15535	FINE-GRAINED OLIVINE-NORMATIVE MARE BASALT	ST. 9A	404.4 g

INTRODUCTION: 15535 is a fine-grained, olivine-bearing mare basalt (Fig. 1) in which fine-grained pyroxenes are enclosed in poikilitic plagioclases and olivine phenocrysts are scattered. It is finer-grained than 15536, chipped from the same boulder. Chemically it is an average member of the Apollo 15 olivine-normative mare basalt group. The sample is medium dark to brownish to olive gray, and is tough, slabby, and subangular to angular. Its surface is irregular and somewhat hackly, with zap pits irregularly distributed. It has 3 to 5% vugs, into which crystals project.

15535 was chipped with 15536 from a 0.75 m boulder about 20 m east of the rim of Hadley Rille, from the north rim of a moderately fresh, blocky, 3 m diameter young crater. The boulders are probably bedrock excavated by the impact event. The orientation of 15535 was documented.

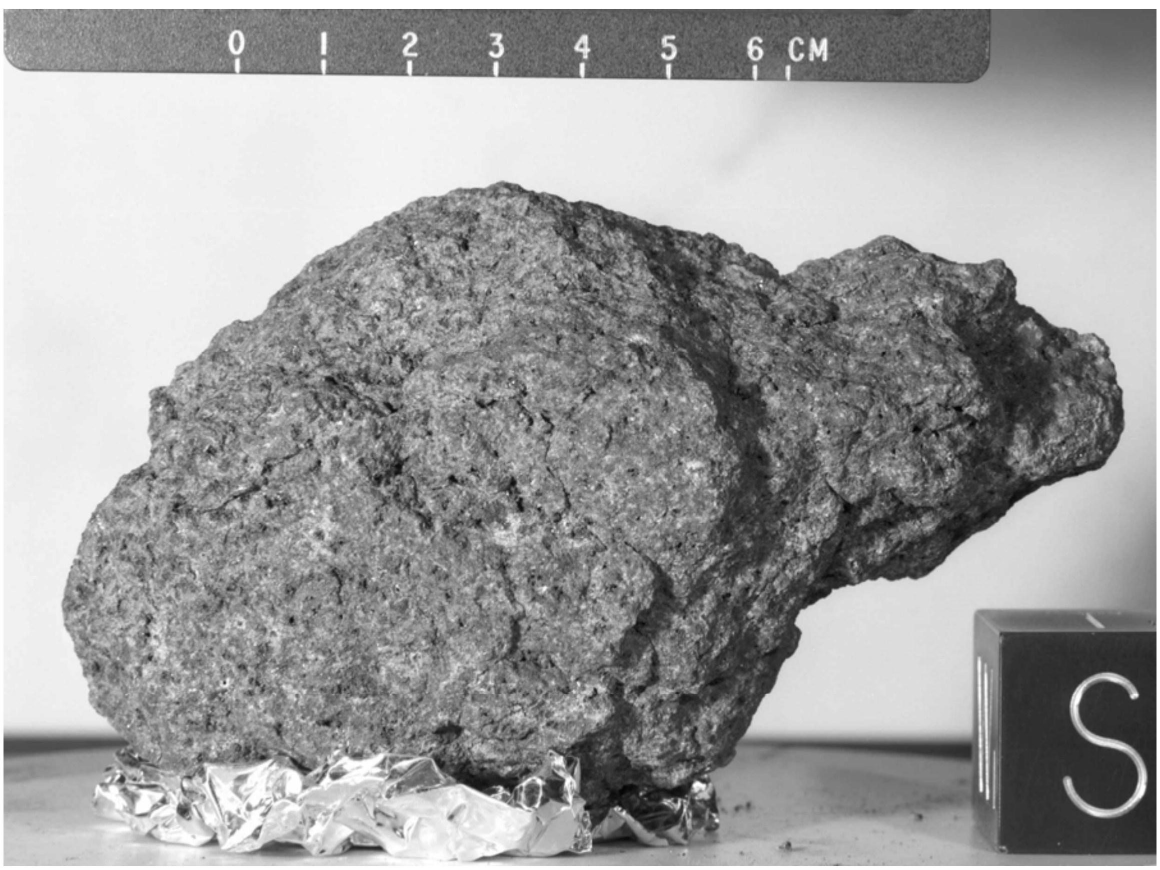

Figure 1. Pre-split view of 15535. The top surface is that broken from the parent boulder. S-71-46850

