15445

Breccia with Shocked Norite and Spinel Troctolite Clasts

287.2 grams

" - the science input now is that we want to forget that large block entirely"

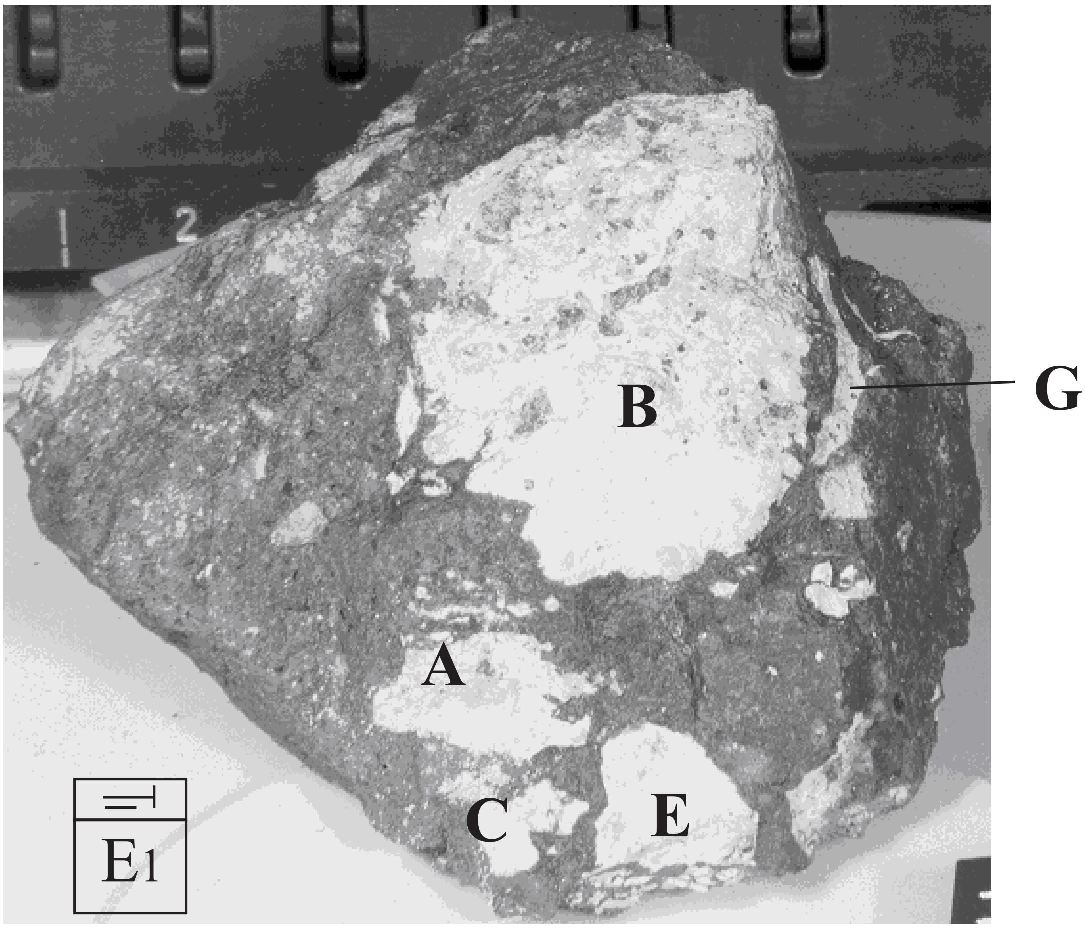


Figure 1: Photo of 15445 showing large white norite clast (B), spinel troctolite clast (A) and other clasts. Sample is 6 cm across. NASA S71-15937. Clasts labled according to Ryder 1985.

Introduction

Lunar sample 15445 is a recrystallized impact melt breccia containing several (~10) individual white clasts, the largest being a shocked norite (clast B) dated at ~ 4.28 - 4.46 b.y . Other white clasts in 15445 contain blood-red spinel and have very high (mafic) Mg/Fe ratios (clast A, G etc.). 15445 is found to be an assemblage of magnesian plutonic and metamorphic lithic clasts of deep-seated origin, embedded in a matrix of mineral fragments bonded by a melt phase. Clasts of surficial origin are absent. The melt phase has recrystallized as a fine-grained matrix of plagioclase, olivine and opaques.

15445 was found lying on the surface near a 1.5 x 0.6 m boulder with white clasts (figure 24) and is believed to have been broken off the boulder (Bailey and Ulrich 1975). This sample and its close companion (15455) are thought to be ejecta from the Imbrium Basin. Their exposure ages (~200 m.y.) may help date the age of Spur Crater where they were found.

Initially, Paul Gast and later, John Wood, acted as consortium chiefs for 15445 and there is careful documentation of 15445 by Ursula Marvin in the Imbrium Consortium booklet (vol. 1), by Ryder and Norman (1979) in "Pristine Non-mare Materials" and

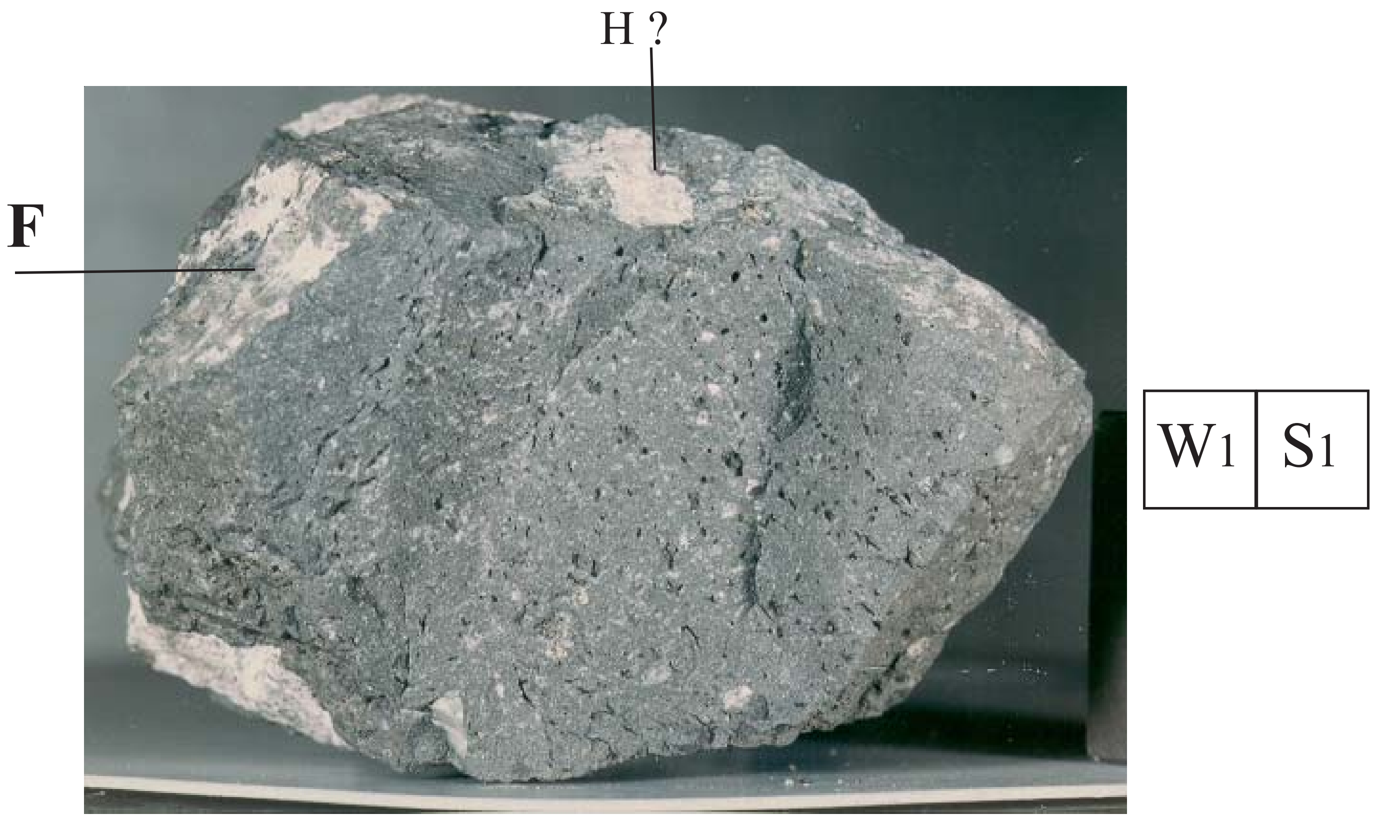


Figure 2: Photo of impact melt lithology of 15445 showing abundant vugs and vesicles on freshly broken side. Bottom clast not identified. NASA S72-15711. Sample is 6 cm across.

by Ryder (1985) in the Apollo 15 catalog. Part of clast B of 15445 was included in the "Norite Consortium" led by Larry Nyquist (Shih et al. 1993). The rock has been substantially broken up (Ryder 1985), but careful detective work will lead to residual fragments that can be studied further.

