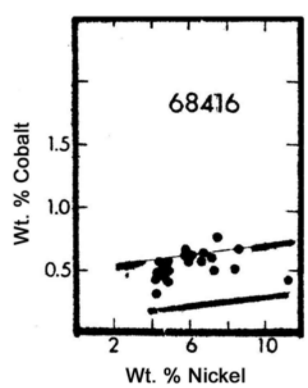

FIGURE 5. Metals; from Misra and Taylor (1975).

CHEMISTRY: Major and some trace element analyses are reported by Juan et al. (1973), Rose et al. (1973) and Hubbard et al. (1973,1974). Partial analyses are reported by Rancitelli et a1. (1973b; K, U, Th), Moore et al. (1973; C), Kirsten et al. (1973; Ca, K) and Compston et al. (1977; Rb, Sr). The data are summarized in Table 1 and Figure 6, and are very similar to those for 68415. The composition is more aluminous and lower in rare-earth, transition metal, and volatile elements than are local soils.

GEOCHRONOLOGY: Rb-Sr isotopic data for plagioclase and "quintessence" separates reported by Papanastassiou and Wasserburg (1975) agree well with the isochron drawn for 68415 (Fig. 7). This shows an age of 3.84 ± 0.01b.y. with initial $^{87}Sr/^{86}Sr$ of 0.69920 ± 3. Compston et al. (1977) obtained an internal Rb-Sr isochron age of 3.79 ± 0.03b.y. (Fig. 8) in good agreement with the data of Papanastassiou and Wasserburg (1975). The initial $^{87}Sr/^{86}Sr$ ratio of 0.69940 is also in good agreement after adjusting for interlaboratory bias.

The ^{40}Ar-^{39}Ar plateau age of 4.0 ± 0.05 b.y. (Kirsten et al., 1973) (Fig. 9) is distinctly higher than the Rb-Sr age for 68416 (and 68415) and the Ar-Ar whole-rock age for 68415. Kirsten et al. (1973) attempt to explain the age difference by interpreting 68416 as a xenolith in 68415; however, this "explanation" does not account for the identical Rb-Sr results nor for the near-identical petrographic and chemical nature of 68415 and 68416.

RARE GAS AND EXPOSURE AGES: The only rare gas data are the Ar isotopic data reported by Kirsten et al. (1973) from which they calculated an exposure age of 39 ± 4 m.y. (identical to their 87 ± 5 m.y. age for 68415).

Yokoyama et al. (1974) note that the cosmogenic nuclide data of Rancitelli et al. (1973a) show that 68416 is saturated with ^{26}Al, thus the exposure age is at least a few million years.

TABLE 1. Summary chemistry of 68416.

SiO_2	45.3	Sr	~160
TiO_2	0.31	La	7.2
Al_2O_3	28.5	Lu	
Cr_2O_3	0.11	Rb	1.8
FeO	4.3	Sc	9.2
MnO	0.06	Ni	~180
MgO	4.6	Co	10-40
CaO	16.2	Ir ppb	
Na_2O	0.43	Au ppb	
K_2O	0.07	C	5
P_2O_5	0.08	N	
		S	500
		Zn	30
		Cu	~10

Oxides in wt%; others in ppm except as noted.

