15498 REGOLITH BRECCIA, GLASS-COATED ST. 4 2339.8 g

INTRODUCTION: 15498 is a coherent, glassy matrix breccia (Figs. 1, 2) with components mainly of mare derivation, including basalt fragments and glass. It is partly covered with vesicular black glass and has fissures filled with glass. It was originally described (Apollo 15 Lunar Sample Information Catalog, 1971) as recrystallized, but subsequent work has shown that interpretation to be in error. Its composition is rather similar to that of regolith collected at Station 4.

15498 was collected at the south rim of Dune Crater, near the boulder from which samples 15485, 15486, and 15499 were taken (Fig. 15485-1). It was one-third to one-half buried in the fillet on that boulder. It is dark gray and angular with a thin, partial glass coat (Fig. 1). It has a few zap pits on one side. It was originally studied in a consortium headed by B. Mason.

Figure 1. 15498 prior to sawing, showing angular nature and vesicular glass. S-72-16723

PETROLOGY: 15498 is medium to dark gray with a brown tint. Clasts larger than ~0.2 mm compose ~85% of the rock; the rest is a glassy matrix (Figs. 2, 3). Glass cuts (veinlets) and surrounds (selvages) clasts, and occurs as a partial coat. Most of the components are of mare origin: basalt fragments, pyroxene fragments, opaque fragments, and mare glasses. McKay and Wentworth (1983) found it to be compact, with intermediate fracture porosity, and to have rare agglutinates, minor spheres, and abundant shock features. Wentworth and McKay (1984) found it to have a bulk density of 2.43 g/cm^3, with a calculated porosity of 23.8%. Its I_s/FeO of 19-29 (McKay et al., 1984) or 18 (Korotev, 1984 unpublished) is immature.

Figure 2. Sawn face of 15498,0, showing pale-colored, cm-sized clasts. S-72-16734

Mason (1972) described the general petrography of the sample. Numerous irregularly-shaped clasts, all lighter in color than the matrix and up to 1 cm across, are prominent. The breccia is well-indurated and tends to break through clasts. It consists of rock, mineral, and glass fragments, with glass spherules and fissures, the whole welded together with interstitial glass. Rock fragments are mainly mare basalts, similar to those