Petrography

Anderson (1973) and Ridley et al. (1973) initially described the mineralogy and chemical composition of the mafic clasts found in15445. Herzberg and Baker (1980) went on to calculate their depth of origin in the lunar crust from their mineral composition.

The largest clast in 15445 (clast B) is a cataclastic norite (figure 1) described below. Shih et al. (1993) were able to date the 15445 norite clast, but they obtained two different old ages (4.28 and 4.46 b.y.). Their interpretation is that the large norite clast may be composed of more than one old plutonic rocks, with distinctly different ages and initial isotope ratios.

Ryder and Bower (1977) studied the matrix of 15445 finding that it is "an aggregate of mineral clasts and minerals that crystallized at least partly from a silicate melt, as demonstrated in particular by the presence of euhedral, skeletal olivines" up to 100 microns in length. About 70% of the matrix is a fine-grained mass of interlocking anhedra of olivine and plagioclase (5-20 microns) with intergranular needles of ilmenite (figure 3). Metallic iron and Mg-Al spinel are minor, but ubiquitous, phases in the matrix and pyroxene is rare. In places there is as much as 10 % void space as vugs and vesicles (figures 2, 3 and 18). Ryder and Bower (1977) note the high meteoritic siderophile element content, similar to that of 15455, and typical of highland breccias. Thus they conclude that sample 15445 is a "fragment-laden impact melt". Ryder and Wood (1977) interpret these two breccias to be Imbrium ejecta.

McGee et al. (1979) reported that there were *"interfingering zones of matrix material and lithic clasts giving the sample an overall foliated appearance, the result of differences in mineralogical and chemical composition and porosity."* However, Engelhardt (1979) describes the 15445 matrix as granular, in a group "without any signs of a sequential order of crystallization" whose members are "granoblastic products of solid state recrystallization", i.e., metamorphic. But the individual mineral fragments within the matrix have only thin margins where they have interacted with the melt. Using the composition of the centers of the minerals, Spudis et al. (1991) found that most of the mineral fragments in the matrix were

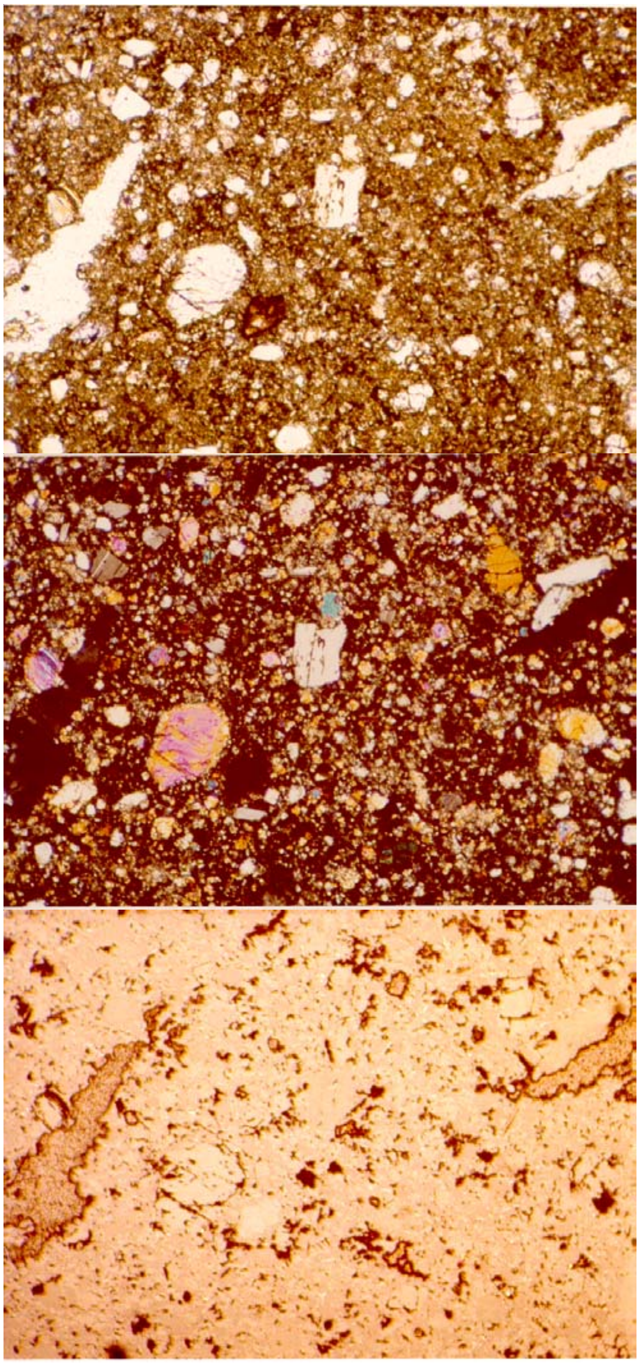


Figure 3: Photomicrographs of thin section 15445,66 showing matrix with mineral fragments and elongate vugs. Scale 1.3 mm across. NASA S79-27446-27448. Top to bottom = plane polarized, cross polarized and relfected light.

derived from troctolites. Mineral fragments from norites, or ferroan anorthosite appear to be mysteriously absent.

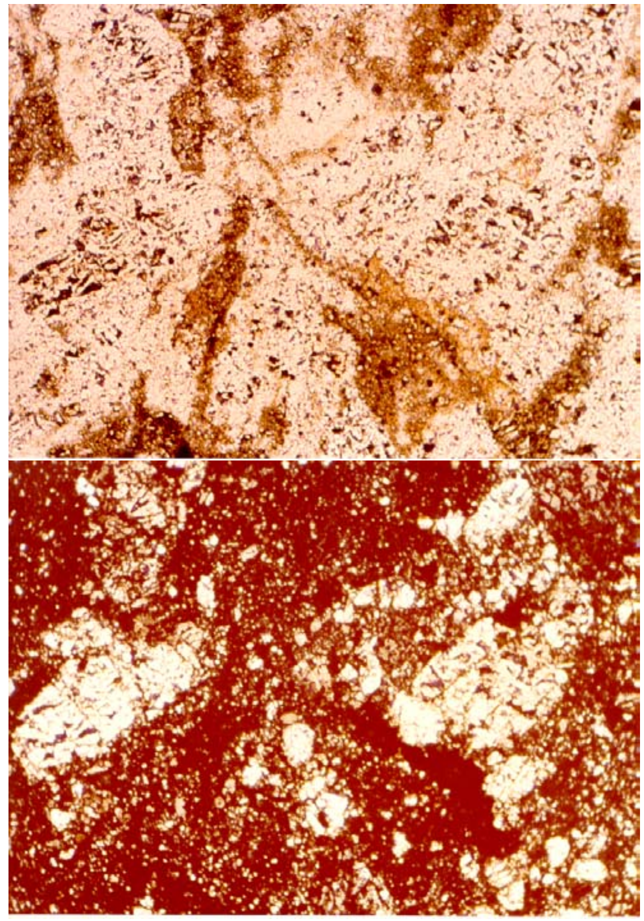


Figure 4: Thin section photomicrographs of heavily shocked norite clast B in 15445,64. Scale is 1.3 mm. NASA S79-27753 and 54. Top is plane polarized light and bottom is cross polarized showing abundant isotropic phase with relic igneous rock fragments.

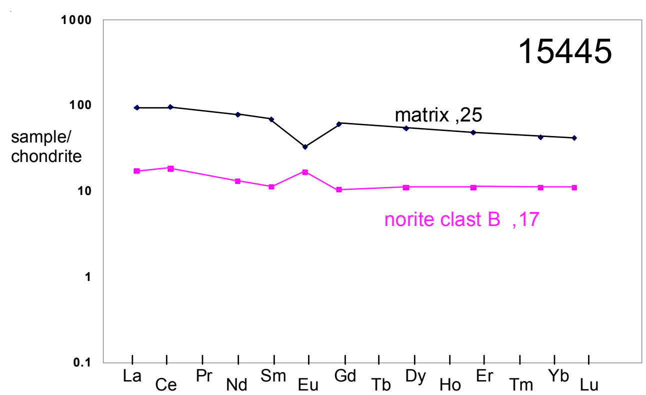


Figure 5: Normalized rare-earth-element diagram for matrix and large norite clast B in 15445 (precise isotope dilution mass spec. data from Wiesmann and Hubbard 1975).

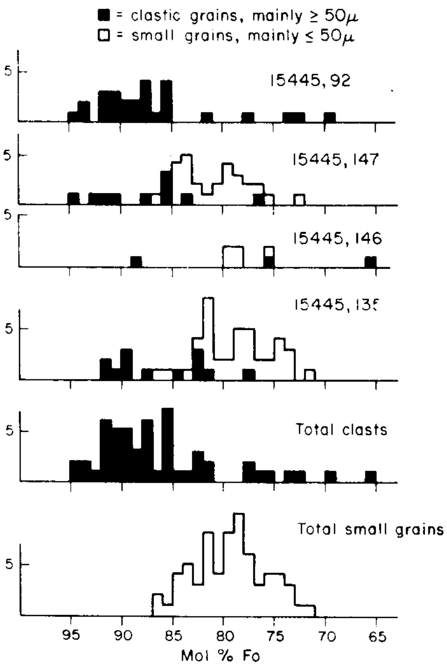


Figure 6: Composition of olivine in clasts and matrix of 15445 (from Ryder and Bower 1977).