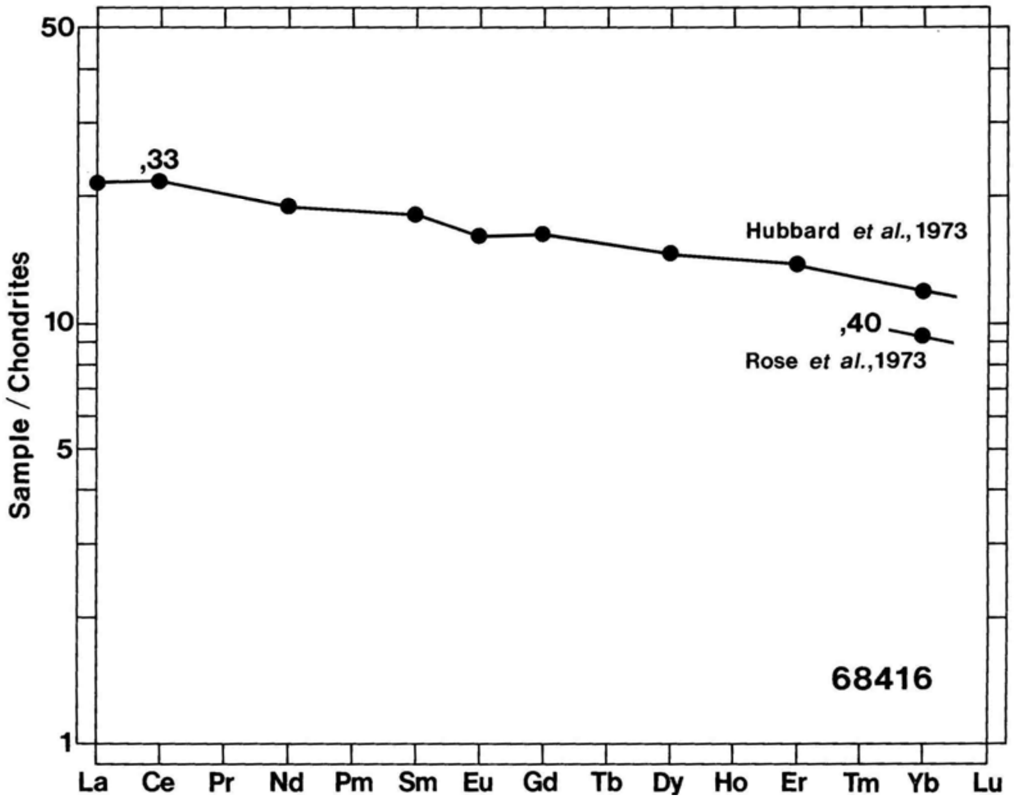

FIGURE 6. Rare earths.

<u>MICROCRATERS</u>: Morrison et al. (1973) report microcrater frequency v. diameter data (Fig. 10) without specific discussion.

<u>PHYSICAL PROPERTIES</u>: Collinson et al. (1973) report that ,23 has an initial natural remanent magnetization (NRM) of 2.0 x 10^{-6} emu·g^{-1}. There appears to be a hard NRM nearly opposed in direction to the soft one. Stephenson et al. (1974) report alternating field (AF) demagnetization results for the same chip ,23 (Figs. 11 and 12). The hard component corresponds to a paleofield of 1.2 Oe—the interpretation is colored by the Kirsten et al. (1973) interpretation of 68415 as a xenolith, i.e. two heating events occurring with sample movement in between them at 3.84-4.0 b.y. can explain a relatively hard secondary component (in reality, because 68416 is almost certainly not a xenolith, the explanation must be more complex). Brecher (1977) notes that the directional data presented by Stephenson et al. (1974) lie on a small circle of constant inclination, demonstrating some kind of planar control.

Abu-Eid et al. (1973) include 68416 in a list of samples studied by Mossbauer and electron absorption spectroscopy in which 1) rims of pyroxenes contain Ti^{3+}, 2) olivines and pigeonite cores contain Cr^{3+}, and 3) olivines and pyroxenes contain no Fe^{3+} and probably no Cr^{2+}. The spectral measurements indicate that the olivines are “magnesian varieties.” Weeks (1973a) reports electron paramagnetic resonance data pertaining to the presence of Fe^{3+} in plagioclases.

