15595 PORPHYRITIC SPHERULITIC QUARTZ-NORMATIVE ST. 9A 237.6 g
MARE BASALT

INTRODUCTION: 15595 is fine-grained, porphyritic mare basalt with conspicuously irregularly distributed vugs (Fig. 1). Pigeonite phenocrysts are set in a spherulitic, almost vitrophyric groundmass. Both phenocrysts and groundmass are finer-grained than in 15596, chipped from the same boulder. Its chemistry is typical of Apollo 15 quartz-normative mare basalts. The sample is olive gray to olive black, angular, and tough. The broken surface is hackly, the others are smoothed to irregular and have zap pits. The vugs make up 30% of the fresh surface.

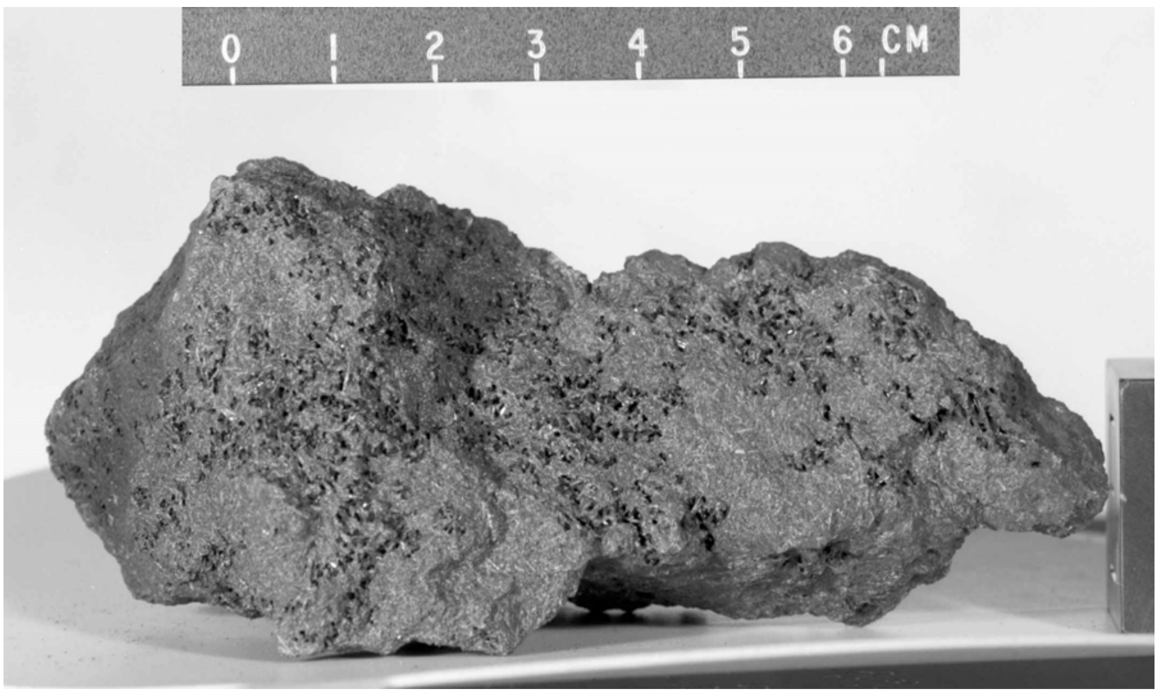

Figure 1. Broken-off face of 15595. S-71-46706

15595 was chipped from a 2 m x 50 cm boulder about 8 m east of the rim of Hadley Rille (Fig. 2). 15596 was chipped from the same boulder. The boulder appeared to be typical of those in the vicinity, which is strewn with boulders, cobbles, and pebbles. The boulder was described as bedrock by the astronauts; the boulder is probably not in situ bedrock, but is also probably very nearly in place.

PETROLOGY: 15595 consists of small pigeonite phenocrysts in a spherulitic groundmass of plagioclase, pyroxene, and glass (Fig. 3). Most of the pigeonite phenocrysts are less than 2 mm long in thin section, but a few reach about 5 mm. They are zoned, with sharply banded rims of augite. Many are hollow (groundmass-filled) and a few have simple twins. Irregularly-shaped vugs are present, and the euhedral phenocrysts project into them. The groundmass consists of fan spherulites of pyroxene (mainly augite), and plagioclase laths. Grove and Walker (1977) gave a mode with 52% phenocrysts and 48% groundmass, Papike et al. (1976) one with 48.1% pyroxenes, 51.6% groundmass, and 0.3% opaque minerals. The sample has more phenocryst volume than the isochemical but more slowly-cooled 15596.