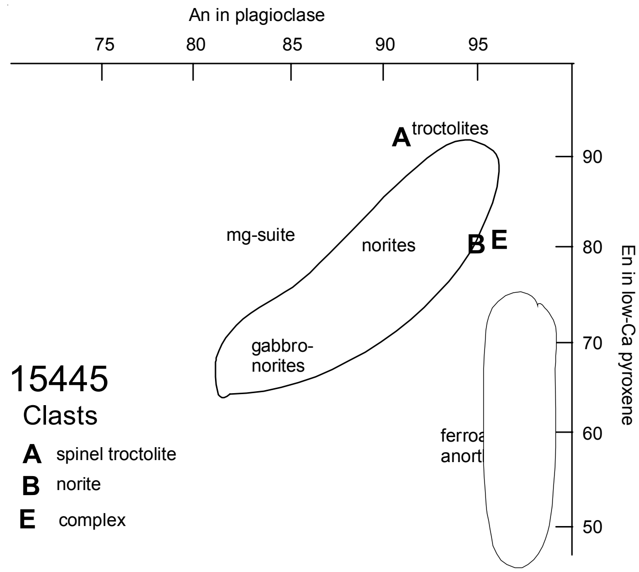


Figure 7: Chemical composition of plagioclase and pyroxene pairs in white clasts in 15445.

Mineralogy

Olivine: The olivine in the spinel troctolite clasts (A and G) has a very high Mg/Fe ratio (Fo_{95-80}). Likewise, some of the individual olivine mineral clasts in the breccia matrix are also very mafic (Fo_{95-65}) (figure 6). The small, euhedral olivine crystals in the breccia matrix are more Fe-rich and crystallized from the matrix. Steele and Smith (1975) found that trace elements (Ca, Ti, Cr, Ni and Al) in olivine from the spinel troctolite clast were extremely low, indicating that this clast formed in a plutonic environment with very slow cooling. Chromite is found as an inclusion in olivine.

Pyroxene: Orthopyroxene in the lithic clasts of 15445 is Mg-rich and augite has not been reported. Pyroxene is lacking as a mineral clast in the matrix, but fine-grained orthopyroxene is intergrown with plagioclase in the recrystallized melt (Ridley et al. 1973).

Plagioclase: Plagioclase is calcic in the clasts and in the matrix (Ryder 1985, Spudis et al. 1991).

Chromite: Ryder and Bower (1977) find that rare chromite has a high Mg/Fe ratio.

Mg,Al spinel: This rock contains rock clasts with blood-red pleonate spinel. Spinel is also found as mineral clasts in the breccia matrix. Table 5 gives the compositions reported.

Armalcolite: Armalcolite was reported in the ultramafic spinel troctolite clast studied by Anderson (1973).

Significant Clasts

Clast A - Spinel Troctolite: (Lith 45E)
Clast A is white with 5-8% red grains (Brett and Butler 1971). Material is very friable so that splits ,8 - ,11 consist of powder only. Split ,7 consists of the only large mineral grains obtained, some of which include matrix, and was made into a grain mount (,60 and ,92). Anderson (1973) studied split 15445,10, finding that it was "ultramafic." Ryder and Bower (1977) did not study clast A directly, but found similar material as small clasts in other thin sections.

Clast B - Norite: (Lith 45D)
Clast B is the largest clast in the rock and consists of white plagioclase with some green material (pyroxene). Splits ,38 and ,39 contain both black matrix and white clast material (figure 22). The pyroxene is orthopyroxene with high Mg/Fe ratio (figure 11) and plagioclase is very calcic (figure 2).

Shih et al. (1993) obtained two different Sm/Nd ages with different initial ratios for two different portions

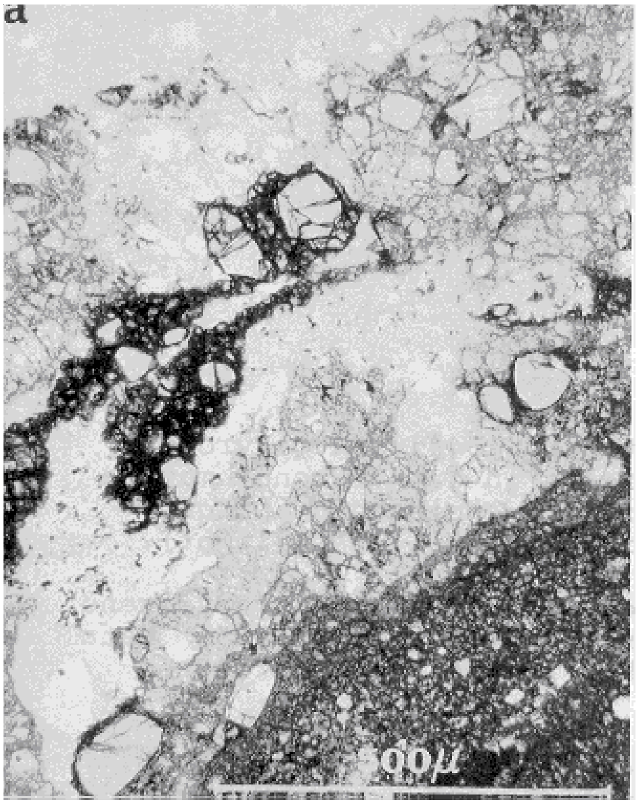


Figure 8: Photomicrograph of Clast A in thin section 15445,92. Spinel troctolite (Ryder and Bower 1977).

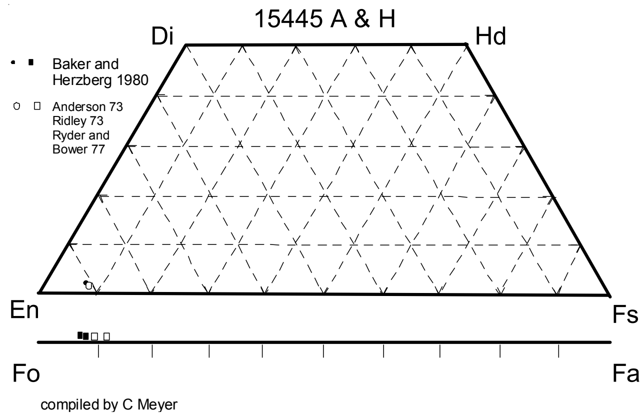


Figure 9: Pyroxene and olivine composition of blood-red spinel troctolite clasts in 15445.

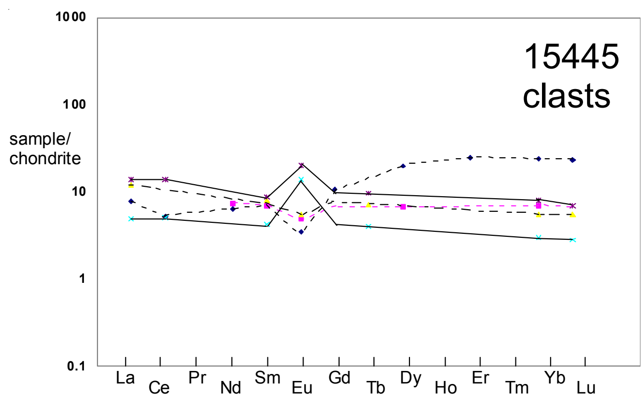


Figure 10: Normalized rare-earth-element diagram for various clasts in 15445. The dashed lines are for data from the blood-red spinel troctolite clasts A and G, while the two solid lines are for the same clast E. Data from table 2.

of this large white clast (see below). They concluded "clast B" is "heterogeneous" and made up of more than one lithology. This has not been studied mineralogically. However, chemical analyses of clast B seem to be similar for different splits (table 2).

Clast E - Noritic Anorthosite: ,175

Warren and Wasson (1978) reanalyzed clast E after Blanchard et al. (unpublished) reported it as an "anorthosite" and found higher trace element content (table 2 and figure 10). This could be due to admixed breccia matrix or the clast could be heterogenous. Ryder and Bower (1977) found that the thin sections (,139 and ,221) purportedly of this clast were quite different. The mafic composition of pyroxene in this clast place it in the field of troctolites (figure 7), rather than anorthosite (although it has abundant plagioclase).

Clast G - Spinel Troctolite:

Figures 20 a, b are close-up photos of the beautiful blood-red spinel in the otherwise white clast G. Analysis by Blanchard (unpublished) and Gros et al.