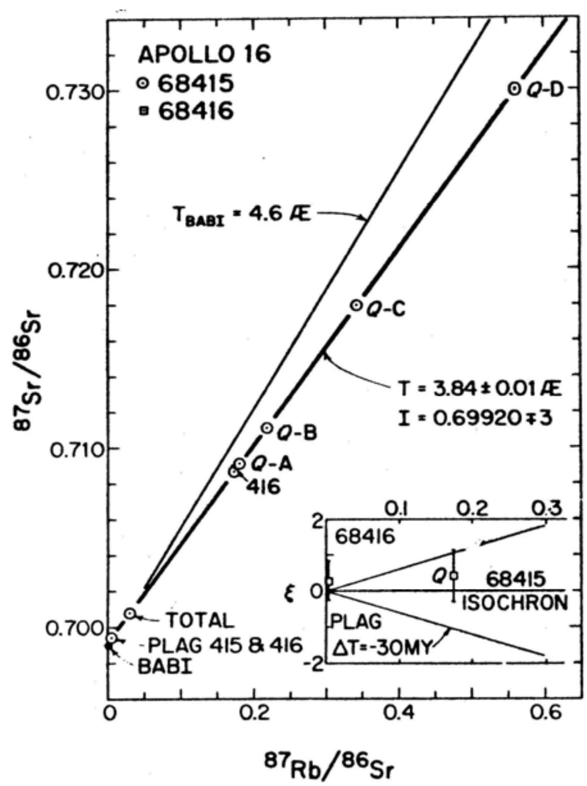

FIGURE 7. Rb-Sr data; from Papanastassiou and Wasserburg (1975).

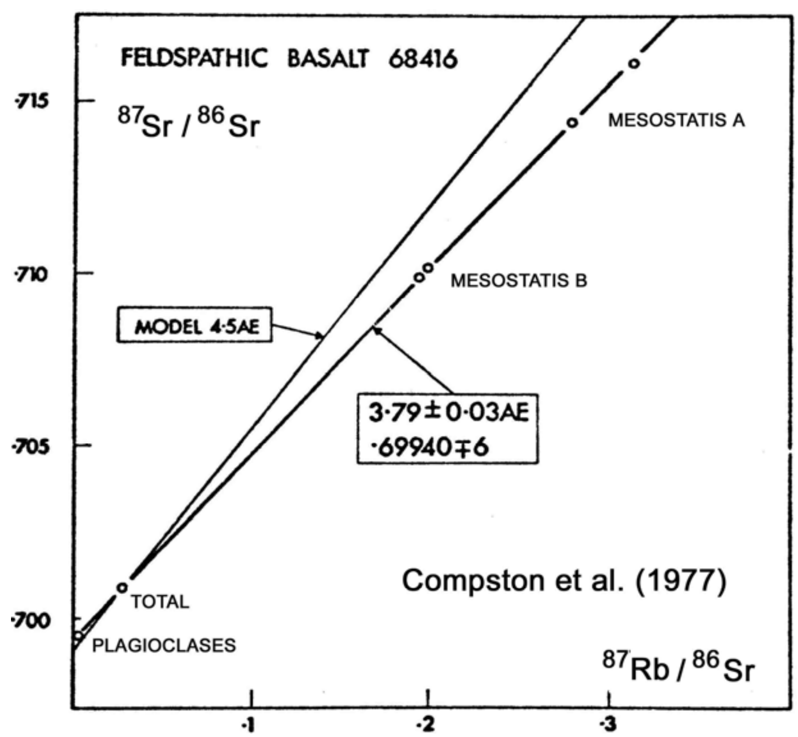

FIGURE 8. Rb-Sr data; from Compston et al. (1977).