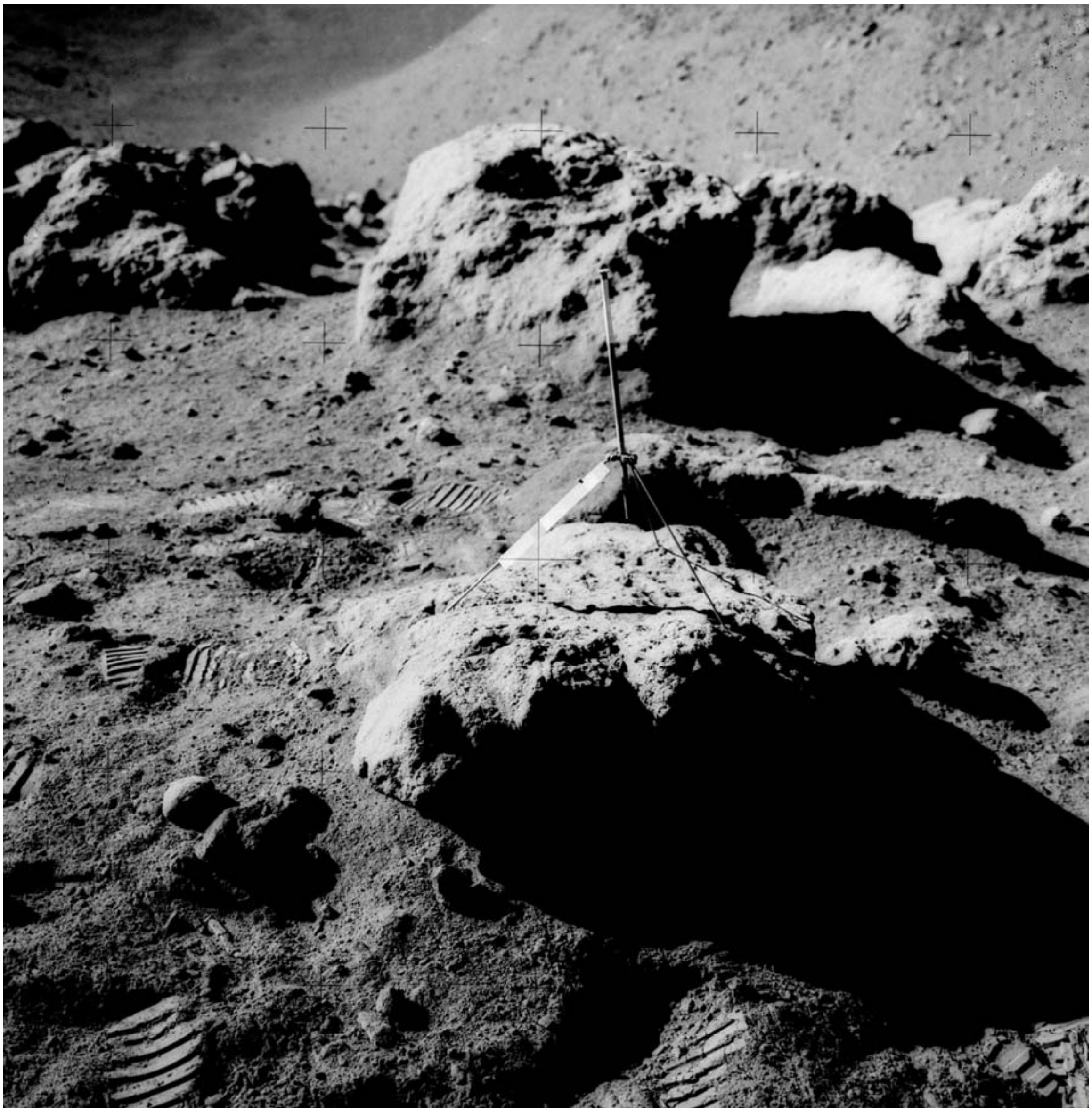

Figure 2. Sampling of 15595 and 15596. AS15-82-11143

Sato (1973) measured fO_2 with temperature variation (1000°C to 1200"C) for a sample of 15595 (Fig. 4). The data form a smooth curve similar to that for Apollo 12 basalts.