Mineralogical Mode for 15445 clast H

	Baker and Herzberg 1980
Olivine	44 %
Pyroxene	2-3
Plagioclase	15
Pleonaste	6-7
Matrix	32

Mineralogical Mode for 15445 clast A

	Ridley et al. 1973	Anderson 1973	Ryder and Bower 1977	Steele and Smith 1975
Olivine	present	>40 %	~50	present
Pyroxene	present	<40	none	
Plagioclase	minor	5	30-40	
Pleonaste	present	15	10-20	

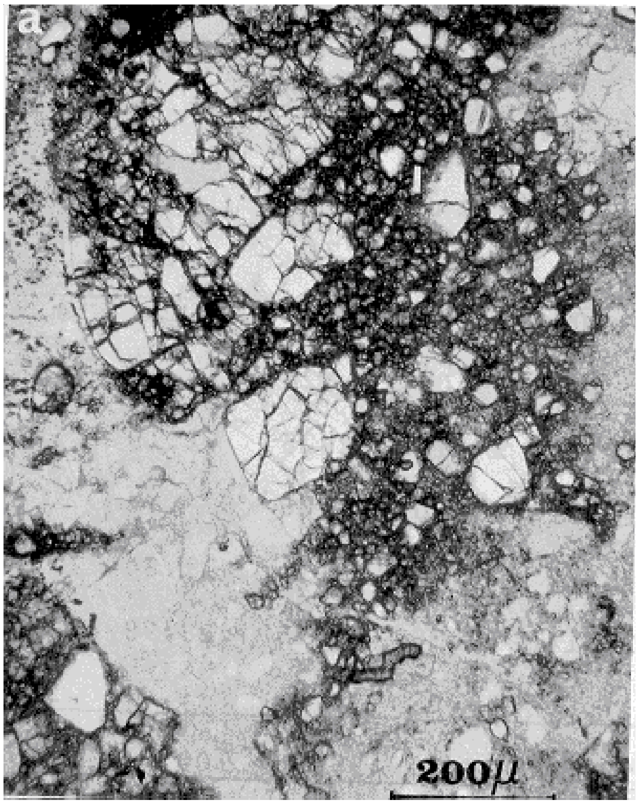


Figure 11: Thin section of norite clast B in 15445,134 (from Ryder and Bower 1977). Note the cataclastic texture.

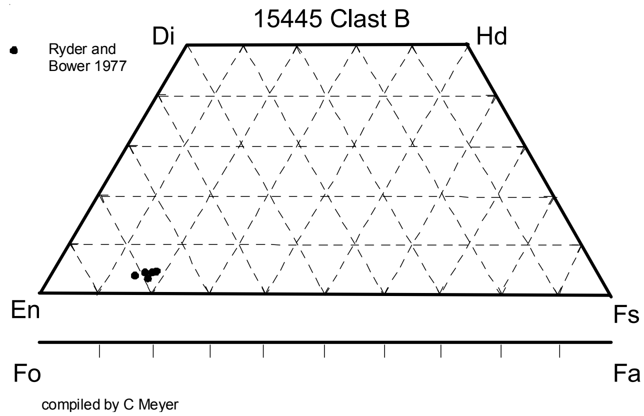


Figure 12: Pyroxene data for norite clast B (data replotted from Ryder and Bower 1977). There was no augite nor olivine reported in clast B.

(1976) of this clast are tabulated in table 2 and figure 10. Mineral compositions haven't been determined.

Clast H – Spinel Troctolite:
Baker and Herzberg (1980) studied thin section 15445,177 of clast H. They found the clast exhibits evidence of extensive shock metamorphism, but were able to obtain mineral compositions: plagioclase An_{95-97}, olivine Fo_{91-93}, orthopyroxene $Wo_1En_{91}Fs_8$ and spinel with Mg/Mg+Fe = 0.81-0.84 and Cr/Cr+Al = 0.07 – 0.11. Herzberg and Baker (1980) calculate a depth of origin of 12 to 32 kilometers for this mineral assemblage.

Clast X "Mystery": This centimeter-sized white clast is seen breaking free from the matrix in original photos of the undusted sample (figure 22). It is in the approximate position of clast D in some documentation. It was removed early (as ,2), because it was breaking free of matrix (as in a loose "tooth"). It has not been studied.

Mineralogical Mode for 15445 clast B

	Ryder and Bower 1977
Olivine	
Pyroxene	35-40
Plagioclase	60-65

Chemistry
Tables 1 and 3 and figure 5 give the chemical composition of the matrix (analyses are in general agreement). The matrix is found to be similar to that of 15455, and Gros et al. (1976) conclude the matrix is the product of the Imbrium impact. Note that the matrix for 15445 and 15455 have characteristically high Mg/Fe ratios, compared to that of other melt rocks.

Table 2 summarizes the chemical composition of the clasts that have been studied to date. Ridley et al. (1973) reported a strange REE pattern for the spinel troctolite clast A that has not been verified (figure 10). The data for the norite clast B are consistent (figure 12) and similar to that of other lunar norites. Data for clast E are so different that one might assume that a sample was misnumbered.

Radiogenic age dating
Bernstein (1983) were unable to obtain a flat plateau in stepwise Ar/Ar dating, but quote an age for the matrix of ~3.76 b.y. Shih et al. (1993) were able to date two different portions of the large norite clast, but they found two distinctly different ages 4.28 and 4.46 b.y. with two different initial Nd isotope ratios (figures 14 and 16), leading them to conclude that "clast B is heterogeneous and contains at least two similar lithologies" (but with different ages). Dating by Rb/Sr proved impossible due to Rb mobilization (figures 13 and 15).

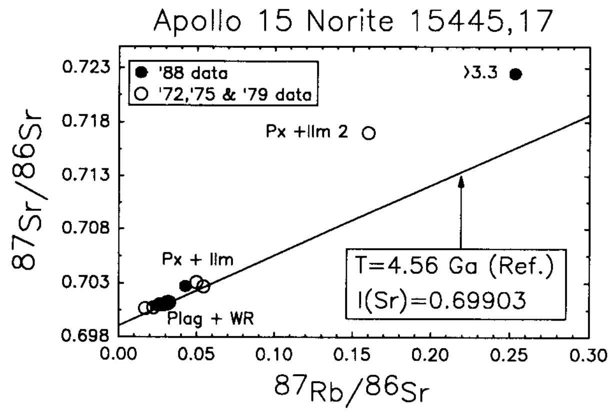


Figure 13: Rb/Sr internal mineral isochron for norite clast (B,17) in 15445 (from Shih et al. 1993). This diagram includes data from earlier analyses.

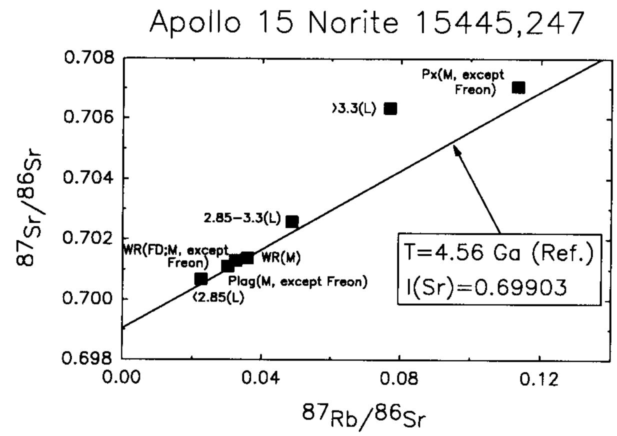


Figure 15: Rb/Sr internal mineral isochron for large norite clast (B,154) in 15445 (from Shih et al. 1993).

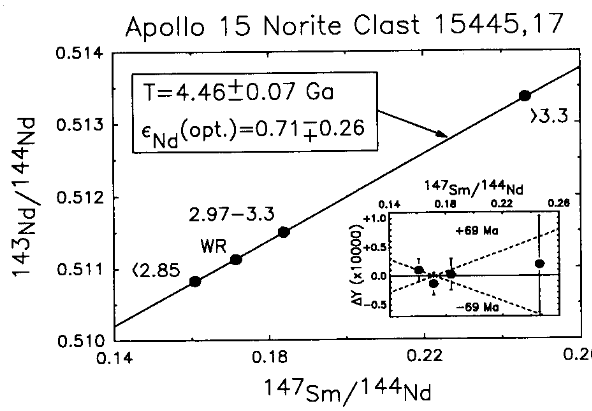


Figure 14: Sm/Nd internal mineral isochron for norite clast (B,17) in 15445 (from Shih et al. 1993).

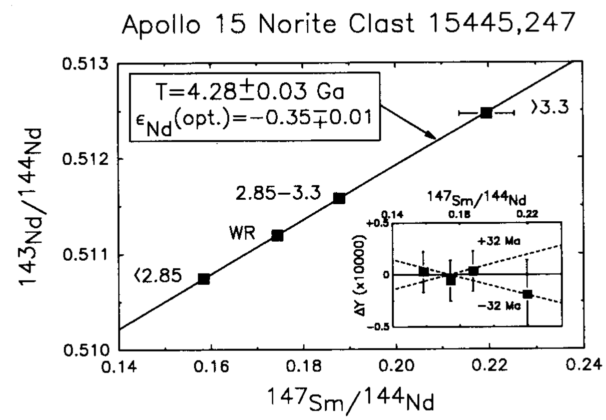


Figure 16: Sm/Nd internal mineral isochron for large norite clast (B,154) in 15445 (from Shih et al. 1993).