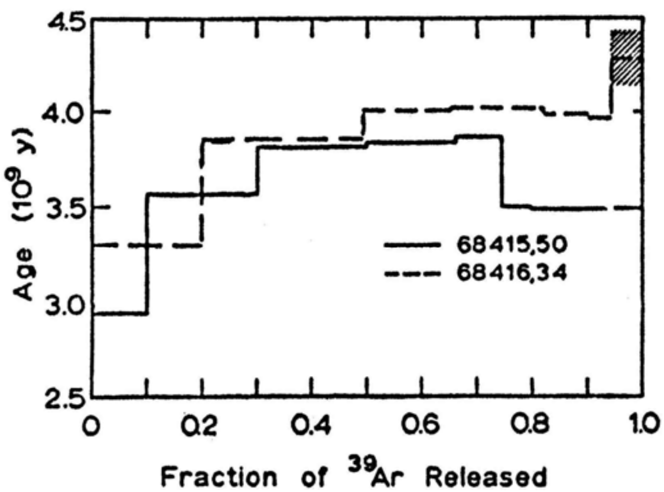

FIGURE 9. Ar release; from Kirsten et al. (1973).

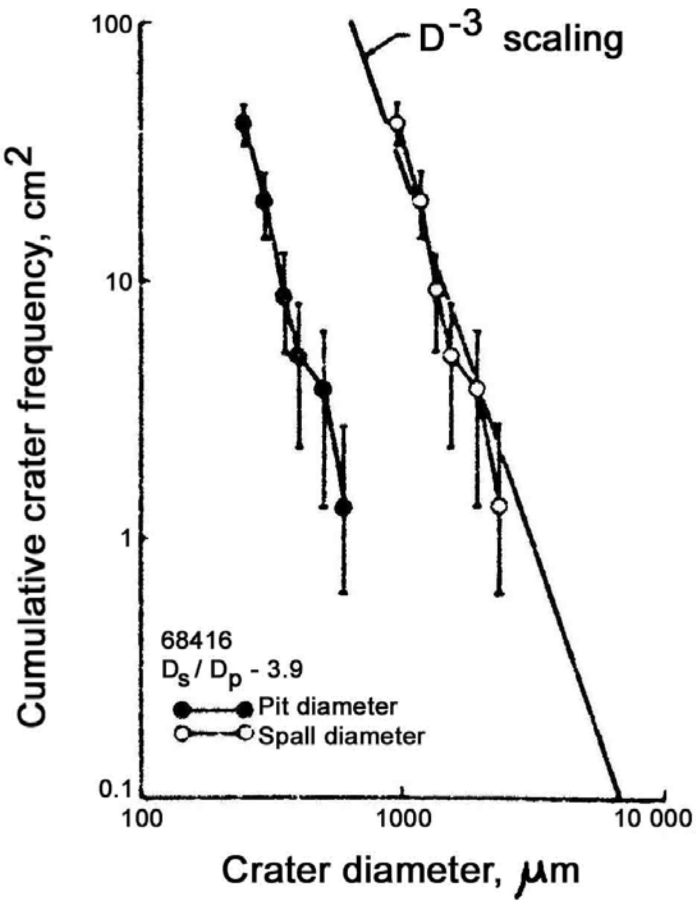

FIGURE 10. Microcraters; from Morrison et al. (1973).