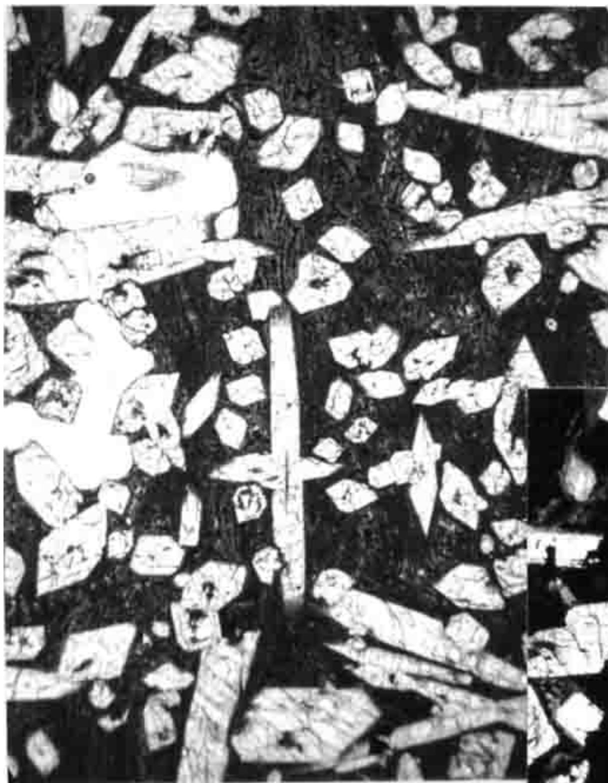

Fig. 3a

Fig. 3b

Figure 3. Photomicrographs of 15595,31.
Width about 3 mm. a) transmitted light; b) crossed polarizers.

<u>Cooling history</u>: Lofgren et al. (1975), in a comparison of natural textures with those produced in dynamic crystallization experiments (known linear cooling rates) deduced a cooling rate of 2 to 5°C/hr for the phenocrysts and about 30°C/hr for the groundmass, i.e., slower than 15597, and faster than 15596. They depicted a cross-section of a pyroxene phenocryst, similar to one grown in the 2.5°C/hr cooling rate experiment. Grove and Walker (1977), in a similar but more sophisticated study, inferred an early cooling rate of about 10°C/hr from the pyroxene nucleation density, an integrated rate of about 3.75°C/hr from pyroxene sizes, and a late-stage cooling rate of about 60°C/hr from the plagioclase sizes. They inferred final crystallization about 12 cm from a conductive boundary. Essentially slow initial cooling was followed by rapid cooling.