Unruh and Tatsumoto (1976) (in Imbrium Consortium) reported U, Th and Pb analysis without obtaining age information (i.e. *Pb has been volatilized, mobilized and contaminated*).

Cosmogenic isotopes and exposure ages

Keith et al. (1973) determined the cosmic-ray-induced activity of ^{22}Na = 45 dpm/kg., ^{26}Al = 81 dpm/kg. and ^{46}Sc = 0.8 dpm/kg. Bernstein (1983) apparently determined a ^{38}Ar exposure age of 220 m.y. Drozd et al. (1977) determined ^{21}Ne and ^{81}Kr exposure ages of 118 m.y. and 157 ± 22 m.y. The spread in exposure ages of samples collected at Spur Crater may indicate that it "excavated a complex set of partially pre-irradiated material" (Arvidson et al. 1975).

Other Studies

Clayton et al. 1973	oxygen isotopes
MacDougall et al. 1973	electron microscopy

Summary of Age Data for 15445

	Ar/Ar	Rb/Sr	Nd/Sm	
Bernstein (1983)	3.76 ± 0.09 (?)			matrix
Shih et al. 1993			4.46 ± 0.07	norite B
			4.28 ± 0.03	norite B

Caution: Be careful with decay constants.

Table 1. Chemical composition of 15445 (matrix and whole).

			unpub.					Ridley73								
reference	Keith 73		*Blanchard*	Lindstrom 88				Wiesmann75		Gros 76		Ryder & Bower 77				
weight			*45A*	,244	,245	,246		,25		,123		,92	,147		,147	
SiO2 %								44.6				45.7	45.3	(e)	44.6	(f)
TiO2				1.24		1.62	(d)	1.48	(a)			1.56	1.7	(e)	1.47	(f)
Al2O3				20.6		17.1	(d)	16.2				17.3	17.5	(e)	16.66	(f)
FeO			10	7.98	8.28	9.17	(d)	10.2				7.9	9.5	(e)	9.83	(f)
MnO												0.11	0.16	(e)	0.14	(f)
MgO				12.9		16	(d)	15.5				13.4	15.7	(e)	16	(f)
CaO				11.4	11.3	9.8	(d)	9.6				11.5	9.7	(e)	10.04	(f)
Na2O			0.54	0.551	0.55	0.523	(d)	0.55				0.62	0.81	(e)		
K2O	0.128	(c)			0.15		(d)	0.16	(a)			0.22	0.18	(e)		
P2O5												0.18	0.27	(e)	0.21	(f)
S %															0.06	(f)
sum																
Sc ppm			17.6	13.4	14.9	16.9	(d)									
V																
Cr			190	1380	1500	1940	(d)	1750								
Co			47.4	35	29	30.5	(d)									
Ni			550	320	270	270	(d)			396	(b)					
Cu																
Zn										2.5	(b)					
Ga																
Ge ppb										630	(b)					
As																
Se										91	(b)					
Rb				<9	6	5	(d)	3.56	(a)	4.02	(b)					
Sr				190	160	170	(d)	160	(a)							
Y																
Zr				190	250	270	(d)	315	(a)							
Nb																
Mo																
Ru																
Rh																
Pd ppb										17.4	(b)					
Ag ppb										2	(b)					
Cd ppb										5.3	(b)					
In ppb										0.32	(b)					
Sn ppb																
Sb ppb										2.44	(b)					
Te ppb										4.7	(b)					
Cs ppm				0.27	0.18	0.21	(d)			0.18	(b)					
Ba				200	200	230	(d)	237	(a)							
La			20.4	16.5	19.4	20.7	(d)	22.1	(a)							
Ce			54	43	50	51.9	(d)	57.6	(a)							
Pr																
Nd				25	32	34	(d)	35.7	(a)							
Sm			10.3	7.65	8.8	9.3	(d)	10.1	(a)							
Eu			1.64	1.63	1.72	1.72	(d)	1.85	(a)							
Gd								11.9	(a)							
Tb			2.4	1.64	1.86	1.97	(d)									
Dy								13.2	(a)							
Ho																
Er								7.71	(a)							
Tm																
Yb			7.2	5.03	5.59	6.01	(d)	6.9	(a)							
Lu			0.98	0.74	0.84	0.88	(d)	1.02	(a)							
Hf			7.4	5.72	6.64	7.7	(d)	10.5	(a)							
Ta			1.1	0.85	0.94	0.96	(d)									
W ppb																
Re ppb										0.67	(b)					
Os ppb										7.44	(b)					
Ir ppb				3.7	2.5	2.6	(d)			6.21	(b)					
Pt ppb				<2	2.1	2.5	(d)									
Au ppb										6.02	(b)					
Th ppm	2.4	(c)	2.4	2.85	3.26	3	(d)									
U ppm	0.63	(c)		0.6	0.68	0.65	(d)	0.8	(a)	0.79	(b)					

technique: (a) IDMS, (b) RNAA, (c) radiation counting, (d) INAA, (e) broad beam e. probe, (f) XRF?

Table 2. Chemical composition of 15445 (clasts).

clast	A	A		B		B	Ridley73		B		E		E		F (G?)		F (G)	
reference	Wiesmann75			Blanchard		Hubbard 74			Gros76		Blanchard		Warren 78		Blanchard		Gros 76	
weight	,9	,71		,104		,17	,17		,107		,113		,175		,103		,102	
SiO2 %				45D							45B		45.6	(c)	45C			
TiO2	0.15	0.6	(a)	0.27		0.14	0.14	(a)			0.01		0.07	(c)	0.25			
Al2O3		7.2		23		20.8					33		30.4	(c)	14.7			
FeO				3.9		3.8					0.53		2.3	(c)	6.4			
MnO													0.04	(c)				
MgO	36.6	31.1		10.2		9.7					1.56		4.7	(c)	33			
CaO	4.76	1.9		12.8		12.6					17.3		16.4	(c)	4.8			
Na2O		0.09		0.32		0.32	0.32				0.31		0.36	(c)	0.14			
K2O	0.015	0.02	(a)	0.066		0.07	0.07	(a)			0.045				0.022			
P2O5																		
S %																		
sum																		
Sc ppm				7.1	(d)						1.9	(d)	4.3	(d)	3.43	(d)		
V																		
Cr				1710	(d)	1560		(a)			228	(d)	890	(d)	6900	(d)		
Co				10.3	(d)						2.64	(d)	10.1	(d)	50.4	(d)		
Ni					(d)				11	(b)	70	(d)	<90	(d)	820	(d)	*901*	(b)
Cu																		
Zn									1.5	(b)			0.81	(d)			13.4	(b)
Ga													4.8	(d)				
Ge ppb									5.1	(b)			3.82	(d)			338	(b)
As																		
Se									4.6	(b)							1.3	(b)
Rb	0.8	0.537	(a)			1.43	1.426	(a)	1.14	(b)							0.66	(b)
Sr	42.6		(a)			130	130	(a)										
Y																		
Zr	35.5					115												
Nb																		
Mo																		
Ru																		
Rh																		
Pd ppb									1.2	(b)							1.2	(b)
Ag ppb									0.52	(b)							1.77	(b)
Cd ppb									2.8	(b)			<9	(d)			2	(b)
In ppb									0.34	(b)			<150	(d)			*10.9*	(b)
Sn ppb																		
Sb ppb									0.42	(b)							18.9	(b)
Te ppb									0.7	(b)							2.7	(b)
Cs ppm									0.27	(b)							0.18	(b)
Ba	23.6	25	(a)			61.9	61.9	(a)										
La		1.84	(a)	4.02	(d)	4.02	4.02	(a)			1.15	(d)	3.3	(d)	2.86	(d)		
Ce		3.22	(a)	10.8	(d)	11.1	11.1	(a)			3.1	(d)	8.6	(d)		(d)		
Pr																		
Nd	3.35	2.89	(a)			5.91	5.91	(a)										
Sm	1.02	1.05	(a)	1.81	(d)	1.65	1.65	(a)			0.61	(d)	1.28	(d)	1.19	(d)		
Eu	0.275	0.196	(a)	0.87	(d)	0.929	0.929	(a)			0.77	(d)	1.14	(d)	0.31	(d)		
Gd		2.09	(a)			2.05	2.05	(a)										
Tb				0.46	(d)						0.15	(d)	0.35	(d)	0.26	(d)		
Dy	1.65	4.88	(a)			2.69	2.69	(a)										
Ho																		
Er		4.04	(a)			1.72	1.72	(a)										
Tm																		
Yb	1.12	3.89	(a)	1.72	(d)	1.78	1.78	(a)			0.49	(d)	1.3	(d)	0.9	(d)		
Lu		0.573	(a)	0.28	(d)	0.268	0.268	(a)			0.069	(d)	0.17	(d)	0.136	(d)		
Hf				1.36	(d)						0.6	(d)	1.2	(d)	0.74	(d)		
Ta				0.13	(d)						0.19	(d)	0.12	(d)		(d)		
W ppb																		
Re ppb									0.01	(b)			7E-04	(d)			0.174	(b)
Os ppb									0.02	(b)							0.32	(b)
Ir ppb									0.07	(b)			0.14	(d)			0.34	(b)
Pt ppb																		
Au ppb									0.02	(b)			0.035	(d)			0.32	(b)
Th ppm				0.82	(d)						0.94	(d)	0.68	(d)	0.27	(d)		
U ppm	0.15								0.14	(b)			0.18	(d)			0.024	(b)

technique: (a) IDMS, (b) RNAA, (c) fuzed bead, (d) INAA

Table 3. Chemical composition of 15445 (glass veins).