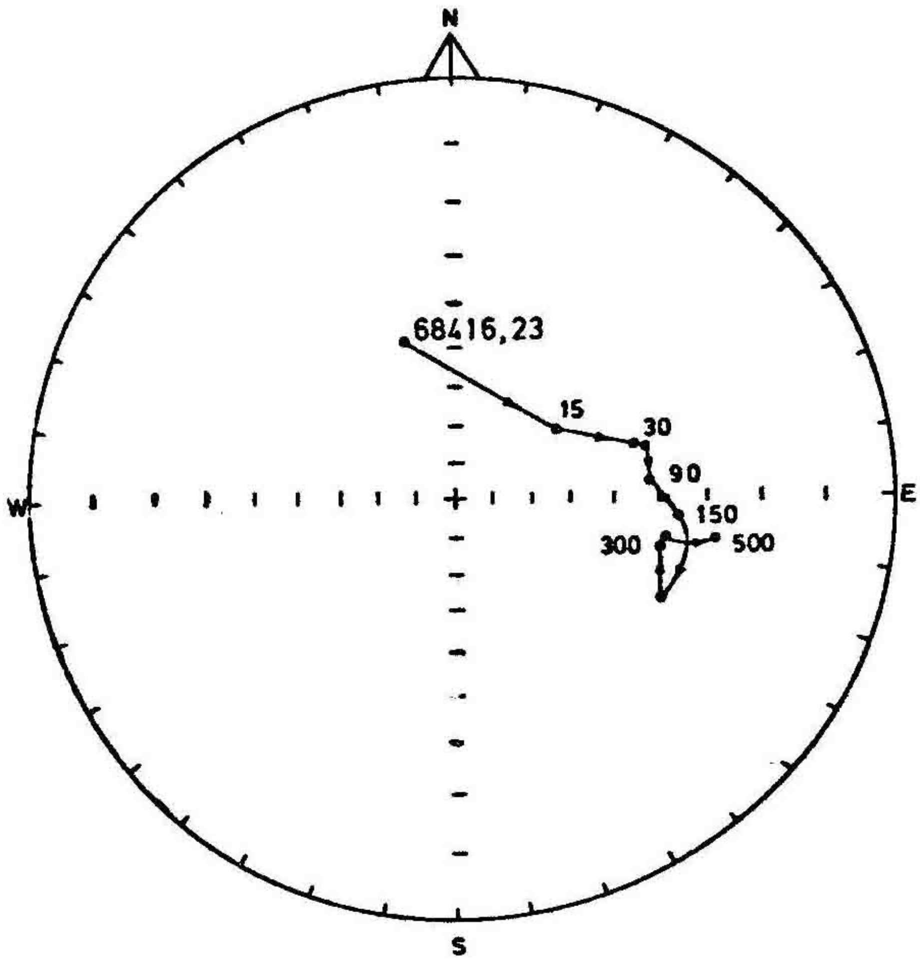

FIGURE 11. Demagnetization; from Stephenson et al.(1974).

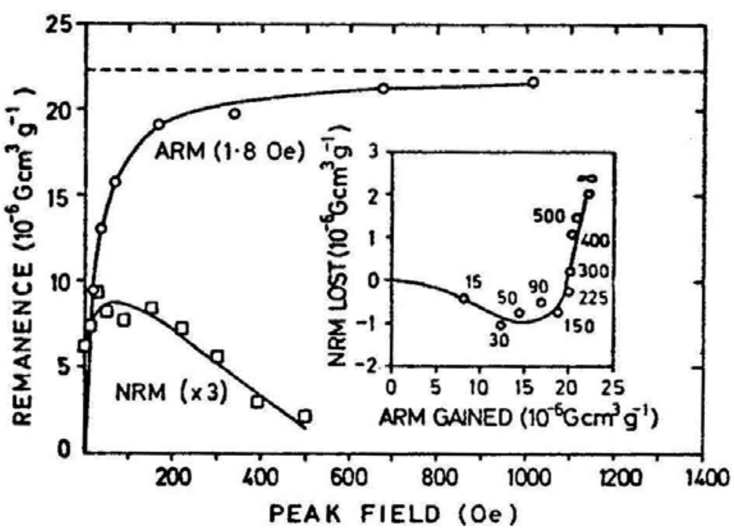

FIGURE 12. Demagnetization; from Stephenson et al. (1974).

Tsay and Live (1976) and Tsay and Bauman (1977) also report the presence of Fe^{3+} in plagioclase using data derived from electron spin resonance spectra. The Fe^{3+}/Fe^0 of 68416 (and other plagioclase-rich rocks) is higher than soils. Some of the Fe^{3+} may be terrestrial but some may also be indigenous.

PROCESSING AND SUBDIVISIONS: 68416 was sawn into the two halves ,8 (102 g) and ,9 (71 g). ,8 is intact and in remote storage. ,9 has been entirely subdivided (Fig.13). The largest pieces remaining are ,10 (8.9 g) and ,27 (15 g); no other splits are over 5 g.