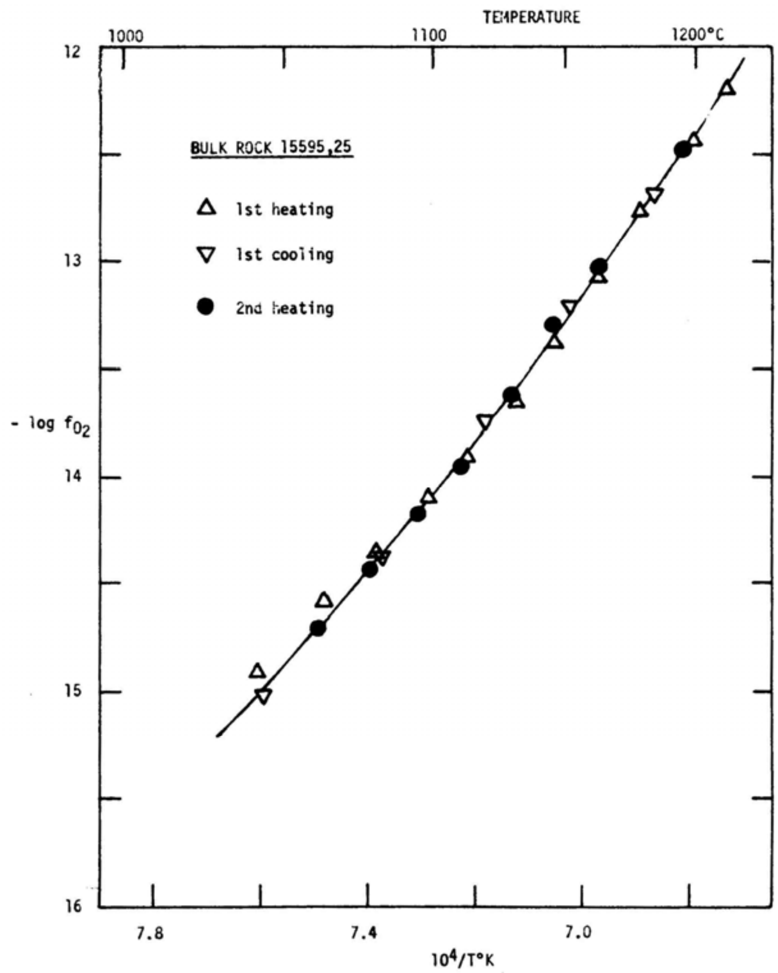

Figure 4. Measured fO_2 as a function of temperature (Sato et al., 1973).

CHEMISTRY: Chemical analyses are listed in Table 1, and the rare earths plotted in Figure 5. The analyses are of a typical Apollo 15 quartz-normative basalt, very similar to 15597, and are reasonably consistent. Compston et al. (1972) noted a systematic difference between their Rb abundances determined by x-ray fluorescence and the more reliable isotope dilution method.

RADIOGENIC ISOTOPES: Compston et al. (1972) presented Rb-Sr isotopic data for a whole-rock sample (Table 2). Assuming an age of 3.3 b.y. gives an initial $^{87}Sr/^{86}Sr$ of 0.69951 ($\lambda = 1.39 \times 10^{-11}$ yr^{-1}), indistinguishable from other Apollo 15 mare basalts.

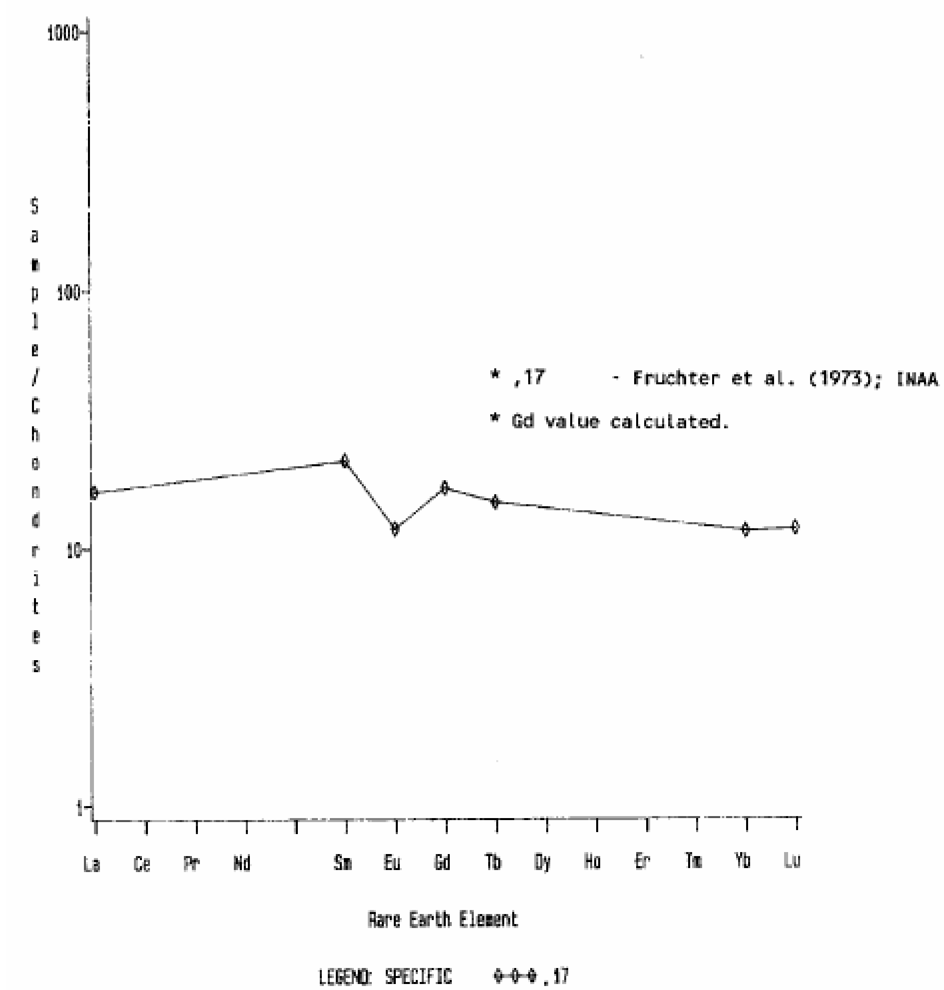

Figure 5. Rare earths in 15595.