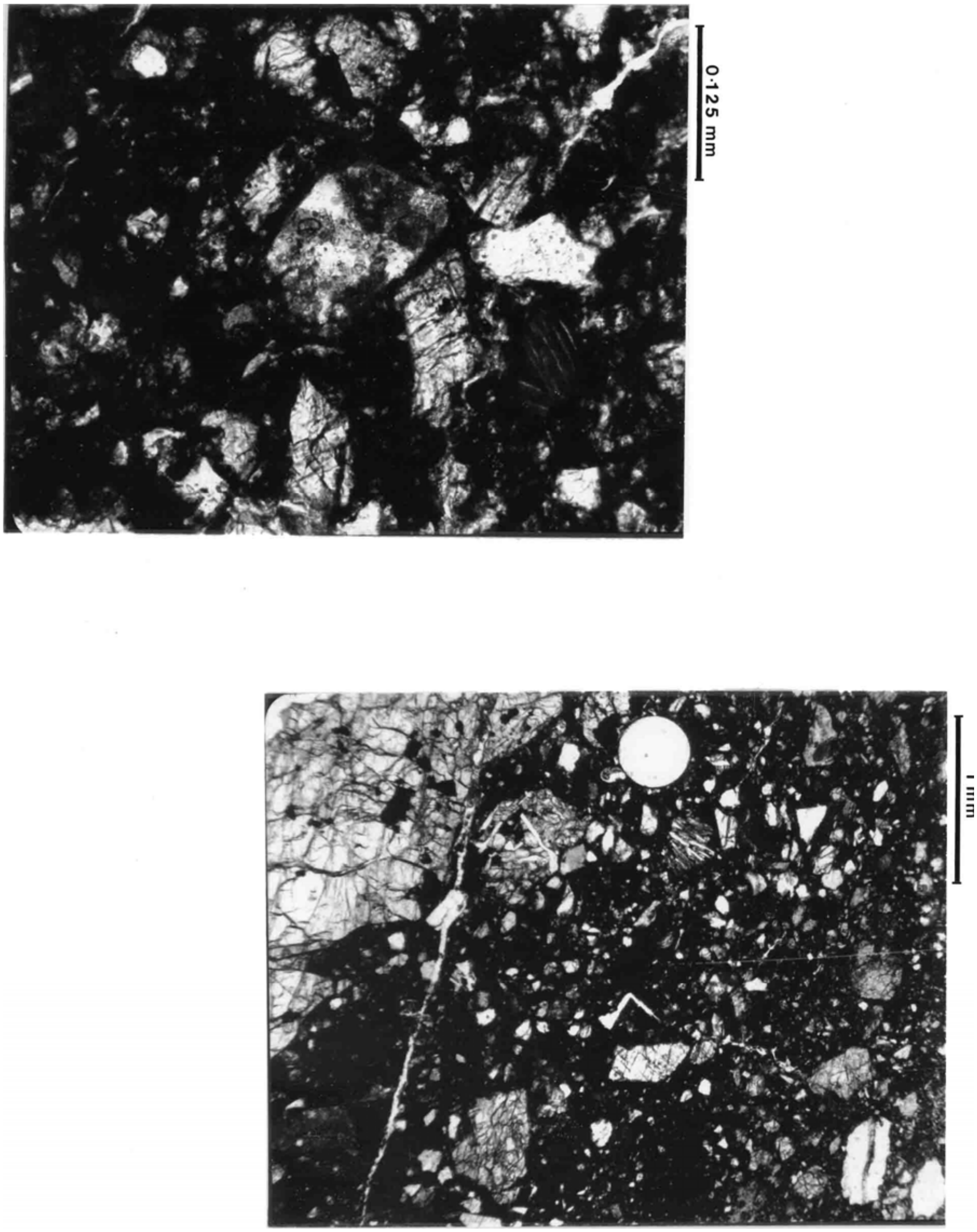

Figure 3. Photomicrographs (transmitted light) of 15498 matrix.

from Dune Crater; some show shock effects. One 0.6 mm fragment is an Apollo 15 KREEP basalt; other plagioclase-rich fragments are not uncommon, particularly among the larger clasts. Mineral fragments compose about half the rock: pyroxenes are almost entirely pigeonites or subcalcic augites with a wide range in composition. The compositions and proportions of minerals are similar to local soils. Glass forms 10% of the non-matrix material. Spheres are rare and small, and most glass occurs as shards. The fissure fillings are vesicular, gray-green glass, whose composition is similar to the bulk rock and to local fines (Table 2). The mineralogy and petrology suggest strongly that 15498 is a local regolith, lithified largely by welding of interstitial glass.

Pearce et al. (1976) described one thin section, ,8, of which 20% is a single olivine gabbro (mare) clast. The rest is glassy matrix (53%) and lithic and mineral clasts (46%), with abundant maskelynite. Metal is estimated to compose 0.01% of the volume (less than that determined by other methods) and is observable in sizes less than 1 µm to 45x18 µm. The iron-nickel metal occurs as single phase particles in glass, in pyroxene, and between fragments. Even the metal grains in the matrix have Co higher than the "meteoritic" range (Fig. 4).

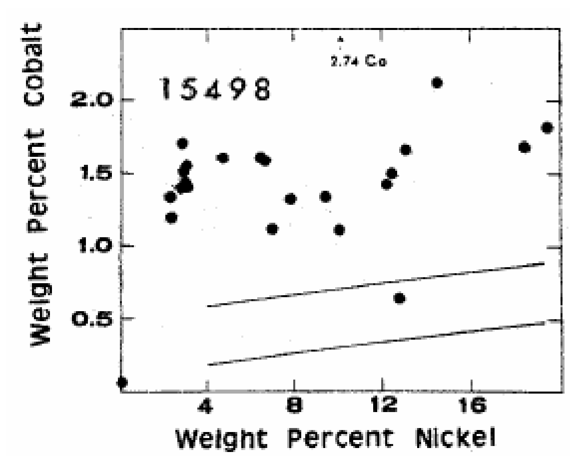

Figure 4. Compositions of metals in 15498 (Pearce et al., 1976).

Christie et al. (1973) studied 15498 with optical and high-voltage electron microscopy techniques. They found low porosity, no evidence for recrystallization, and 50% glass matrix. Most clasts show extensive evidence of deformation, and none show no deformation; Christie et al. (1973) interpreted this observation to mean that deformation took place in situ. There is no evidence for clast annealing as in some higher-grade rocks. They concluded that 15498 formed from unconsolidated regolith by the passage of shock waves of a few tens of kilobars.

Steele et al. (1980) made ion-probe analyses of the plagioclase in the basalt clast in ,8, finding 7.4 ppm Li, 10.8 Wt % Ab, 1690 ppm Mg, 465 ppm K, 435 ppm Ti, 350 ppm Sr, and 25 ppm Ba.

Uhlmann's group (Uhlmann and Klein, 1976; Uhlmann and Onorato, 1979; Yinnon et al., 1980; and Uhlmann, 1981) studied the viscous flow and crystallization behaviour of a glass purportedly of 15498 composition in order to constrain the thermal history of 15498. The data are used in models of varying complexity to determine cooling rates. However, the composition used is unlike any published analysis of 15498, being much higher in $A1_2O_3$ (19.8%) and lower in FeO (8.4%) than data in Table 1, hence the results are not of direct application. In a study on 15498 glass itself, Uhlmann and Klein (1976) found that annealing increased its density, a characteristic which suggests that it formed by cooling from a molten state, not from shock which would already have given it a high density. They thus suggested that the shock features observed by Christie et all (1973) are unrelated to lithification itself.