PETROLOGY: 15535 is a plagioclase-poikilitic mare basalt with scattered olivine phenocrysts (Fig. 2). The mass of the rock consists of clustered, granular clinopyroxenes and some olivines a few hundred microns across. The poikilitic plagioclases are up to 3 mm across, and the scattered, corroded, olivine phenocrysts are rarely as large as 2 mm. The opaques cluster with the mafic clusters, and are dominantly ulvospinel and some late-stage ilmenite. Chromite is rare. Cristobalites up to about 200 microns, fayalite, troilite, rare Fe-metal and residual glass are present. Many olivines and pyroxenes are optically zoned, and feldspars have curved twin planes. 2-mm sized vugs are scattered. Two published modes are listed in Table 1 and are reasonably consistent.

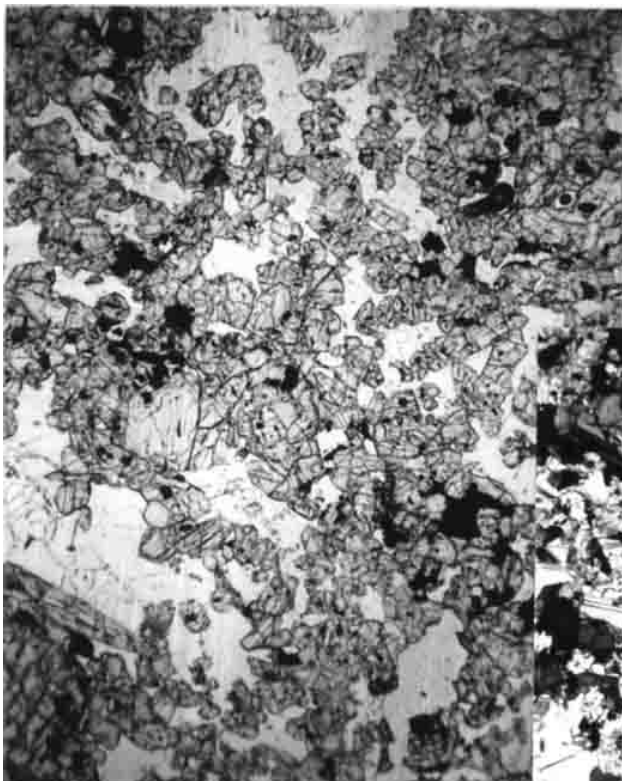

Fig. 2a

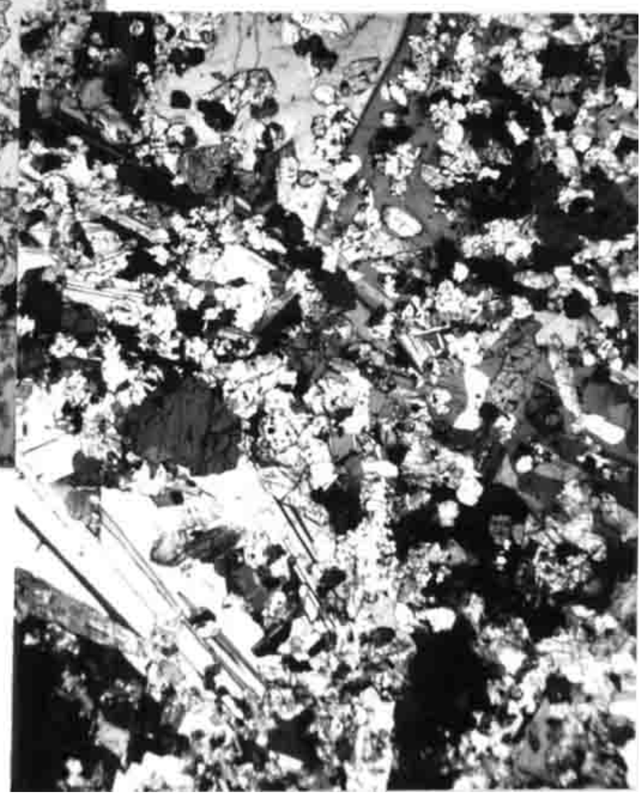

Fig. 2b

Figure 2. Photomicrographs of 15535,9 showing clustering of small, granular mafic grains and opaque minerals; j poikilitic plagioclases; and a small olivine phenocryst (left center). Width about 3 mm. a) transmitted light; b) crossed polarizers.