reference	Ryder and Bower 1977			
weight				
SiO_2 %	40.2	42.2	43.4	(a)
TiO_2	0.18	0.17	0.21	(a)
Al_2O_3	25.4	25.4	24.5	(a)
FeO	4.8	4.7	4.9	(a)
MnO	0.08	0.09	0.09	(a)
MgO	13.7	13.6	13.7	(a)
CaO	13.7	13.8	13.6	(a)
Na_2O	0.45	0.51	0.52	(a)
K_2O	0.07	0.07	0.07	(a)
P_2O_5	0.01	0.03	0.02	(a)

technique: (a) broad beam elec. Probe

Table 4	clast	U ppm	Th ppm	K ppm	Rb ppm	Sr ppm	Nd ppm	Sm ppm	
technique									
Shih et al. 1993	norite, 154				1.387	112.2	5.361	1.546	IDMS
	norite ,17				1.34	126.3	6.07	1.72	IDMS
					1.377	122.9			IDMS
					1.426	129.8			IDMS
	sp. Troct.				0.638	47.15	4.36	1.169	IDMS
	matrix ,25				3.56	160.3			IDMS
	,118				3.427	147.7	34.2	9.87	IDMS
Tatsumoto and Unruh 1972	norite ,106	0.16	0.893						IDMS
Jovanovic and Reed 77	matrix	0.56							color.
Gros et al. 77	matrix	0.788							RNAA
Keith et al. 1972	bulk	0.63	2.4	0.128					
counting									

Table 5: Composition of spinel (pleonaste) in 15445.

	Anderson73	Ridley 77	Ridley 73				Baker 80
TS#	,10	,9	,9	,9	,9	,9	,177
Cr_2O_3	14	13.4	13.4	13.23	13.72	11.84	7.89
FeO	9.3	9.52	9.52	9.54	9.59	9.24	7.74
MgO	20.4	20.1	20.1	20.25	20.26	20.71	22.34
Al_2O_3	57.3	56.97	56.97	57.41	57.32	59.03	61.86
TiO_2	0.03		0.01		0.02		0.05
MnO			0.06	0.06	0.06	0.06	0.11
CaO							0.04

Processing

For various reasons, the splitting and dissection of 15445 appears to have been complicated and confused. Perhaps this is because the rock was inherently fractured and some of the clasts were powdery, making exact splitting impossible (*" - - had a great fall"*). That some of the clasts were interesting, was apparent already in PET. A first round of chipping occurred in 1972 (splits up to ,44 figure 22), again in 1973 (,68 - ,100) and sawing of a slab in 1975 (there is careful documentation by Ursula Marvin in the Imbrium Consortium booklet (vol. 1). The curatorial data pack and the documentation by Ryder and Norman (1979) serve to guide any reconstruction. At one point an effort was made to identify and number specific lithologies (45A, B etc.), rather than individual clasts (A, B et.), but this only added to the confusion (see table 7). Several thin sections contain more than one clast, leading to further confusion (table 6). "*All the Kings men - - -".*

Note: The study of specific white clasts in 15445 has not been reported in an entirely consistent manner and there is some confusion in literature reports as to which clasts yielded the reported data (table 7). This summary follows that of Ryder 1985. It seems a great shame that the astronauts were not allowed(by the Science Team!)to sample the boulder(figure 24).

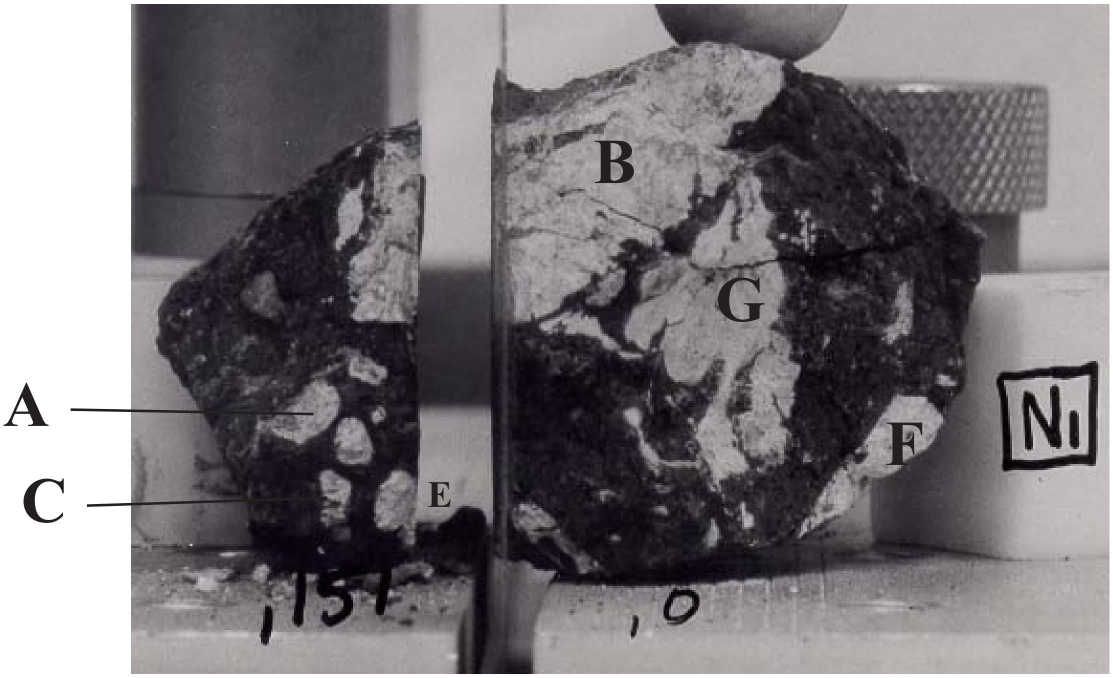


Figure 17: Position of first saw cut of 15445 in 1975. NASA S76-21629. Sample is 6 cm. across.

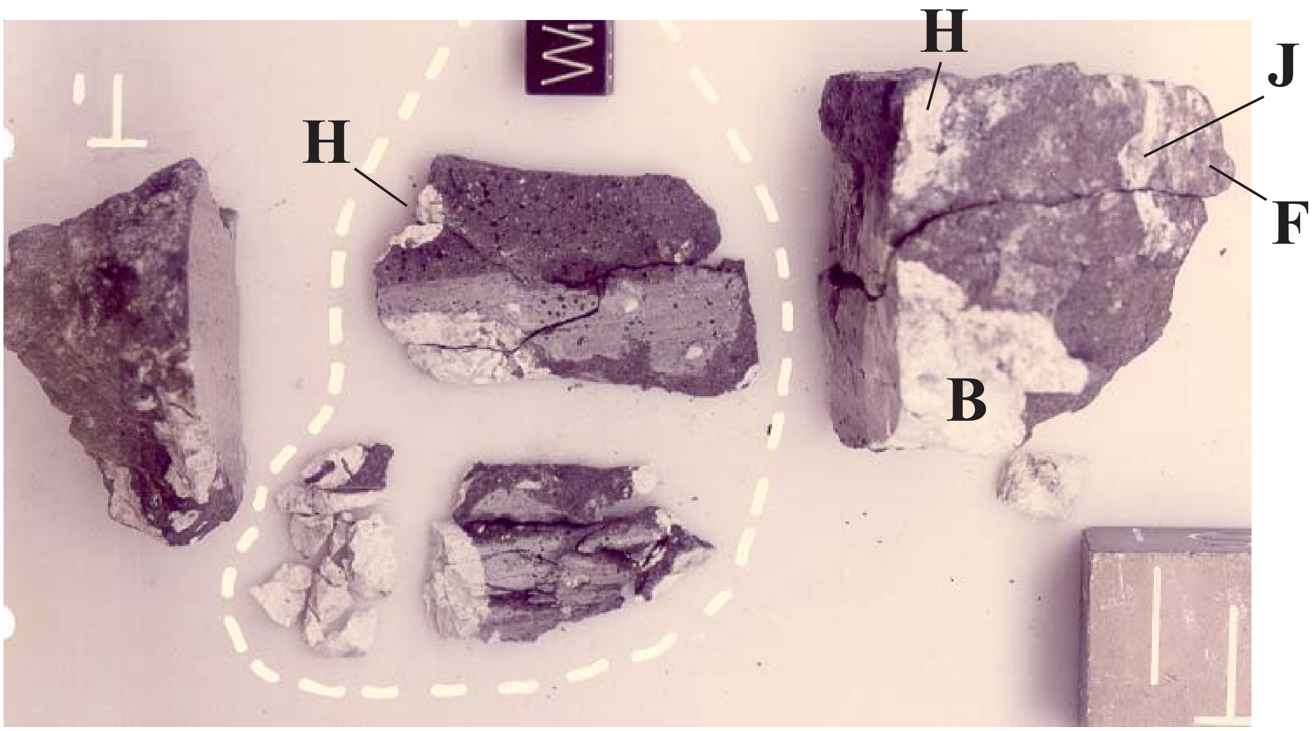


Figure 18: Exploded parts diagram of 15445 after slab was cut (circled pieces). NASA S75-33435. Small cube is 1 cm, large cube is 1 inch.