CHEMISTRY: Published analyses of 15498 are listed in Tables 1 and 2, with rare earths plotted on Figure 5. The identities of the two splits analyzed by Laul and Schmitt (1973) are not precisely known: they were listed as breccia "clasts" but the samples from which they were taken were general matrix. The similarity of their K, U, and Th with the determinations on the bulk rock (,0; O'Kelley et al., 1972) suggest that they are general matrix samples. The matrix is similar to local soil compositions and 15498 was thus presumed by Laul et al. (1972) and others to be lithified soil. The glass fissure analysis is similar to the Laul and Schmitt (1972) "clast" analyses. The abundant mare component is conspicuous. The analysis of Wanke et al. (1976) is of a light gray clast, and it is clearly a mare basalt. The Si, Fe, Sc, and Th abundances strongly suggest that it is a quartz-normative basalt.

Modzeleski et al. (1972) reported data for compounds of carbon i.e., CO, CO_2, and CH_4; and Kaplan et al. (1976) also reported CH_4 data (as C = 12.6 ppm). Wanke et al. (1977) reported an oxygen analysis for the mare basalt clast. Kaplan et al. (1976) used an acid hydrolysis method to determine an Fe-metal abundance of 0.53%.

STABLE ISOTOPES: Kaplan et al. (1976) reported isotopic ratios for light elements: δC^{13} = -19.9, $\delta^{15}N$ = -41, $\delta^{34}S$ (from combustion) = +8.0, and $\delta^{34}S$ (from hydrolysis) = +5.1. The nitrogen and carbon isotopes are quite dissimilar from typical soils, even though the absolute abundances are similar to soils.

TABLE 15498-1. Bulk analyses of 15498

		,45A	,46A	,0	,32	,31	,126
Wt %	SiO2						
	TiO2	1.6	1.6				1.93
	Al2O3	12.9	13.7				11.2
	FeO	17.3	16.7				17.9
	MgO	10	11				9.7
	CaO	10.8	11.1				8.5
	Na2O	0.385	0.395				0.36
	K2O	0.13	0.13	0.1374			
	P2O5						
(ppm)	Sc	34	31				34.1
	V	160	150				117
	Cr	3150	3100				3090
	Mn	1700	1600				1175
	Co	43	44				45.7
	Ni						169
	Rb						
	Sr						120
	Y						
	Zr						250
	Nb						
	Hf	5.7	5.3				6.7
	Ba	140	150				149
	Th	1.9	2.1	2.5			2.4
	U	0.7	0.7	0.65			0.68
	Pb						
	La	15	16				15.4
	Ce	42	43				43
	Pr						
	Nd						25
	Sm	7.8	7.8				7.92
	Eu	1.2	1.2				1.24
	Gd						
	Tb	1.6	1.6				1.66
	Dy	9.6	10				
	Ho						
	Er						
	Tm						
	Yb	5.5	5.8				5.6
	Lu	0.79	0.85				0.75
	Li						
	Be						
	B						
	C				16.4	62	
	N					55	
	S					660,680	
	F						
	Cl						
	Br						
	Cu						
	Zn						
(ppb)	I						
	At						
	Ga						
	Ge						
	As						
	Se						
	Mo						
	Tc						
	Ru						
	Rh						
	Pd						
	Ag						
	Cd						
	In						
	Sn						
	Sb						
	Te						
	Cs						150
	Ta	800	800				830
	W						
	Re						
	Os						
	Ir						7.1
	Pt						
	Au						1.6
	Hg						
	Tl						
	Bi						
		(1)	(1)	(2)	(3)	(4)	(5)

References and methods:

(1) Laul and Schmitt (1973); INAA
(2) O'Kelley et al. (1972); Gamma ray spectroscopy
(3) Hodzeleski et al. (1972); Vacuum pyrolysis/MS
(4) Kaplan et al. (1976); Pyrolysis/hydrolysis
(5) Korotev (1984 unpublished); INAA

TABLE 15498-2

		,52 CLAST	GLASS FISSURE
Wt %	SiO2	47.1	47.4
	TiO2	1.97	1.9
	Al2O3	9.8	12.8
	FeO	19.19	16.8
	MgO	9.1	10.5
	CaO	10.1	9.8
	Na2O	0.255	0.41
	K2O	0.041	0.11
	P2O5	0.087	
(ppm)	Sc	45.9	
	V	182	
	Cr	4020	
	Mn	2070	
	Co	44.9	
	Ni	90	
	Rb	0.80	
	Sr	75.83	
	Y	35	
	Zr	94	
	Nb	10	
	Hf	2.49	
	Ba	60	
	Th	1.08	
	U	0.18	
	Pb		
	La	5.93	
	Ce	18.0	
	Pr	2.40	
	Nd	12	
	Sm	3.58	
	Eu	0.76	
	Gd	4.91	
	Tb	0.79	
	Dy	5.35	
	Ho	1.09	
	Er	3.19	
	Tm		
	Yb	2.62	
	Lu	0.37	
	Li	7.7	
	Be	1.12	
	B		
	C		
	N		
	S	670	
	F	31	
	Cl	4.2	
	Br	0.034	
	Cu	7.73	
	Zn	15	
(ppb)	I		
	At		
	Ga	3000	
	Ge	<250	
	As	1.5	
	Se	~30	
	Mo		
	Tc		
	Ru		
	Rh		
	Pd		
	Ag		
	Cd		
	In		
	Sn		
	Sb		
	Te		
	Cs	40	
	Ta	390	
	W	96	
	Re		
	Os		
	Ir		
	Pt		
	Au	0.13	
	Hg		
	Tl		
	Bi		
		(1)	(2)