TABLE 15535-1. Modes of 15535

Phase	%	%
Ol	10	10
Cpx	53	60
Plag	32	25
Ulvo	2	
Ilm	1	4
Troil	<0.1	
Fe-Ni	<0.1	
Crist	0.5	
Glass	1	<1
Zircon	-	
	(1)	(2)

(1) Lunar Sample Information Catalog Apollo 15 (1971)
(2) Juan et al. (1972a)

Juan et al. (1972a) noted that the clinopyroxene was commonly twinned with (100) as the twin plane, and was zoned from a pigeonite core to a subcalcic augite rim. Fernandez-Moran et al. (1973) studied 16 mg of zoned small grains ($En_{50\pm10}Wo_{15.6\pm6.5}$) using electron optical techniques. The grains were crushed and impurities removed. Electron micrographs showed exsolution lamellae in 20% of the grains. Dense bands were 25-555 Å wide (av. 250 Å), the interbands were 50-900 Å wide (av. 330 Å). Virgo (1973a) used the same pyroxenes for x-ray diffraction and Mossbauer studies. The pigeonite cores (Ti/Al about 1/4) zoned towards Ca, Fe-rich rims (Ti/Al<1/2), and their patterns showed deviations from Lorentzian line-slopes and broader line widths consistent with their chemical heterogeneity. The Mossbauer study showed a high degree of disorder of the Fe^{2+}-Mg distributions; the interpretation is difficult because of the chemical heterogeneity and the mixture of structural states.

Juan et al. (1972a) reported that the olivines had a composition of Fo_{76}, (and that some had inclusions of clinopyroxene and ilmenite) and that plagioclases are An_{83}. They attributed fracture, wavy extinction, and bent twin lamellae for plagioclases to a shock event. They interpreted the crystallization sequence as cpx→ol→plag.

Haggerty (1972a,c,d) reported spinel compositional data (Fig. 3). The data display a typical bimodal ulvospinel-rich and a chromite-rich distribution, but there are also a few spinels of intermediate composition. Engelhardt (1979) tabulated 15535 as showing ilmenite crystallization as starting with plagioclase crystallization, and ending before the end of pyroxene crystallization.

Muan et al. (1974) reported that they had conducted equilibrium liquid-solid experiments (Fe-metal equilibria) on a representative powder of 15535, but apart from its having olivine or spinel on the liquidus, gave no specific data.

CHEMISTRY: Chemical analyses are listed in Table 2 and the rare earths shown in Figure 4. The data are fairly consistent except for TiO_2 (whose variation is probably a