<u>RARE GASES, TRACKS, AND EXPOSURE</u>: Behrmann et al. (1972) reported abundances of ^{S}He, ^{21}Ne, ^{38}Ar, and spallation Kr and Xe data. The ^{21}Ne, ^{38}Ar, and ^{81}Kr-Kr exposure ages are similar (112, 105, and 110 ± 17 m.y. respectively) and indicate a simple exposure history. ^{3}He gives a much lower exposure age of 6.5 m.y. Spallation Kr and Xe show a fairly hard cosmic ray isotopic spectrum, suggesting a single-step transition from a well-shielded to an unshielded position, such as might occur in a major rock slide. Fission ^{132}Xe is about the amount expected for a 3.5 ± 0.3 b.y. old rock with its U abundance. Drozd et al. (1974) reported Kr isotopic data, and total Kr at 1100°C. They gave uncertainties for the Behrmann et al. (1972) exposure ages of 26(^{21}Ne), 34(^{38}Ar), and 9(^{81}Kr-Kr) m.y. Pepin et al. (1974) noted that 15595 was the only sample which gave concordant exposure ages using the Bogard et al. (1972) production rates and discordant ages using the production rate derived from the drill core, raising questions about such production rates.

TABLE 15595-1. Bulk rock chemical analyses

		,17		,15		,16	,5
wt %	SiO_2		48.07				
	TiO_2	1.62	1.77				
	Al_2O_3	9.1	9.06				
	FeO	18.96	20.23				
	MgO		9.21				
	CaO		10.52				
	Na_2O	0.286	0.35				
	K_2O		0.05				
	P_2O_5		0.07				
(ppm)	Sc	45					
	V						
	Cr	3450	3560				
	Mn		2330				
	Co	42					
	Ni						
	Rb		0.72			0.90	
	Sr		103.8			99.4	
	Y		26				
	Zr		94				
	Nb		8				
	Hf	2.0					
	Ba						
	Th						
	U				0.196		0.208
	Pb						
	La	5.4					
	Ce						
	Pr						
	Nd						
	Sm	3.9					
	Eu	0.81					
	Gd						
	Tb	0.7					
	Dy						
	Ho						
	Er						
	Tm						
	Yb	2.3					
	Lu	0.40					
	Li						
	Be						
	B						
	C			18			
	N						
	S		500				
	F						
	Cl						
	Br						
	Cu						
	Zn						
(ppb)	I						
	At						
	Ga		2800				
	Ge						
	As						
	Se						
	Mo						
	Tc						
	Ru						
	Rh						
	Pd						
	Ag						
	Cd						
	In						
	Sn						
	Sb						
	Te						
	Cs						
	Ta	350					
	W						
	Re						
	Os						
	Ir						
	Pt						
	Au						
	Hg						
	Tl						
	Bi						
		(1)	(2)	(3)	(4)	(5)	(6)

References and methods:

(1) Fruchter et al. (1973); INAA
(2) Chappell and Green (1973); XRF
(3) Moore et al. (1973); combustion, gas chromatography
(4) Graf et al. (1973); tracks
(5) Compston et al. (1972); ID/MS
(6) Drozd et al. (1974), Behrmann et al. (1972);

TABLE 15595-2. Rb-Sr isotopic data (Compston et al., 1972)

Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
0.9 (ID)	99.4 (ID)	0.0261	0.70074 ± 10
0.72 (XRF)	103.8 (XRF)		0.70055 ± 10*