References and methods:

(1) Wanke *et al.* (1977); Combined XRF, INAA, etc.
(2) Mason (1972); Microprobe

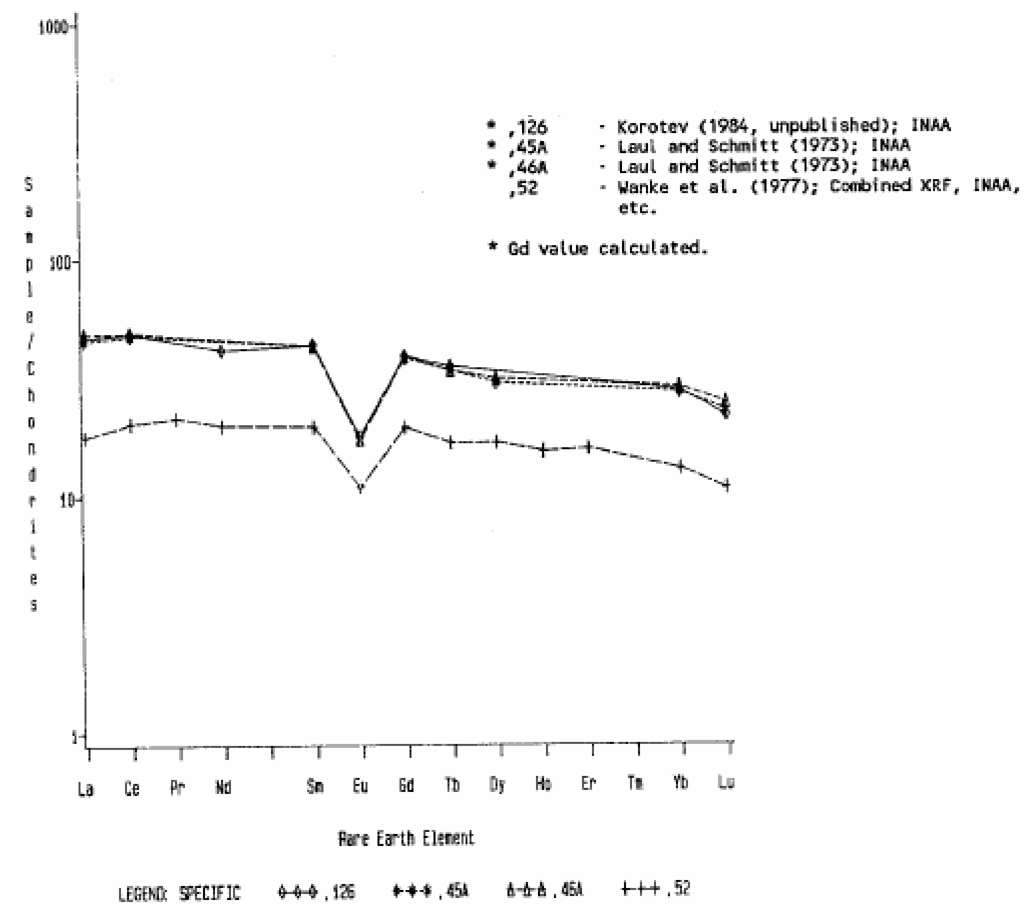

Figure 5. Rare-earths in materials from 15498.

RARE GASES AND EXPOSURE: Bogard and Nyquist (1972) and PET (1972) tabulated noble gas contents and isotopic abundances. Kaplan et al. (1976) reported He abundances, which are lower than soils. Megrue (1972, 1973) reported noble gas isotopic abundance for four splits (laser probe, mass spectrometry methods). The essential gas component is a highly fractionated solar wind, with cosmogenic gases primarily within a light-colored lithic fragment and the fine-grained matrix in one sample. Glass from sample ,55 requires a source separate from the others. The data suggest that 15498 is a consolidated lunar soil.

The data of Eldridge et al. (1972) suggest that ^{26}Al is saturated, thus 15498 has been exposed at least 2 m.y.