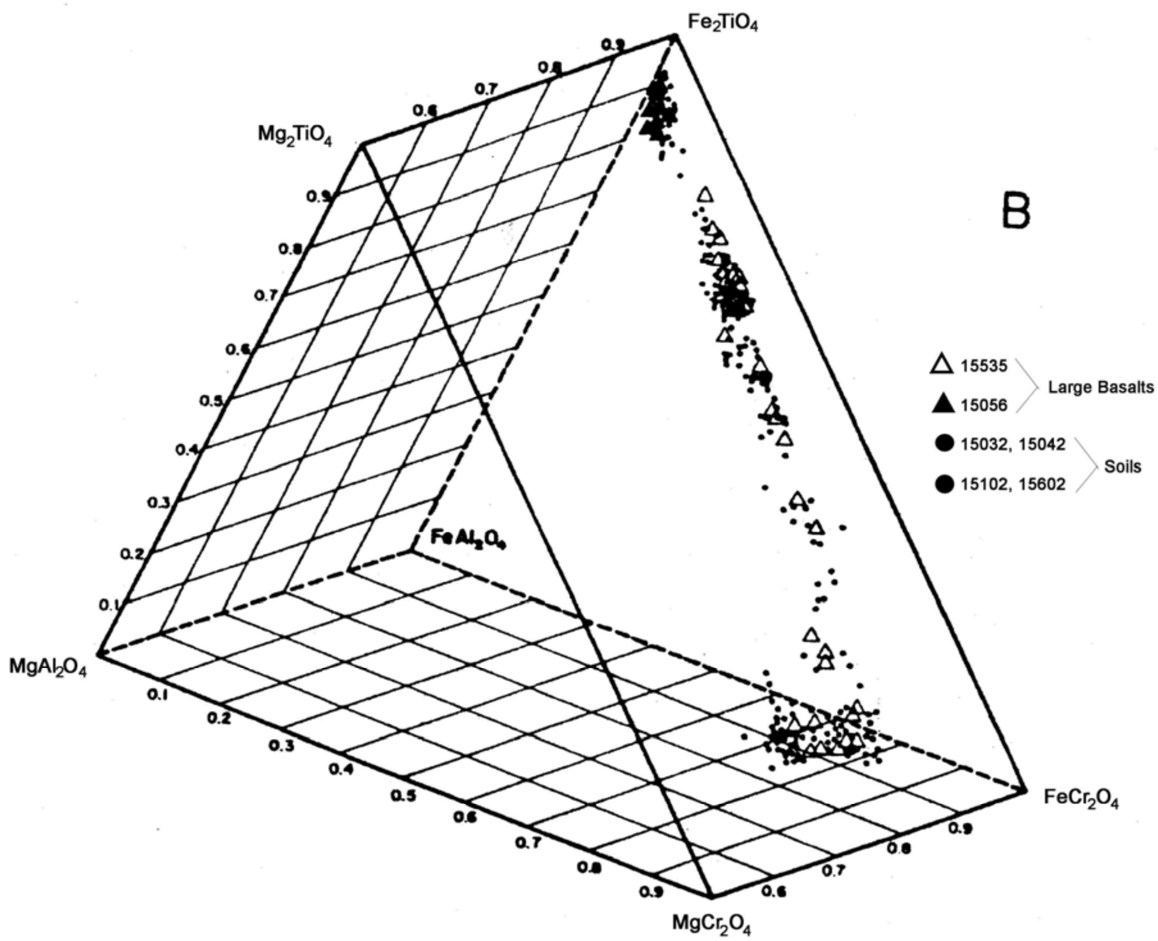

Figure 3. Compositions of spinel group minerals in 15535 (open triangles) and other Apollo 15 samples (Haggerty, 1972c) .

reflection of the localized distribution of ulvospinel and ilmenite) and show 15535 to be an average member of the Apollo 15 olivine-normative basalt suite. However, the rare earths are slightly lower than is typical, again probably a sampling problem. Mason et al. (1972) suggested caution because of the small sample sizes used.

EXPOSURE, TRACKS, AND RARE GAS: Rancitelli et al. (1972) tabulated disintegration count data for cosmogenic radionuclides, and stated that ^{26}Al was saturated, indicating a long exposure in comparison with the ^{26}Al half-life. However, Yokoymama et al. (1974) found the Rancitelli et al. (1972) data to indicate that the ^{26}Al was not saturated (^{22}Na-^{26}Al method).

Bhandari et al. (1972, 1973) diagrammed track density with depth (Fig. 5) showing a very shallow slope. The track density was 5 x $10^6/cm^2$. They tabulated a "sun-tan" exposure age of less than 1 m.y. and a "subdecimeter" exposure age of 10 m.y. (1973 report) or less than 10 m.y. (1972 report).

TABLE 15535-2. Bulk rock chemical analyses

		,2	,4	,6	,5	,32	,31	,30	,0
Wt %	SiO2	45.50	44.73	45.3		44.46			
	TiO2	2.51	2.83	2.15		2.19			
	Al2O3	9.70	9.55	8.37		8.68			
	FeO	21.70	22.15	22.9		23.80			
	MgO	10.34	10.34	11.2		11.27			
	CaO	9.30	8.92	9.68		9.20			
	Na2O	0.195	0.195	0.267		0.28			
	K2O	0.041	0.046	0.044		0.04			0.059
	P2O5					0.06			
(ppm)	Sc								
	V					140			
	Cr	4120	3910			3900/4800			
	Mn	2250	2210		2190	2560			
	Co	77	59			52			
	Ni	92	76		46	70		75	
	Rb	3.8	3.8			<5			
	Sr	201	184		87	83			
	Y					42			
	Zr					85			
	Nb								
	Hf								
	Ba				45	38			
	Th								0.45
	U						0.11		0.104
	Pb					<2			
	La				3.49				
	Ce				9.7				
	Pr								
	Nd				6.7				
	Sm				2.60				
	Eu				0.69				
	Gd				3.6				
	Tb				0.59				
	Dy				4.07				
	Ho				0.73				
	Er								
	Tm								
	Yb				1.69				
	Lu				0.236				
	Li	8	7			7	7.1		
	Be								
	B					4			
	C								
	N								
	S								
	F								
	Cl						2.79		
	Br						0.017		
	Cu	3	7			8			
	Zn	12	17					1.4	
(ppb)	I						2.0		
	At								
	Ga	<10,000	<10,000			3000		3100	
	Ge							19	
	As								
	Se								
	Mo								
	Tc								
	Ru								
	Rh								
	Pd								
	Ag	32	26						
	Cd							1.4	
	In							0.34	
	Sn								
	Sb								
	Te						1.4		
	Cs								
	Ta								
	W								
	Re								
	Os								
	Ir							0.059	
	Pt								
	Au	4	2					0.060	
	Hg								
	Tl								
	Bi								
		(1)	(1)	(2)	(3)	(4)	(5)	(6)	