* unspiked sample

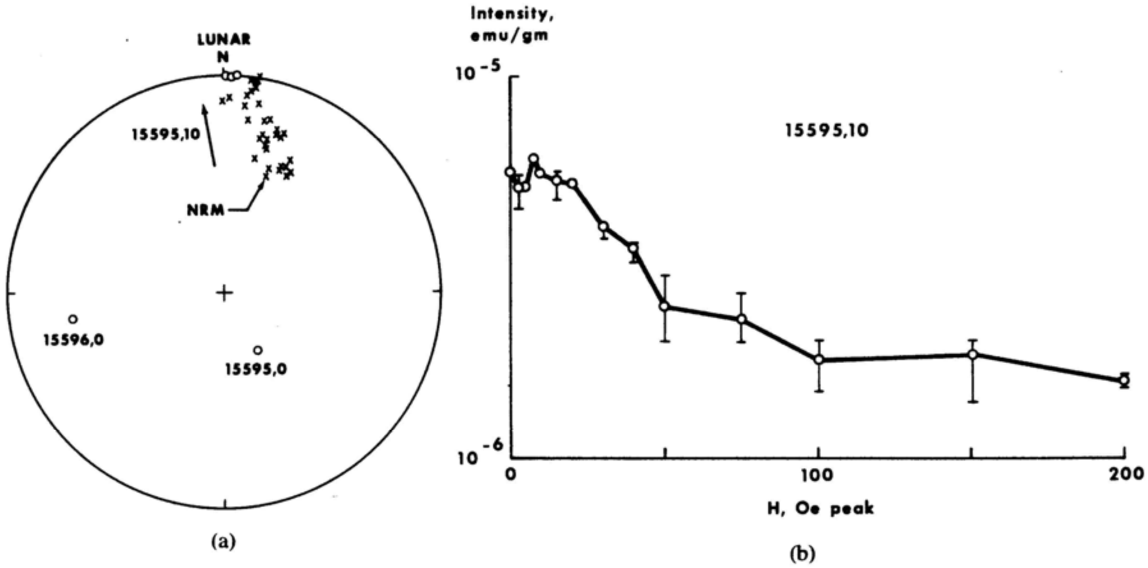

Figure 6. a) Direction of magnetization in lunar coordinates of three samples from the same boulder. Only 15595,10 was allowed to be demagnetized--the arrow shows change in direction, b) change in intensity during AF demagnetization of 15595,10.

Behrmann et al. (1972) found that track densities in large pyroxene crystals in a surface chip are highly zoned and anomalously low considering the 100 m.y. rare gas exposure age and inferred simple exposure history. The tracks suggest that the boulder was recently chipped on the centimeter scale or that the thermal stability of tracks in pyroxene is low.

PHYSICAL PROPERTIES: Gose et al. (1972) and Pearce et al. (1973) measured the natural remanent magnetism (NRM) and magnetic properties of two chips of 15595, and also the NRM of bulk sample 15596, from the same boulder (Fig. 6). One chip of 15595 was oriented, the other was not. The NRM of one chip was 1.7 x 10^{-6}, of the other about 1 x 10^{-5} emu/g. The directions are random and thus unlikely to be of lunar origin. On demagnetization a stable direction was found, and should be the direction of lunar magnetism if the boulder was actually bedrock, i.e., the direction was almost due north and horizontal. An inflection (Curie point) in the hysteresis loops at about 200°C indicates a metal with 30-40% Ni, and one at about 750°C indicates normal, low-Ni iron metal (Fig. 7). The magnetic properties indicate 0.060 of Fe^0 equivalent and 17.2% of Fe^{2+} equivalent. The magnetic properties are listed in Table 3. Brecher (1975, 1976) noted the inhomogeneity of direction of NRM in 15595 in her study proposing textural remanent magnetization of lunar samples.

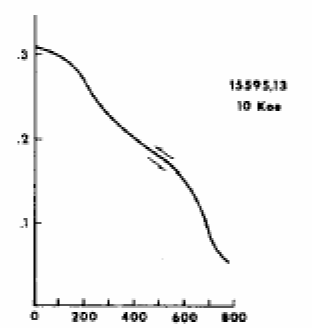

Figure 7. Magnetization as a function of temperature.
Horizontal axis in °C, vertical axis in emu/g.

PROCESSING AND SUBDIVISIONS: 15595 was sawn to produce a slab through the interior (Fig. 8). ,1 broke off before its cut was completed, and the remainder which was cut was labeled ,2 (17.3 g). ,1 had only 0.16 g of its "W" end (,11) chipped off; it is now 76.63 g and is in remote storage in Brooks. ,0 has not been further subdivided and is now 98.37 g. The slab piece ,3 was extensively subdivided and allocated (Fig. 8). All the thin sections, ,30 to ,39, were made from chip ,21.