PHYSICAL PROPERTIES: Gose et al. (1972, 1973a) and Pearce et al. (1973) found a paleomagnetic intensity of 2100 ± 85 gammas using the Thellier-Thellier method, one of the few intensities considered at all reliable (however, Collinson et al. (1975) stated that this intensity is uncertain because of the way the slope of the data is constrained on a plot of NRM lost vs. pTRM gained, and they suggested a revised intensity of at least 7,000 gammas). Gose et al. (1972) also tabulated basic magnetic data derived from hysteresis loops. They found 0.34% metallic iron, like soils, which is not meteoritic but from subsolidus reduction of Fe^{2+}. 15498 is very unusual under demagnetization in having an extremely stable intensity which does not change in direction (Fig. 6). At the same time it shows a strong viscous remanent magnetization acquisition (see also Gose et al., 1973b), with a classical Richter-type effect similar to Apollo 14 low-grade breccias and typical of rocks containing metal grains of a few hundred angstroms size. The high stability is undoubtedly due to the presence of single domain grains.

Pearce et al. (1976) reported magnetic data from heating and thermal demagnetization of ,36 and found no reason to doubt their previous 2100 gammas paleointensity determination. Hale et al. (1978) studied a small clast, too small to permit analysis of hysteresis characteristics, using microwave heating (in an attempt to determine its usefulness) and conventional heating techniques; they depicted demagnetization curves for NRM, ARM, and IRMs. The paleointensity determined following microwave heating was 27000 gammas, significantly higher than that of Gose et al. (1972, 1973a).

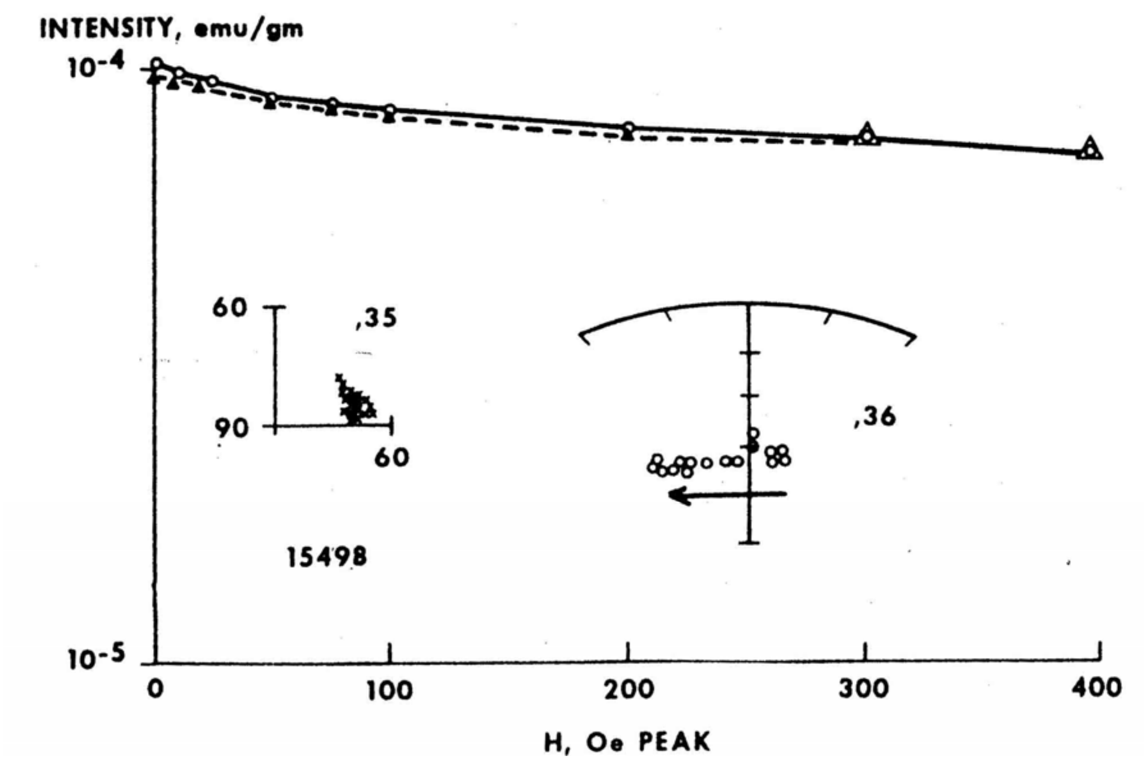

Figure 6. Change in intensity and direction upon
AF demagnetization of 15498,35 and ,36 (Pearce et al., 1973).