References and methods:

(1) Juan et al. (1972a, b); AAS, colorimetry
(2) Helmke et al. (1973); INAA, AAS
(3) Helmke and Haskin (1972), Helmke et al. (1973); RNAA
(4) Mason et al. (1972); general silicate analysis, gravimetry, flame photometry, colorimetry
(5) Reed and Jovanovic (1972); INAA
(6) Baedecker et al. (1973); RNAA

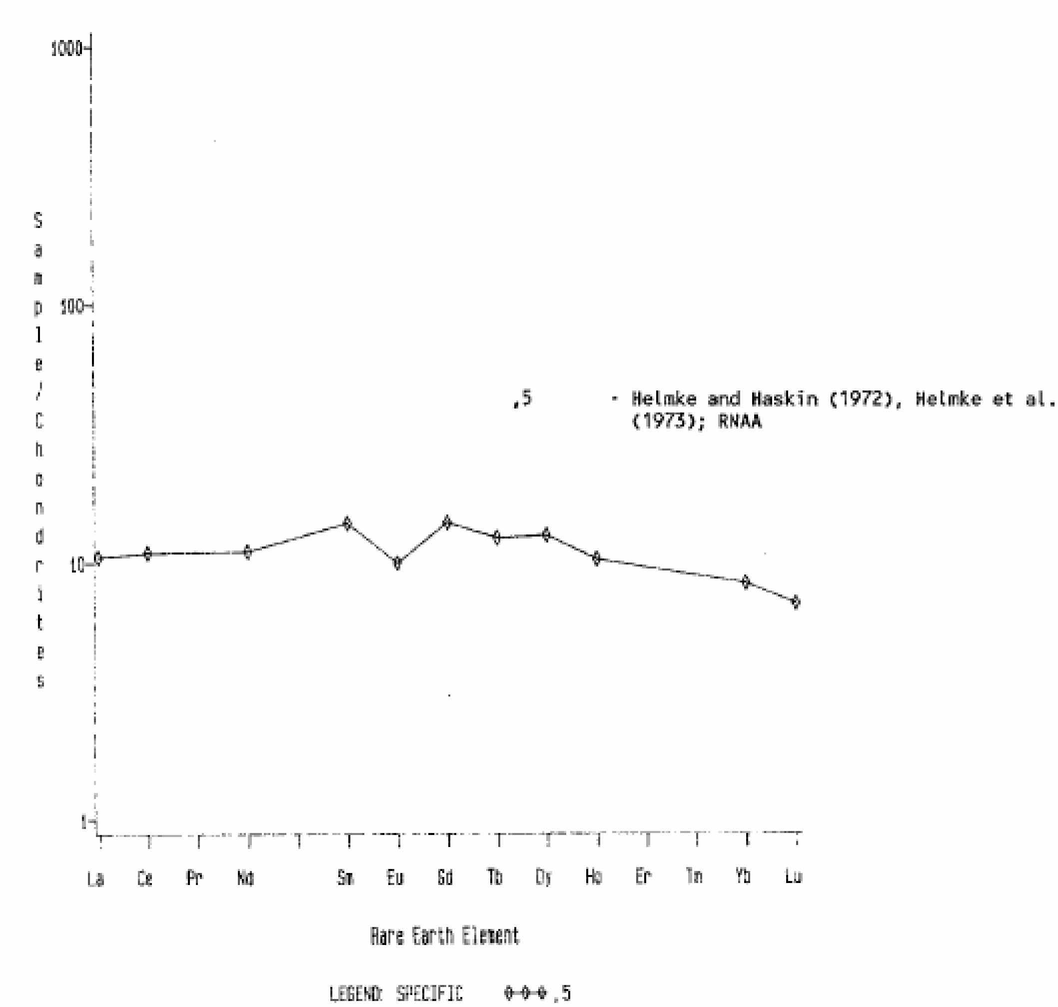

Figure 4. Rare earths in 15535.