TABLE 15595-3. Magnetic properties (Pearce et al., 1973)

Js emu/g	Xp emu/g Oe	Xo emu/g Oe	Jrs/Js --	Hc Oe	Js/Xo K Oe
0.13	37.4	0.48	0.006	33.0	2.7

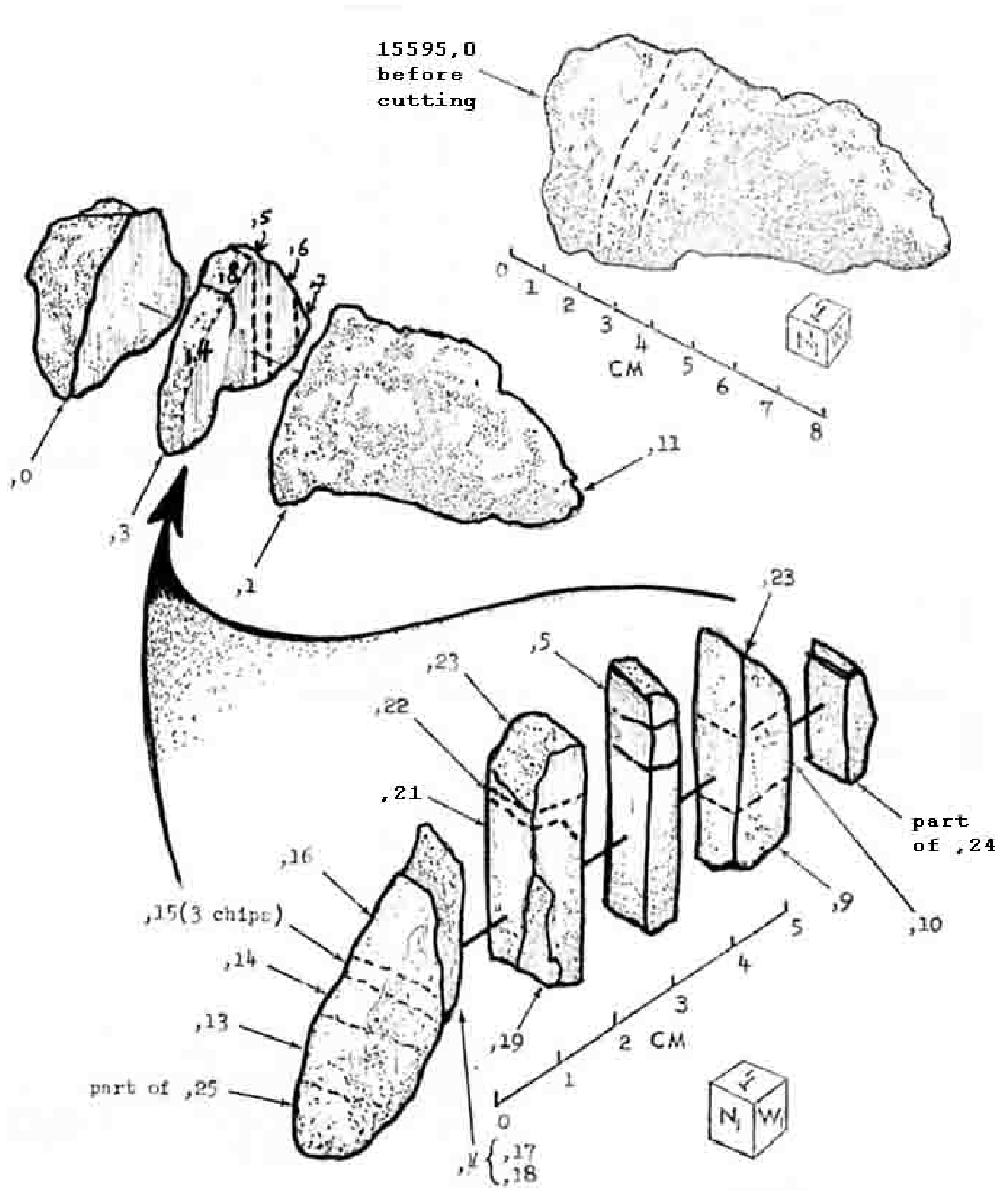

Figure 8. Cutting of 15595.