Fig. 7a

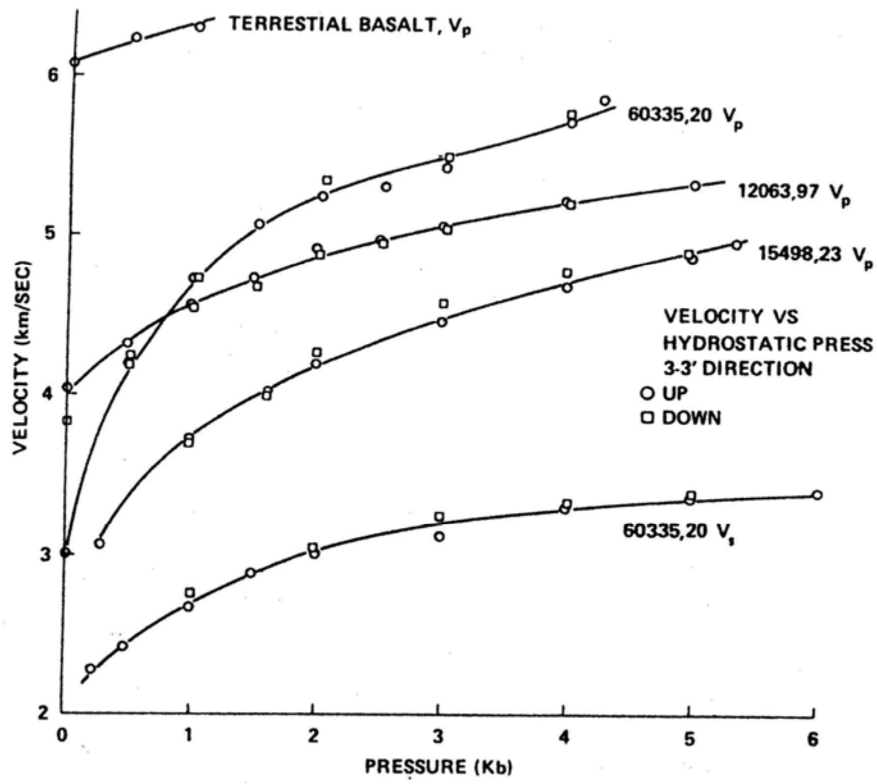

Fig. 7b

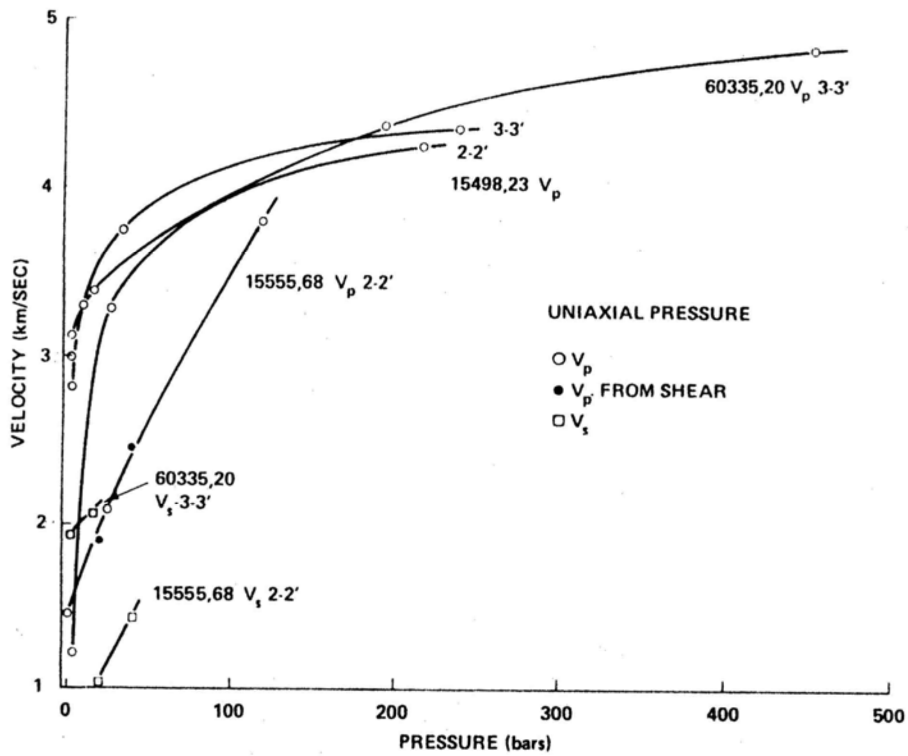

Figure 7. Velocity profile for 15498
(a) hydrostatic pressure
(b) uniaxial loading (Warren et al., 1973).

Brecher (1975, 1976) listed 15498 as an example showing magnetic "textural remanence" on account of its stable direction of NRM under AF-demagnetization. Housley et al. (1976) presented ferromagnetic resonance (FMR) spectra for 15498, listing the response as strong, and similar to lunar fines.

Warren et al. (1973) depicted the variation of Vp with pressure, both hydrostatic and under uniaxial loading (Fig. 7). They also plotted strain vs. pressure (Fig. 8); at high pressure strains become homogeneous and independent of orientation. Trice et al. (1974) depicted linear strain measurements made up to 5 Kb hydrostatic pressure (Fig. 9).

Alvarez (1975) used 15498 to study the effect of solar radiation on electrical properties (which are normally measured in the dark). His photoconductivity studies showed a 5-fold increase in surface conductivity when the sample was illuminated for 22 minutes with infrared and ultraviolet sources, since this was far from reaching equilibrium, real values are probably more than 5-fold increases.