<u>PHYSICAL PROPERTIES</u>: Banerjee et al. (1972) and Hoffmann and Banerjee (1975) measured the natural remanent magnetization of 15535, in particular alternating field demagnetization. The sample showed extreme "zigzag" behavior, i.e., changes of intensity and direction (Fig. 6). The behavior is characterized by non-reproducible remanent magnetization values upon demagnetization at a given peak AF. The direction is roughly confined in a plane. The behavior is attributed to the presence of a few, planar, multidomain grains representing a local mineral fabric. These "super-grains" do not demagnetize, and if present in any given sample could easily render any paleointensity determination of little value. Hoffmann and Banerjee (1975) also conducted experiments of viscous acquisition and decay on their sample, with results consistent with the "super-grains" responsible for the zigzag NRM behavior.

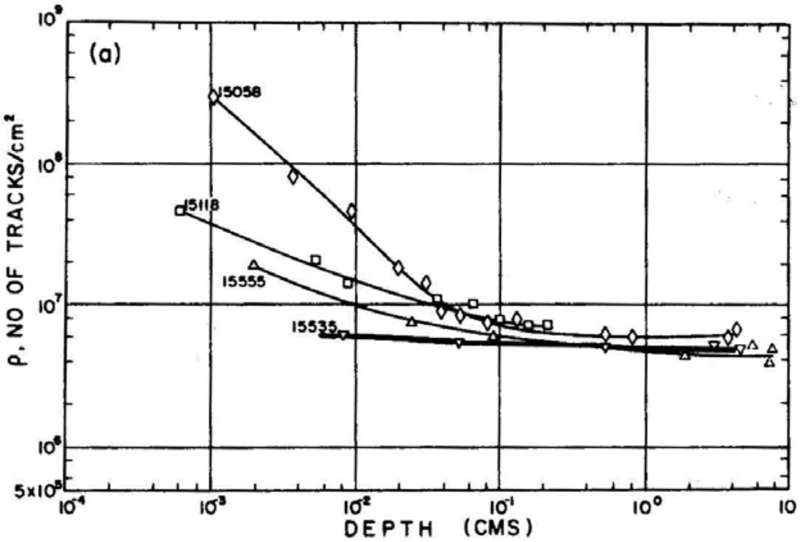

Figure 5. Track density profile for 15535 and other Apollo 15 rocks
(Bhandari et al., 1975).