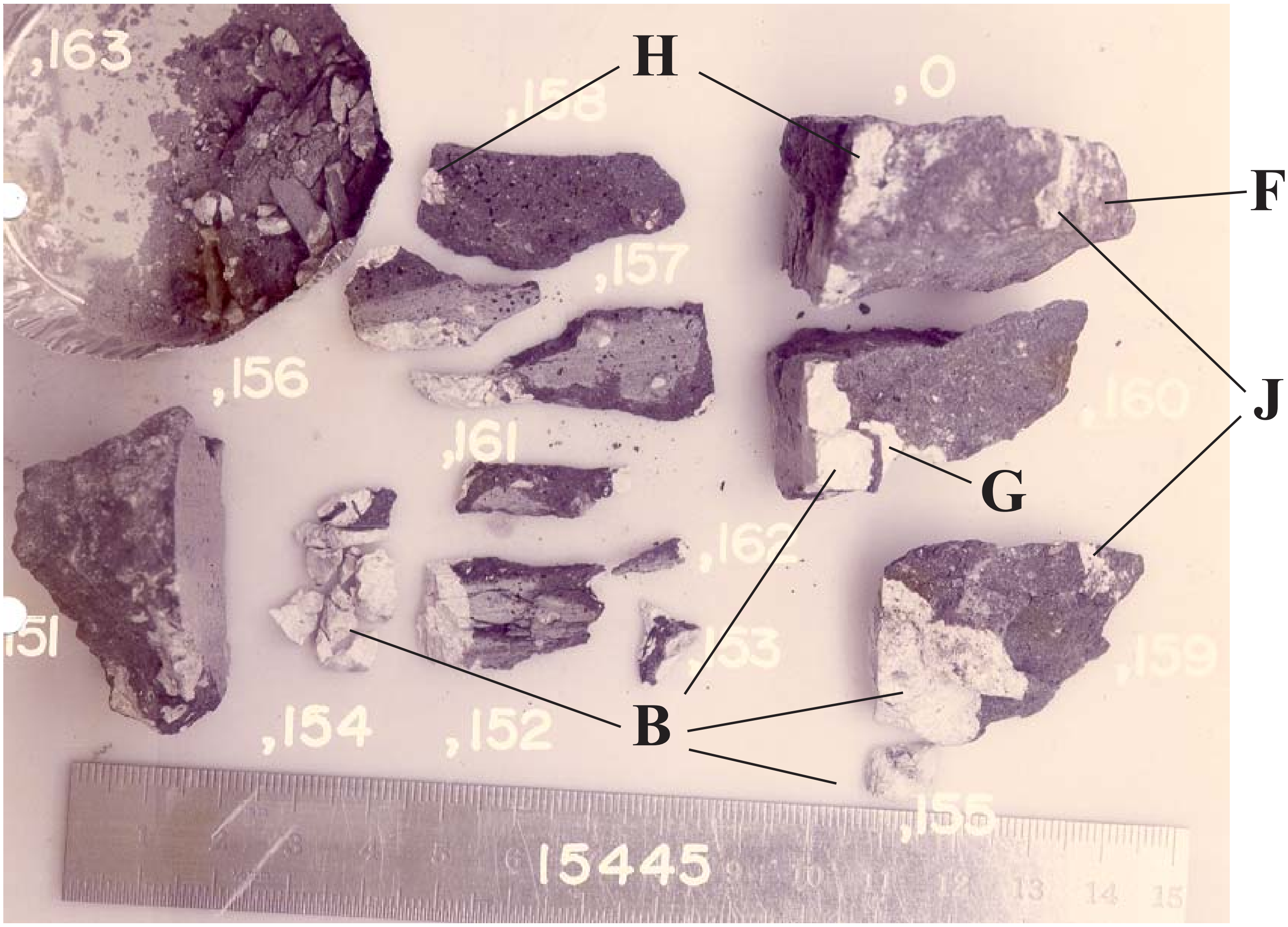
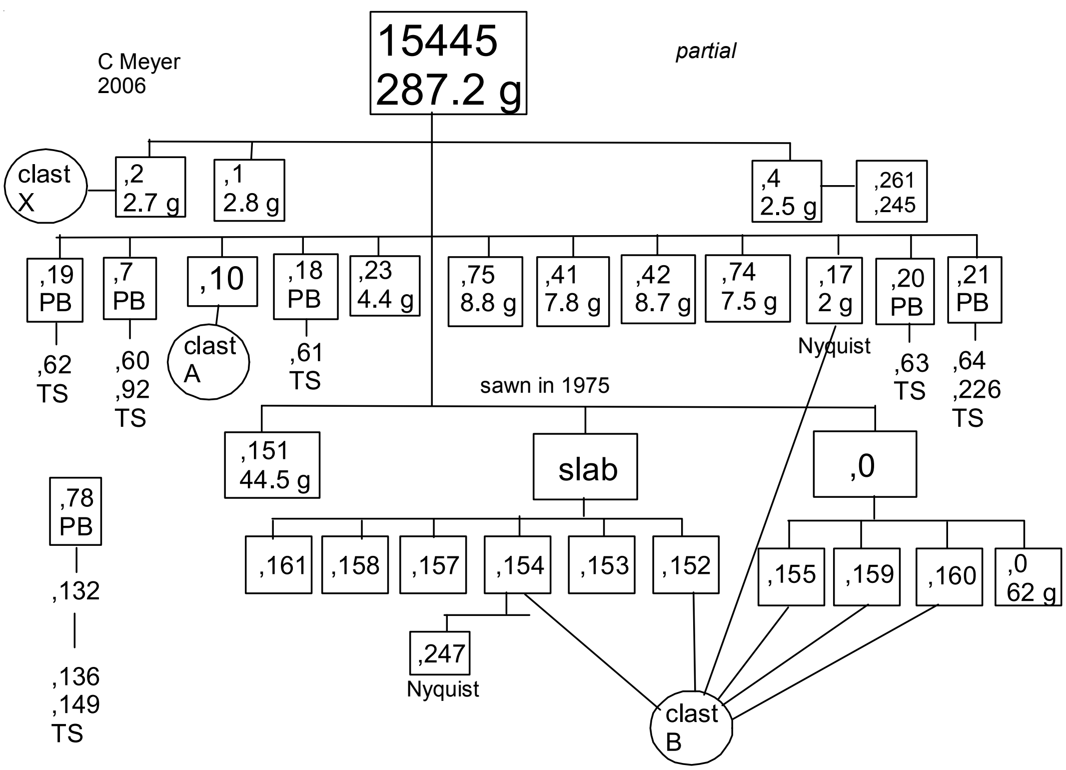


Figure 18: The numbered pieces of 15445 after sawing in 1975. Ruler is marked in mm/cm. NASA S75-33434.



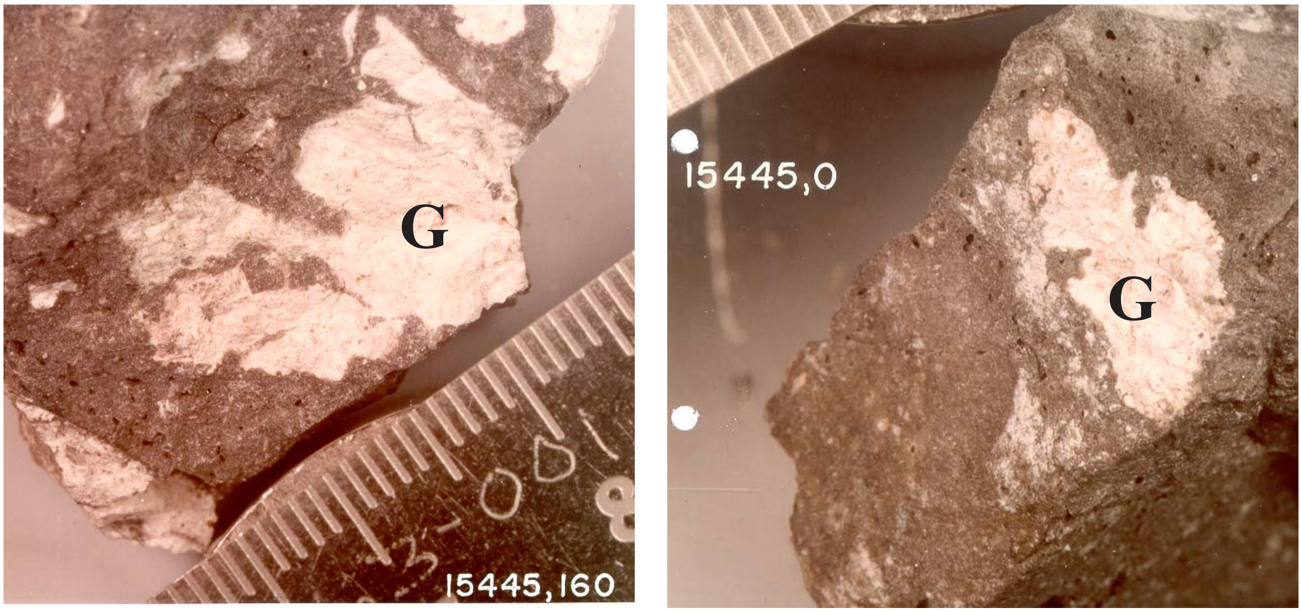


Figure 20 a,b: Photos of blood-red spinel troctolite clast (G) in 15445. NASA S77-30841 and NASA S77-30840. Scale marked in mm/cm. Abundant red mineral(spinel) is obvious in original photos.