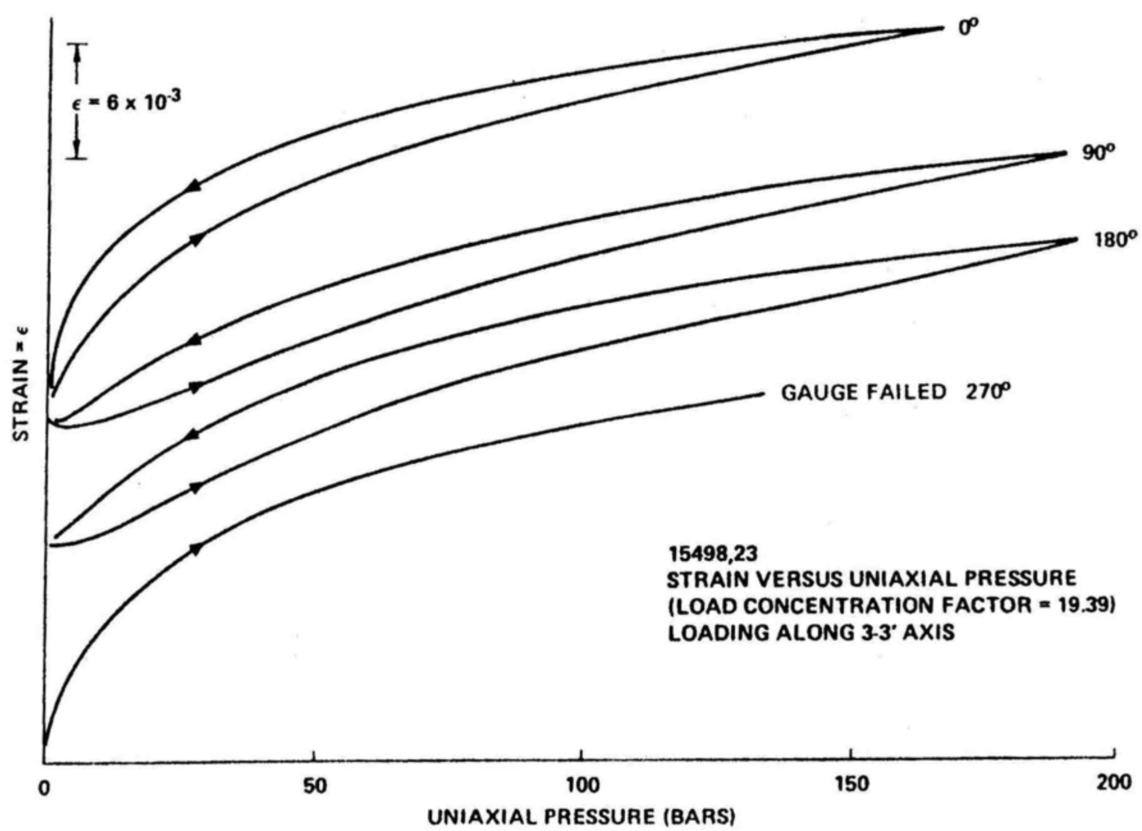

Figure 8. Strain results under axial loading for 15498,23
(Warren et al., 1973).