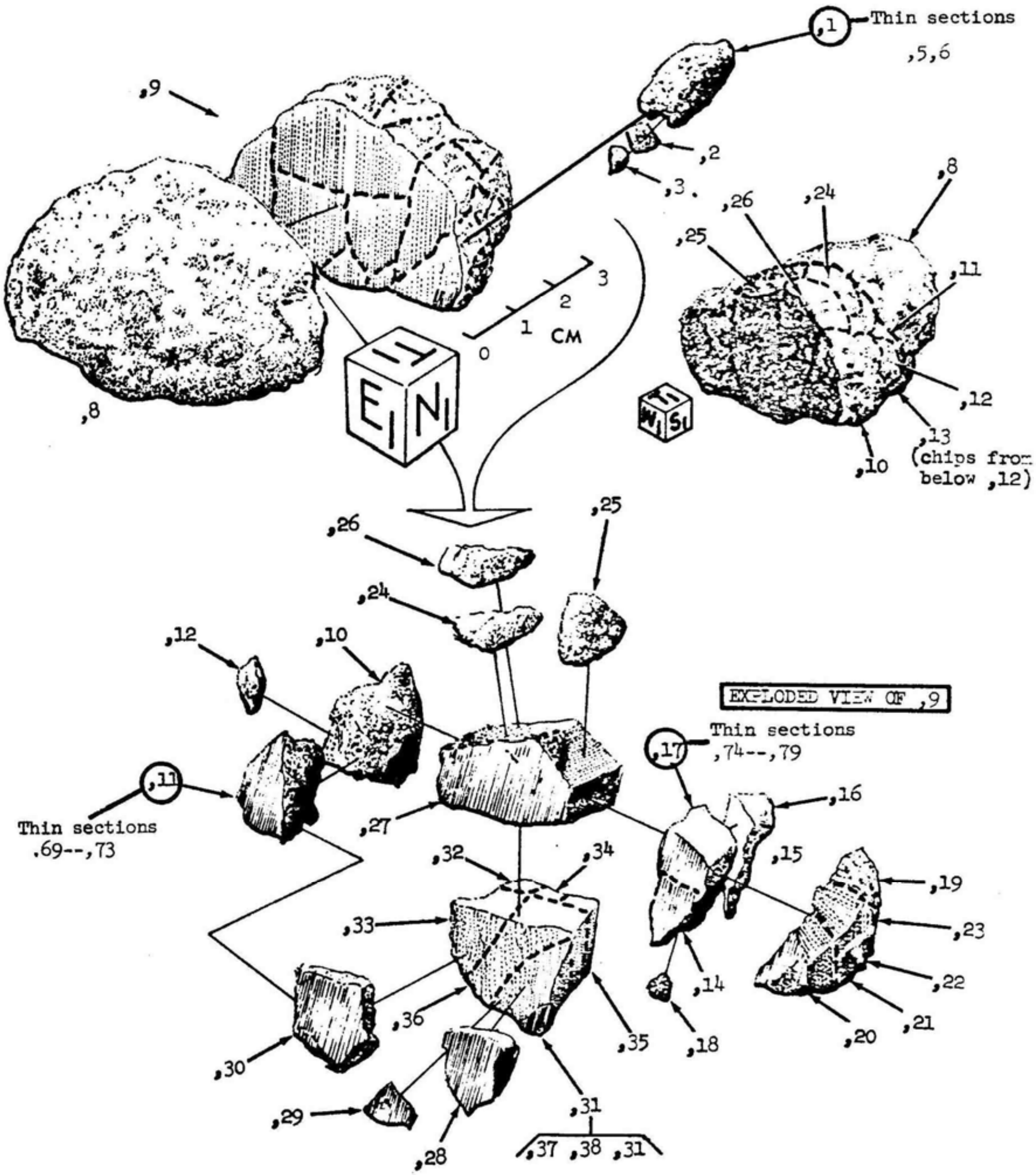

FIGURE 13. Cutting diagram.