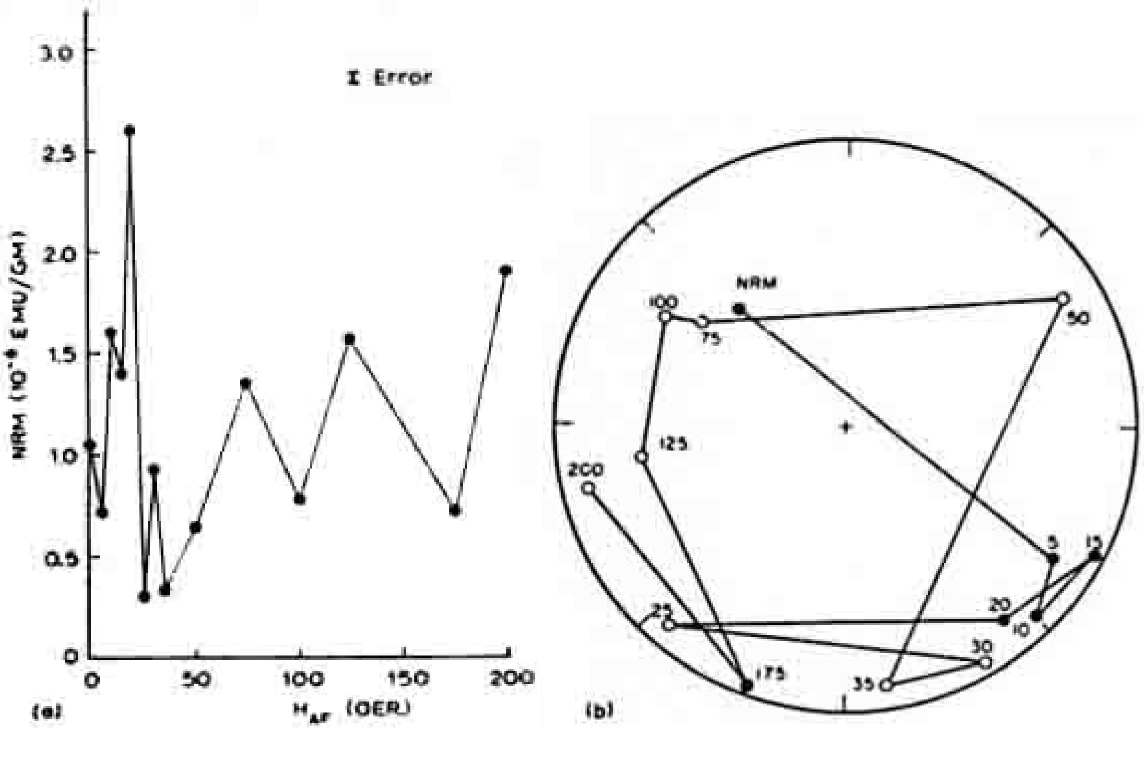

Figure 6. a) AF-demagnetization curve of NRM for 15535,28;
b) stereographic projection of NRM directions after stepwise
demagnetization of the indicated peak AF values.
Solid and open circles refer to the upper and lower hemispheres respectively
(Hoffman and Banerjee, 1975).

PROCESSING AND SUBDIVISIONS: A chip was removed from the sample (,1) and subdivided to produce ,2 to ,8 (total about 8 g). ,3 was made into a potted butt and produced all the thin sections from 15535, i.e., ,9 and ,11 to ,15. Subsequently the sample was sawn to make a slab which was dissected (Fig. 7). Most allocations were made from those pieces. About 10 g of the slab piece was homogenized as a fine material (,34 and daughters) and part of it allocated for experimental studies. ,0 is now 230.0 g, and end piece ,18 (61.28 g) is in remote storage in Brooks.

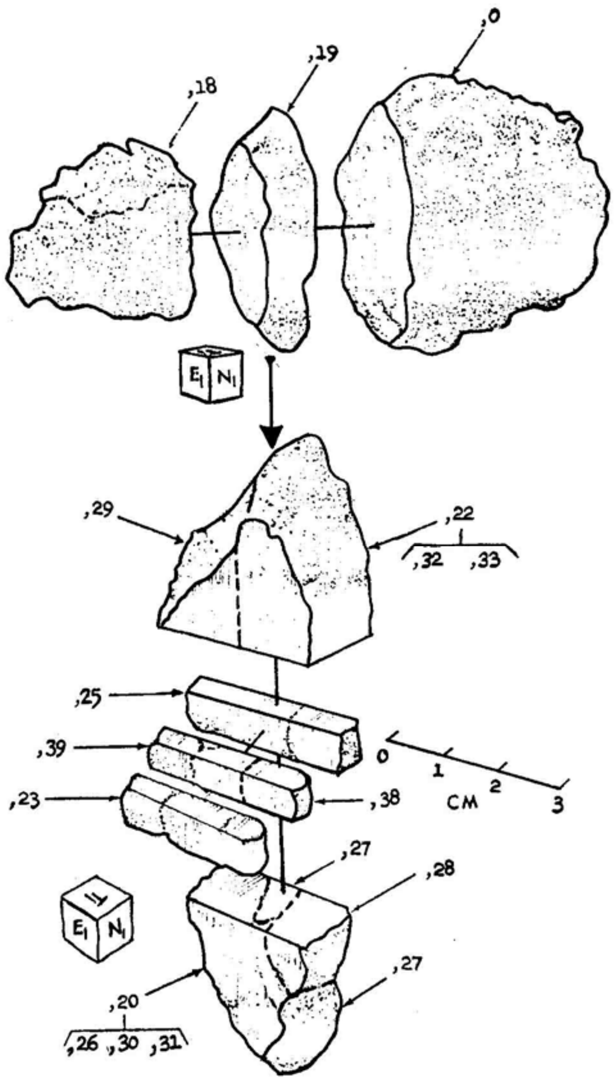

Figure 7. Basic splitting of 15535.