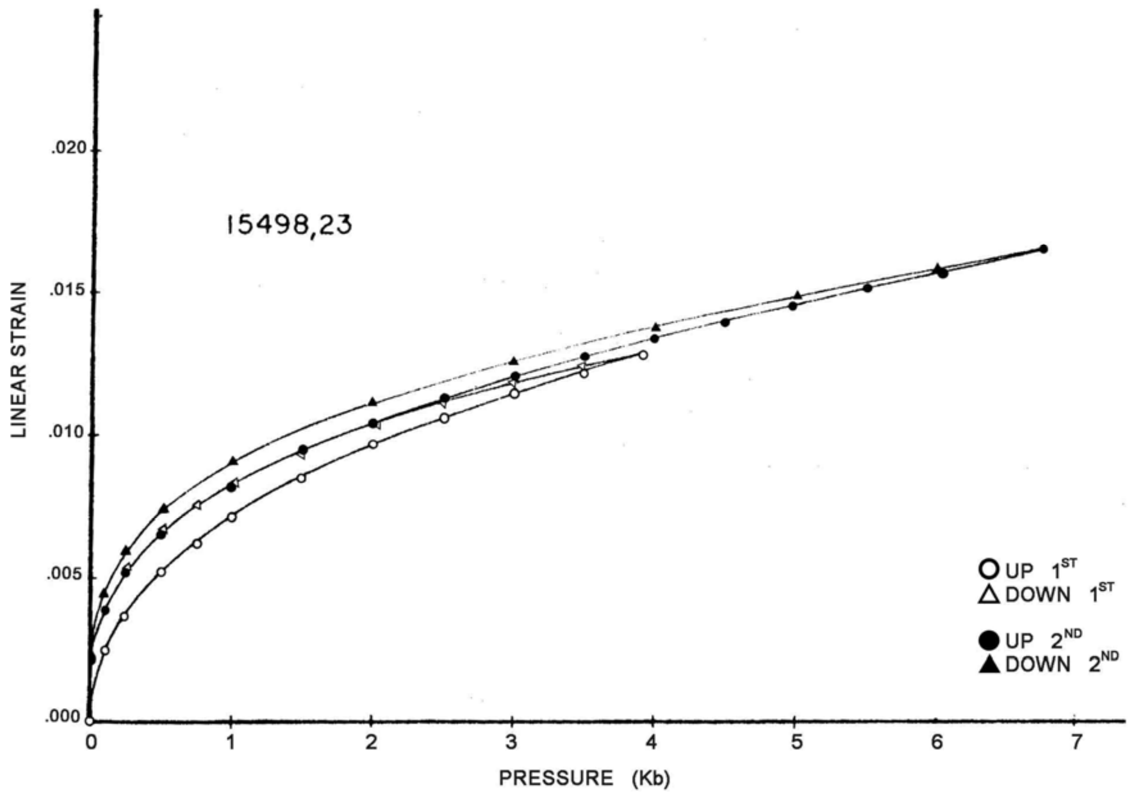

Figure 9. Linear strain vs. pressure for 15498,23
(Trice et al., 1974) .

PROCESSING AND SUBDIVISIONS: A slab ,17 was cut through the sample, leaving ,0 (1708 g) as one end and several pieces as the other (Fig. 10). Pieces ,0, ,14 (62 g) and ,16 (213 g) remain almost intact, the latter in remote storage. The slab was substantially divided (Fig. 10), and ,20 (38 g) is in remote storage. All the thin sections (,5; ,6; ,8; ,9; ,99; ,100; and ,101) were made from a single small piece ,3 chipped off prior to sawing, with the exception of several grain mounts made from pieces of the slab.

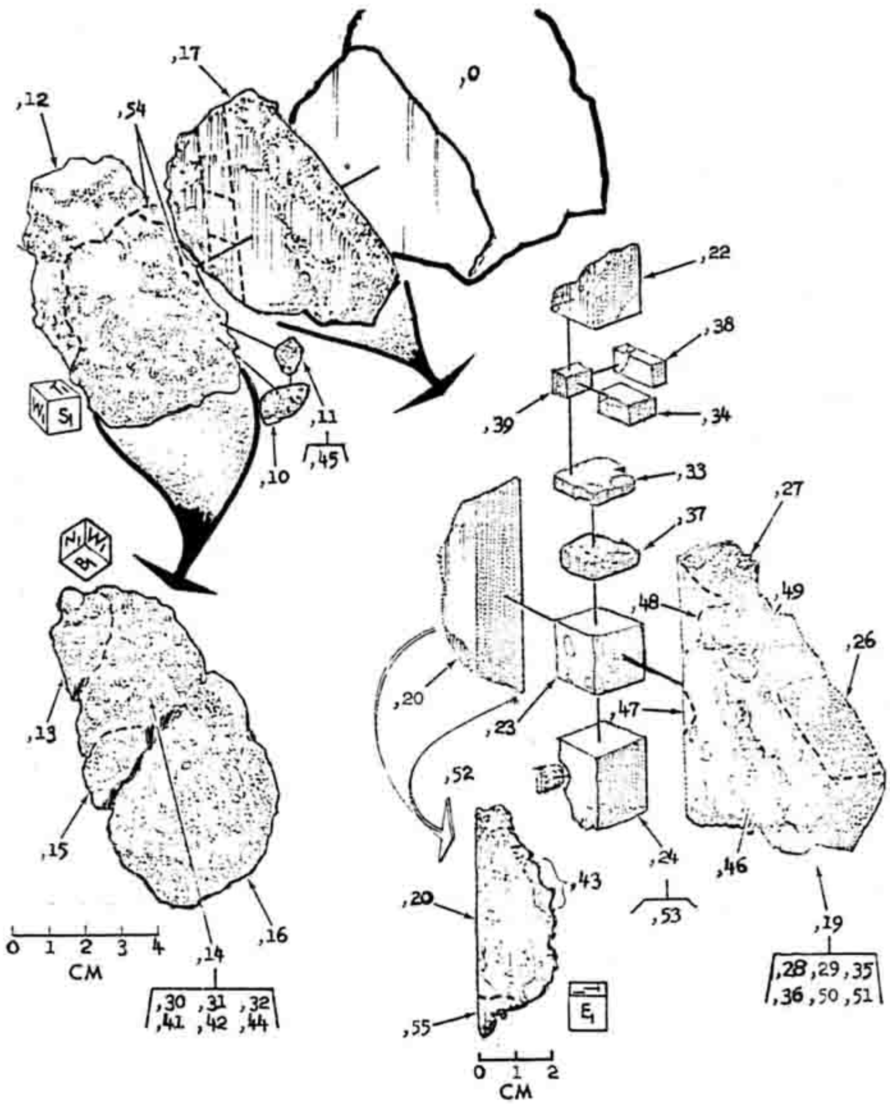

Figure 10. Cutting diagram for 15498,
showing splits following saw-cutting and slab dissection.