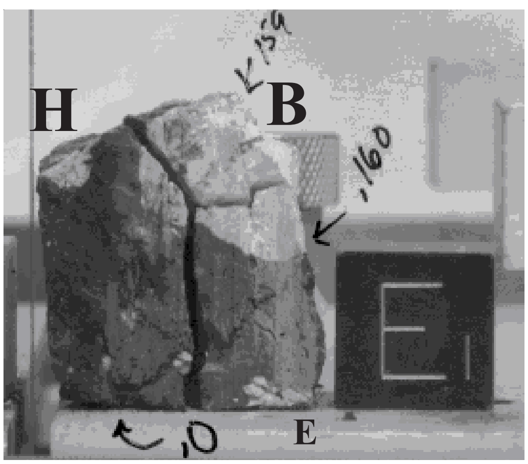


Figure 21: Photo of end piece after 2nd saw cut (from datapack). Compare with figure 19. Cube is 1 inch.

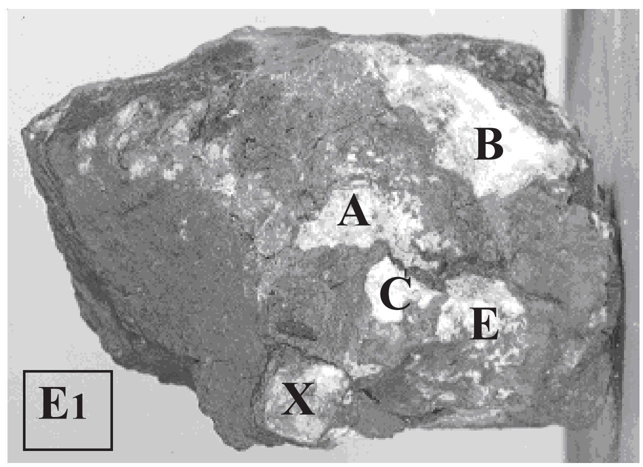


Figure 22: This original photo of 15445, before dusting, shows a mystery clast X in the process of breaking free of the matrix (like a loose tooth). NASA S71-45034. Compare with figure 1.

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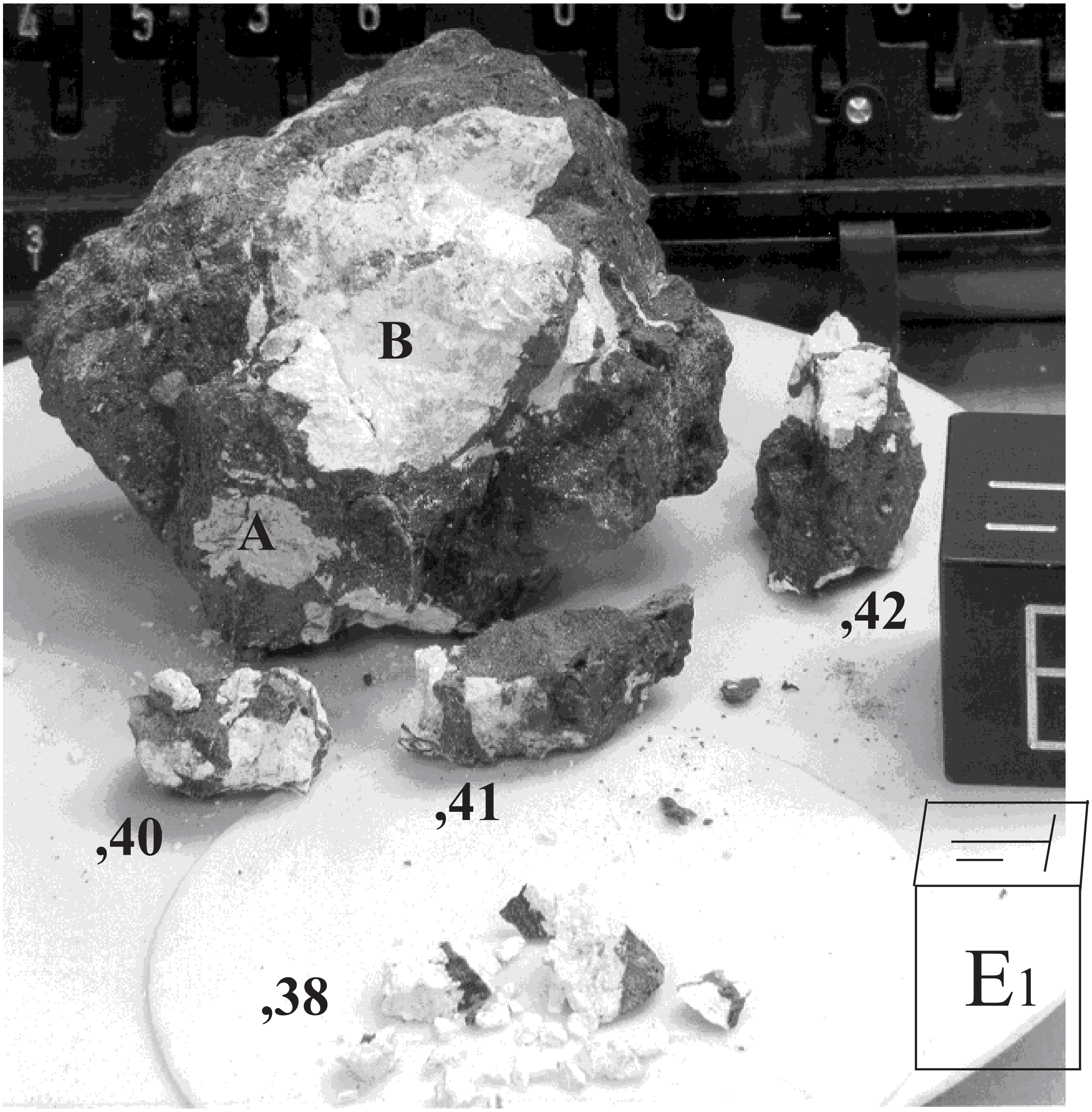

Figure 23: Early processing (chipping 1972) photo of 15445. NASA S72-16089. Cube is 1 inch. Compare with figure 1.

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Table 6: Thin sections for 15445.

butt	section		butt	TS		butt	TS
,7	,60	A	,101	,143		,180	,185
	,92	A		,144	ST		,186
,18	,61	B	,109	,141			,225
,19	,62	B		,142		,222	,227
,20	,63	B	,117	,139	E		,257
,21	,64	B	,124	,137		,254	,256
	,226	B		,138			
,24	,66	matrix	,126	,145			
,32	,67	F		,146			
,35	,65			,147	matrix		
,78	,132			,148			
	,133		,156	,177	H		
	,134	B	,160	,179			
	,135	ST	,171	,220			
	,136		,173	,221	E		
	,149		,175	,187			

Table 7: Clast comparison for 15445.

Clast	Marvin	Ridley	type	TS #s
A	45E	Type B	spinel troctolite	,60 ,92
B	45D	Type A	norite	,61 ,134
C				
D				
E	45B		anorthosite (?)	,139 ,221
F	45C	Type B	spinel troctolite	,67
G			spinel troctolite	
H			spinel troctolite	,177
J	adjacent to F			
X	“mystery”		“tooth in ,2”	
Matrix	45A	,25	matrix	,66 ,147
Bulk	45X			

stability (abs). *Lunar Planet. Sci.* **X**, 537-539. Lunar Planetary Institute, Houston.

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Figure 24: Surface photo of boulder on rim of Spur Crater showing numerous light-colored clasts in dark matrix. Sample 15445 was found on the lunar surface just to the left of the end of the boulder and was clearly derived from this boulder (see transcript). Boulder is 1.5 meters long.. AS15-86-11689.

Transcript

CC Okay, Dave, while you're working there we're thinking that we'd prefer just a very quick sampling of the large rock, if at all. And perhaps just a quick photodocumentation of that large rock and then some rake samples.

CC Dave and Jim, the science input now is that we want to forget that large block entirely.

CDR I'll get the gnomon. And while you're putting the rake on I'll photograph this thing , anyway. I think it looks very much like the 14 rocks. Though, it looks maybe a little darker-gray. There's a convenient piece broken off, right here (15445).

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